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Intake of ultra-processed foods and associations with body weight among children and adolescents: Evidence from The Hellenic National Nutrition and Health Survey

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PhD (Doctor of Philosophy) in Nutrition and Dietetics

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Abstract

Background: Over the past few decades, traditional foods have been displaced by ultra-processed foods (UPFs), with the latter being associated with various health problems. The consumption of UPFs plays an important role in the development of childhood obesity worldwide. The aim of this thesis was to review all existing knowledge regarding the association between the consumption of UPFs with obesity and cardiometabolic risk factors among children and adolescents. Furthermore, using data from children and adolescents ≥2-18 years enrolled in the Hellenic National Nutrition and Health Survey (HNNHS), to: a) assess the main food groups contributing to UPF consumption, b) assess the association of UPF consumption with weight status, c) to estimate the nutrient content contributed by UPFs and d) to examine associations between consumption of UPFs and nutrient intake recommended in international guidelines for the prevention of NCDs

Methods: Firstly, a systematic search on the impact of ultra-processed foods on obesity and cardiometabolic co-morbidities in children and adolescents conducted using the Preferred Reporting Items for Systematic Review (PRISMA-P) criteria included observational studies up to February 2022. Based on the inclusion and exclusion criteria, seventeen observational studies involving children and adolescents aged ≤18 years were included. Of these, 9 were cross-sectional studies, 7 were cohort studies, and one study combined the results of both cross-sectional and cohort studies. In particular, 14 studies investigated the relationship between UPFs intake and overweight/obesity, while 8 examined the relationship between UPFs and cardiometabolic risk factors. Subsequently, data from 478 children and adolescents ≥2-18 years enrolled in the Hellenic National Nutrition and Health Survey (HNNHS) - a cross-sectional study, were analyzed. Two 24hr recalls were used to estimate dietary intake. Following this, the UPFs were classified based on the NOVA system. The proportion of UPFs' contribution to the daily energy intake was calculated. Main UPF food contributors were derived for the total population, by weight status and across tertiles. The association between weight status and UPF intake for the main contributors was examined using generalized linear models. The prevalence of inadequate or excessive intakes of macro- and micronutrients were defined using the dietary recommendations of the American Heart Association for macronutrients and the Estimated Average Requirement (EAR) for micronutrients. A linear regression model adjusted for covariates was used to test trends in the dietary energy share provided by UPFs across tertiles.

Results: Results from systematic review demonstrated that most studies (14/17) found that increased UPF consumption was associated with a higher prevalence of overweight/obesity and cardiometabolic risk factors such as dyslipidemia, blood pressure, and metabolic syndrome in children and adolescents, while 4/17 (3 cross-sectional studies and 1 cohort study) did not show any correlation. According to study quality assessment tools, the majority of cohort and cross-sectional studies were classified as good quality based on NIH (National Institutes of Health) and NewCastle-Ottawa, respectively. Findings of the original research showed that the percentage of total daily energy provided in the diets of children and adolescents by UPFs was 41%. Four major food groups were found to contribute > 10% of total UPF intake: ready-to-eat/heat dishes (36.2%), sweet grain products (21.4%), savoury snacks (15.4%) and sweets (12.9%). These provided 86% of the total UPF intake, with no significant differences between children's weight status. Total UPF intake was not associated with body weight status, but the likelihood of obesity significantly increased for children consuming savoury snacks and baked goods of > 62% of their total caloric intake. Regarding diet quality children with higher UPFs consumption consumed more energy [1416kcal (95% CI 1128, 1776) 1st tertile vs. 1920kcal (95% CI 1477, 2426) 3rd tertile], carbohydrates (from 42.6 to 43.7% kcal), added sugars (from 4.5 to 8.1% kcal), saturated fats (from 14.9 to 16% kcal), polyunsaturated fats (from 4.9 to 5.2% kcal) and sodium (from 1641 to 2485 mg/day) compared to children in the lowest tertile of UPF intake. In contrast, UPF intake was negatively associated with the consumption of protein [15.9% (14, 19.4) 1st tertile vs 14.6% (11.7, 16.2) 3rd tertile], and potassium [(<70% AI), (1953 (1953, 2576) 1st tertile vs 1799 (1398, 2307) mg/day 3rd tertile)]. The prevalence of excessive intake of added sugars ≥10% of total energy (17.2% 1st tertile vs 39.7% 3rd tertile) increased significantly across tertiles of UPFs.

Conclusions: There is a positive relationship between UPF intake and overweight/obesity, as well as cardiometabolic co-morbidities in children and adolescents according to our systematic review. Regarding the results of the Hellenic National Nutrition and Health Survey (HNNHS), the contribution of UPFs to total energy intake was high for all children irrespective of weight status. It was also highlighted that a greater dietary share of UPFs demonstrates a poor quality of children’s and adolescents’ diets, which are characterized by higher dietary content of NCD-promoting and lower dietary content of NCD-protecting nutrients. This evidence adds to previous studies indicating that more effective public health strategies to improve diet quality are needed, aiming to promote the reduction of the obesity pandemic among children.

Keywords: Ultra-processed foods, children, adolescents, overweight, obesity, NOVA system, NOVA 4, diet quality, non-communicable chronic diseases

Dedication

It is dedicated to..

my family for their support and love!!

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The PhD was a dream that followed me from the moment I finished my postgraduate studies. Today, after 5 years my dream has come true.

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Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Nicosia. This thesis has been composed solely by myself except where stated otherwise by reference or acknowledgement. It has not been previously submitted, in whole or in part, to this or any other institution for a degree, diploma or other qualifications.

Signed Evgenia Petridi Date 14/08/2024

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Abbreviation Index

AHA	American Heart Association
AI	Adequate intake
BF	Body Fat
BMI	Body Mass Index
BMR	Basal Metabolic Rate
BP	Blood Pressure
CI	Confidential Intervals
CVD	Cardiovascular Diseases
DBP	Diastolic Blood Pressure
EAR	Estimated Average Requirement
FAO	Food and Agriculture Organization
FFQ	Food Frequency Questionnaire
HDL	High Density Lipoprotein Cholesterol
HNNHS	Hellenic National Nutrition and Health Survey
IOFT	International Obesity Task Force
IOM	Institute of Medicine
GRECO study	Greek Childhood Obesity Study
LDL	Low Density Lipoprotein Cholesterol
MetS	Metabolic Syndrome
NCDs	Non-Communicable Diseases
NHANES	National Health and Examination Surveys
NOVA classification	not an acronym
NW	Normal Weight
OB	Obesity
OR	Odds Ratio
OW	Overweight
PA	Physical Activity
PR	Prevalence ratios
RCTs	Randomized Control Trials
SD	Standard Deviation
SSBs	Sugar Sweetened Beverages
ST	Screen time
T2D	Type 2 Diabetes

TEI	Total Energy Intake
UPFs	Ultra-Processed Foods
WC	Waist Circumference
WHO	World Health Organization

CHAPTER 1 INTRODUCTION

1.0 Introduction

Childhood overweight and obesity is one of the most serious public health problems of the 21st century, and the rate of increase in prevalence is alarming worldwide. While individual susceptibility, social norms, and environmental influences all play a role in weight management, there is a growing consensus among scientists that recent shifts in our environment are a major driver behind rising obesity rates (Swinburn et al., 2011). These environmental changes are likely to interact in complex ways with individual characteristics and social determinants, ultimately leading to an imbalance between energy intake and expenditure and a buildup of excess body fat (Heeren et al., 2023). The rising rates of childhood obesity are linked to behavioral changes, including insufficient physical activity, lack of proper sleep, excessive television watching, and poor dietary habits like skipping breakfast and consuming sugar-sweetened beverages (Poorolajal et al., 2020). Additionally, the intake of highly processed foods has been correlated with increased body fat, the onset of metabolic syndrome and deteriorating lipid profiles among children and adolescents (Tavares et al., 2012).

Overweight or obesity is associated with adverse health consequences later in life, and there is a combination of several causes and contributor factors that contribute to obesity. Given the undeniable link between diet and human health, researchers continuously strive to define optimal dietary patterns that can promote well-being and prevent the growing burden of non-communicable diseases (NCDs) in our society. Traditionally, public health dietary guidelines have focused on ensuring adequate nutrition through recommendations for nutrient-rich food groups and maintaining healthy body weight to prevent obesity and degenerative disorders (GBD 2017 Diet Collaborators, 2019). However, the evolving approach to tackling metabolic and degenerative diseases has shifted towards identifying macro and micronutrients, specific foods, and, most recently, well-defined dietary patterns with demonstrably positive health effects that can be recommended to the public. Notably, managing energy intake remains crucial. Minimizing the imbalance between calorie consumption and expenditure is essential, as excess calorie intake is likely the primary driver of weight gain and obesity, regardless of other dietary choices (GBD 2017 Diet Collaborators, 2019). Malnutrition-related risk factors stand out as a leading contributor to the global burden of disease and mortality, surpassing the combined impact of tobacco use, alcohol consumption, and other drug use (Moodie et al., 2013). In this chapter, I am going to analyze all these causes and consequences.

1.1 Definition of obesity

According to WHO, “Overweight and obesity are defined as abnormal or excessive fat accumulation that presents a risk to health” (World Health Organization, 2020a). However, for children, there are no widely accepted diagnostic definitions or cut-off points available (Krebs et al., 2007).

The most accepted methods for assessing excess body fat include assessing total body fat mass, body fat distribution, body composition, and ectopic fat (Cornier et al., 2011). There are various techniques available, ranging from relatively simple and affordable such as weight, height, body mass index (BMI), circumferences (e.g., waist circumference, hip circumference) and skinfold measurements, to more costly and specialized approaches, such as bioelectrical impedance (BIA), underwater weighing, dual-energy X-ray absorptiometry (DEXA), air displacement plethysmography (ADP), magnetic resonance imaging (MRI), computed tomography (CT) and ultrasound (US) (Horan et al., 2015). These techniques can measure fat, fat-free mass, bone mineral content, total-body water, extracellular water, total adipose tissue and its subdepots (visceral, subcutaneous, and intermuscular), skeletal muscle, select organs, and ectopic fat depots. Laboratory methods, some of those that produce the most accurate data, so-called “gold standard” or reference methods, are generally more precise than "field" methods, but they are also more expensive, time-consuming, and necessitate a higher level of technical training and skill (Cornier et al., 2011). The most widely used approach to measuring overweight and obesity is the Body Mass Index (BMI), a simple index, which classifies overweight and obesity in adults. It is calculated as the weight in kilograms divided by the square of the height in meters (kg/m^2). Because it is the same for both sexes and all ages of adults, BMI is the most useful population-level measure of overweight and obesity (World Health Organization, 2021). It is significant to mention that BMI is a simple weight-for-height measure that calculates body fatness but does not measure body composition and does not consider the impact of muscle mass or bone mineral density (Prentice & Jebb, 2001). In adulthood, overweight, or pre-obesity, is classified as a BMI of 25-29.9 kg/m^2, while obesity is classified as a BMI of 30 kg/m^2. “World Obesity” refers to a WHO expert report that proposed these BMI thresholds, which reflect the escalating risk of excess weight as BMI surpasses the optimal range of 21-23 kg/m^2, the recommended median goal for adult Caucasian populations (World Obesity, 2022b).

Childhood obesity is generally defined through the whole-body fatness and its relationship to health outcomes, cut-off points based on distributions of anthropometric measurements (e.g., weight and BMI) due to lack of established criteria. It is difficult to create a single index for measuring childhood and adolescent overweight and obesity because as they grow, their bodies go through several physiological changes (Krebs et al., 2007). The BMI of a child changes significantly with age. To define child obesity, a cut-off point related to age is required, based on the same principle at different ages, such as using reference centiles. Cole et al. (2000) developed the international (IOTF) cut-off points for body mass index for overweight and obesity from 2-18 years, shown in Table 1.1 at half-year intervals. For epidemiological purposes, a cut-off points at the mid-year value (for example, age 7.5 for the 7.0-8.0 age group) will provide an unbiased estimate of the prevalence of overweight/obesity (Cole et al., 2000).

Furthermore, in 2012, Cole and Lobstein (2012) created new cut-offs that differ slightly from the originals. Still, the differences are minor and have no material impact on estimates of overweight or obesity prevalence. These derived new cut-offs are expressed as centiles or SD scores, and it is easier to compare directly with the international and WHO cut-offs (Cole & Lobstein, 2012).

Table 1.1 International cut-off points for BMI overweight and obesity (Cole et al., 2000).

	Body mass index 25 kg/m^2		Body mass index 30 kg/m^2	
Age (years)	**Males**	**Females**	**Males**	**Females**
2	18,41	18,02	20,09	19,81
2,5	18,13	17,76	19,80	19,55
3	17,89	17,56	19,57	19,36
3,5	17,69	17,40	19,39	19,23
4	17,55	17,28	19,29	19,15
4,5	17,47	17,19	19,26	19,12
5	17,42	17,15	19,30	19,17
5,5	17,45	17,20	19,47	19,34
6	17,55	17,34	19,78	19,65
6,5	17,71	17,53	20,23	20,08
7	17,92	17,75	20,63	20,51
7,5	18,16	18,03	21,09	21,01
8	18,44	18,35	21,60	21,57
8,5	18,76	18,69	22,17	22,18
9	19,10	19,07	22,77	22,81
9,5	19,46	19,45	23,39	23,46
10	19,84	19,86	24,00	24,11
10,5	20,20	20,29	24,57	24,77
11	20,55	20,74	25,10	25,42
11,5	20,89	21,20	25,58	26,05
12	21,22	21,68	26,02	26,67
12,5	21,56	22,14	26,43	27,24
13	21,91	22,58	26,84	27,76
13,5	22,27	22,98	27,25	28,20
14	22,62	23,34	27,63	28,57
14,5	22,96	23,66	27,98	28,87
15	23,29	23,94	28,30	29,11
15,5	23,60	24,17	28,60	29,29
16	23,90	24,37	28,88	29,43
16,5	24,19	24,54	29,14	29,56
17	24,46	24,70	29,41	29,69
17,5	24,73	24,85	29,70	29,84
18	25,00	25,00	30,00	30,00

1.2 Prevalence of obesity

1.2.1 Prevalence of obesity in adults

According to recent evidence from WHO, in 2022, 2.5 billion adults aged ≥18 years old were overweight, with more than 890 million adults suffering from obesity. This equated to 43% of adults aged 18 and above being overweight (43% of males and 44% of women), a rise from 25% in 1990. Overweight prevalence varied by region, ranging from 31% in the WHO's Africa and South-East Asia regions to 67% in the Americas. Furthermore, in 2022, 16% of adults globally who were ≥18 years old were obese. This means that one out of every eight individuals worldwide is living with obesity. Interestingly, obesity rates have more than doubled globally between 1990 and 2022 (World Health Organization, 2024).

The National Health and Nutrition Examination Survey, a cross-sectional study in the US, provided the most recent national estimates of adult obesity from 2017 to 2018 and analysed in-depth trends in adult obesity in the USA from 2003 to 2018. This study analysed data from 42,266 adults aged ≥20 years and found that in 2017-2018 there was a 73.8% (95% CI: 71.1% to 76.4%) and 42.8% (95% CI: 39.5% to 46.1%) prevalence of overweight (including obesity, BMI ≥25 kg/m^2) and obesity (BMI ≥30 kg/m^2), respectively. Between 2003 and 2018, there was a noteworthy rise in the proportion of American adults who were overweight [including obese; overall adjusted OR for 2017–2018 vs 2003–2004, 1.08 (95% CI: 1.04 to 1.13) and obese (overall adjusted OR for 2017–2018 vs 2003–2004, 1.15 (95% CI: 1.10 to 1.21)]. Nonetheless, there was no discernible difference between the years before and following 2009–2010 in terms of mean BMI changes or the prevalence of overweight and obesity. Different factors, such as sex, age, race, daily total energy consumption, physical activity level, economic situation, and education, substantially affected the prevalence of overweight and obesity (all $p<0.05$). To sum up, 42.8% of individuals in America were considered obese in 2017–2018, putting 76 million of them at risk for severe and expensive chronic illnesses (Li et al., 2022).

A longitudinal analysis using data from 14 consecutive rounds (rounds 6 through 19) of a linked individual-level nationally representative survey evaluated the most recent prevalence of adult overweight and obesity in Australia. Data from 26,713 people who were at least 15 years old between 2006 and 2019 was examined. The findings showed that among Australian adults in 2019, the prevalence of being overweight, living with obesity, or combined overweight and obese was 34%, 26%, and 60%, respectively. The data demonstrated that geographic remoteness had an impact on the prevalence of overweight and obesity (Keramat et al., 2021).

In China, a cross-sectional study conducted in 2019 among 21,771,683 participants aged ≥18 years old assessed the prevalence of overweight/obesity and associated complications. There were 15,770,094 eligible adults with a median age of 40 years old. In terms of BMI, 14.1% of Chinese people were obese, and 34.8% were overweight. There was a higher prevalence of overweight and obesity in male participants compared to female individuals (overweight 40.2% vs. 27.4% and obesity 17.6% vs. 9.6%). Compared to participants with a normal BMI, those who were overweight or living with obesity had a higher prevalence of assessed complications ($P < 0.001$ for trends) (Chen et al., 2023).

In 2022, according to estimates from the World Health Organization, 59% of adults worldwide suffered from overweight or obesity, with over half of those adults residing in 50 of the 53 European Region's Member States. In most countries, the prevalence was higher in men (63%) than in women (54%), with male prevalence approaching or surpassing 70% in some nations. In addition, over one-fifth of people in 49 out of 53 Member States suffered from obesity, with rates rising to one-third in many nations. Almost a quarter (23%) of adults in the European Region were obese. Compared to overweight, at the WHO European Region level and in approximately half of the nations, obesity was more common in women (24%) than in men (22%). More specifically, the Mediterranean and Eastern European countries had the highest rates of overweight and obesity (World Health Organization, 2022).

The most recent data about the prevalence of overweight and obesity comes from the third wave of the European Health Interview Survey (EHIS), conducted from 2018 to 2020 and included people aged ≥15 years old. These data showed that there were significant disparities in the percentage of overweight or obese adults within the EU based on gender and socioeconomic status. In 2019, the percentage of adults (≥18 years old) classified as overweight ranged from 52.9% in France to 73.2% in Croatia for men and from 37.1% in Italy to 58.5% in Croatia for women. The countries with the lowest percentages of obese women among those over the age of 18, specifically Italy (10.7%), Romania (10.8%), Bulgaria (11.9%), and Cyprus (14.1%), were noted for their adult populations. On the other hand, the countries with the highest percentages of obese women were Estonia (23.6%), Latvia (25.7%), Ireland (26.0%), and Malta (26.7%), whereas the countries with the highest percentages of men living with obesity were Croatia (23.7%), Ireland (25.7%), Hungary (25.8%), and Malta (30.6%) (Eurostat, 2019).

Furthermore, in 2017-2018, the TackSHS survey, which was conducted on 10,810 adults in 12 European countries (Bulgaria, England, France, Germany, Greece, Ireland, Italy, Latvia, Poland, Portugal, Romania, and Spain), investigated the prevalence of overweight and obesity in Europe. Of the individuals, 48.1% (95% CI: 47.2–49.1) reported being overweight or obese (54.1% of men and 42.5% of women), while 12.6% (95% CI: 12.0–13.2) reported being obese (11.3% of men and 13.8% of women). The rate of obesity was highest in Greece (19.7%) and Romania (21.1%) and lowest in Italy (7.5%) and France (8.8%). Further analyses found that the prevalence of obesity was associated with lower levels of socioeconomic status and education and higher age. Western and Southern European countries demonstrated a much lower prevalence of obesity compared to those in northern Europe. In Eastern and Northern European countries, the trend in the prevalence of obesity was higher than in a companion survey carried out in 2010. On the other hand, nations like France and Italy, which had the lowest rates of obesity (less than 10%), demonstrated a declining tendency. The estimates of overweight and obesity rates in Europe were concerning, notwithstanding significant national variations. Most of the continent's countries - especially those in Eastern and Northern Europe - reported obesity prevalence rates of 20% or more. In the majority of these nations, the prevalence of obesity has risen since 2010 (Stival et al., 2022).

In England, between 2021 and 2022, it was estimated that 63.8% of adults aged 18 and up were overweight or obese. This represented a 63.3% increase from 2020 to 2021. Compared to men (69.1%), women (58.4%) continued to have a lower prevalence of adult overweight or obese individuals. Regarding the rate of obesity, it was estimated that 25.9% of adults in England aged ≥18 years old lived with obesity in 2021–2022, and this was a 25.2% increase from 2020 to 2021. Both men (25.6%) and women (26.1%) continued to have similar rates of adult obesity in 2021 and 2022 (GOV.UK, 2023).

Another study aimed to examine the trend in the prevalence of obesity in 17 autonomous Spanish communities from 1987 to 2020 among participants aged ≥ 15 years. The rates of obesity increased from 7.3% (95%CI, 7.0-7.7) in 1987 to 15.7% (95%CI, 15.1-16.3) in 2020. More specifically, the prevalence of obesity in men increased until 2009 and then stabilized, while in women, the rates increased until 2001 and subsequently also stabilized. Consequently, since 1987, there has been an increase in the incidence of obesity in Spain; however, throughout the past ten years, the prevalence has stabilized at levels above 15%. Still, during the research, there was an increase in the prevalence of obesity in the group of people aged 15 to 24 (Feijoo et al., 2024).

Diamantis et al. (2022) in the Feel4Diabetes study - a cross-sectional study - conducted in 24,562 adults residing in low socioeconomic areas in six countries (Belgium, Finland, Greece, Spain, Bulgaria, and Hungary), investigated the prevalence of adult overweight and obesity in European nations and examined the relationship between different socioeconomic characteristics and how those factors added up to an individual's status as overweight or obese. To account for unemployment, financial insecurity, and education ≤ 12 years, the Socioeconomic Burden Score (SEBS) was developed. Findings showed that the highest prevalence of overweight/obesity was observed in Greece (37.5%/17.8%) and Hungary (35.4%/19.7%). Age under 45 and female sex were found to be negatively correlated with overweight/obesity after controlling for covariates, whereas poor educational attainment (≤12 years), unemployment, and financial insecurity were favorably correlated. There was a correlation between the risk of being overweight or obese and the rise in SEBS. All the nations under investigation showed a clear correlation between SEBS scores and overweight/obesity, except men in low-income countries like Bulgaria and Hungary, where the highest SEBS score was negatively correlated with overweight/obesity (Diamantis et al., 2022).

1.2.2 Prevalence of obesity in children and adolescents

Over the last four decades, the number of children and adolescents with obesity aged 5-19 years has increased more than tenfold worldwide. The prevalence of overweight among individuals aged 5-19 years has risen dramatically from 4% in 1975 to just over 18% in 2016, and the prevalence of obesity increased from less than 1% in 1975 to nearly 7% in 2016. In 2016, 213 million children and adolescents were overweight and 124 million were obese respectively (World Health Organization, 2017). According to more recent evidence by the WHO, in 2022, more than 390 million children and adolescents aged 5 to 19 years old were overweight (including obesity). Between 1990 and 2022, the percentage of children and adolescents aged 5-19 who were overweight or obese increased significantly from 8% to 20%. Both boys' and girls' rates of overweight have increased: in 2022, 21% of boys and 19% of girls were overweight. Although in 1990, there were only 31 million children and adolescents aged 5 to 19 years old who were living with obesity (2% of children and adolescents), by 2022 there were 160 million young people aged 5 to 19 years old who were living with obesity, or 8% of the population (World Health Organization, 2024). Furthermore, the number of children under the age of 5 years with overweight or obesity was estimated at 38.2 million in 2019 (World Health Organization, 2021). East Asia, the Middle East, North Africa, South Asia, and the high-income English-speaking regions had the greatest increase in obese children and adolescents (NCD Risk Factor Collaboration, 2017). In 2022, WHO had indicated that 37 million children ≤5 years old were predicted to be overweight. Overweight, often thought to be an issue exclusive to high-income nations, was becoming more prevalent in low- and middle-income countries. Since 2000, there has been a nearly 23% increase in the number of overweight children under five in Africa. Asia accounted for about half of the world's under-5-year-old overweight or obese population in 2022 (World Health Organization, 2024).

In a pooled analysis of 2,416 population-based studies from 1975 to 2016 with measurements of height and weight on 128.9 million individuals aged 5 years and older and using the WHO growth reference for children and adolescents found that the prevalence of obesity in children and adolescents increased from 0.7% in 1975 to 5.6% in 2016 among girls, and from 0.9% in 1975 to 7.8% in 2016 among boys. From 1975 to 2016, the rates of obesity increased in every country. However, Polynesia and Micronesia were the countries with the highest prevalence of obesity in both sexes, 25.4% in girls and 22.4% in boys, followed by the high-income English-speaking regions (NCD Risk Factor Collaboration, 2017).

In U.S. youth, according to the Centers for Disease Control and Prevention (CDC), the prevalence of obesity was 18.5% (13.7 million) in 2015-2017. The rates were 13.9% among preschoolers, 18.4% in school-aged children and 20.6% among adolescents with no significant difference between boys and girls overall or by age group (Centers for Disease Control and Prevention, 2022b). In Australia, the prevalence of overweight or obesity among 746,000 children aged 5–14 years was 24%, of which 17% were overweight and 7.7% were obese, with similar portions for boys and girls (Australian Institute of Health and Welfare, 2022). Findings from the China Health and Nutrition Survey (CHNS) and China Nutritional Transition Cohort Study (CNTCS), which based on two waves of the survey in 12 provinces conducted in 2011 and 2015, among 1,458 children and 1,084 adolescents aged 7 to 18 years and using the WGOC criteria, indicated that the prevalence of overweight and obesity have remained stable among children between 2011 and 2015, (10.6% to 11% and 11.4% to 9.7%) respectively. However, the prevalence of overweight among adolescents has increased from 10.6% to 13.2% and the prevalence of obesity has significantly increased from 5.2% to 9.3% between 2011 and 2015 (Zhang et al., 2018).

According to the most recent data (2015–2017) from the WHO Childhood Obesity Surveillance Initiative (COSI), southern European countries had the highest rate of child obesity. One in 5 boys (ranging from 18% to 21%) in Cyprus, Greece, Italy, Malta, San Marino, and Spain was obese. On the other hand, Denmark, France, Ireland, Latvia and Norway had the lowest rates, ranging from 5% to 9% in either sex (World Health Organization, 2018). In the UK, in 2019, 12% of boys and 15% of girls (aged 2-15 years) were overweight and 20% of boys and 13% of girls were obese (NHS, 2022).

The global prevalence of overweight for children aged 5–17 years will rise from 13.9% in 2010 to 15.8% in 2025. Based on the World Bank's assumptions of continued population growth, there will be an increase from 219 million children (5–17 years) in 2010 to 268 million in 2025. For obesity, this increase will be from 76 million children (4.8%) in 2010 to 91 million (5.4%) by 2025 (Lobstein & Jackson-Leach, 2016).

1.2.3 Prevalence of childhood and adolescent obesity in Greece

In 2010, the Hellenic study of COSI conducted on 5,701 children 7.0–7.9 and 9.0–9.9 years old and using BMI cut-off points of WHO and International Obesity Task Force (IOTF) evaluated the prevalence of overweight and obesity showed that the prevalence of abdominal obesity for 7-year-old boys and girls was similar at 25.2% and 25.3%, respectively, but among 9-year-old children was more prevalent in boys at 33.2% than in girls at 28.2% (Hassapidou et al., 2017).

Farajian et al. (2011) in the Greco study, a cross-sectional study that was conducted in 10 regions in 2011 among 4,786 schoolchildren, found that the prevalence of overweight and obesity was 29.5% and 11.7%, respectively, according to IOTF BMI cut-off points. The prevalence of overweight and obesity in boys was 29.5% and 12.9% and in girls 29.2% and 10.6%, respectively (Farajian et al., 2011).

Findings from another cross-sectional study of 200 participants aged 10-13 years old found that the prevalence of overweight and obesity was 39.1% and 13% in boys and 25.9% and 8.3% in girls (Jelastopulu et al., 2012).

Interestingly, in West Attica, a longitudinal study shortly before and during the early years of the Greek economic crisis in 2012 that examined 1,327 children for 2.5 years showed that according to IOTF BMI cut-off points, there was a decrease in the prevalence of overweight and obesity, which was statistically significant for both sexes. During the 2.5-year study period, it decreased from 43% to 37.3% in boys and 33.4% to 26.9% in girls (Kleanthous et al., 2016).

Grammatikopoulou et al. (2014) during the Adolescent Nutrition (ADONUT) study indicated that among 37,344 adolescents aged 12–19 years old, 23.6% were overweight and 7.5% were obese. Among adolescent boys, the prevalence of overweight was 27.9% and obesity 8.9%, and among girls, it was 19.4% and 6.0%, respectively (Grammatikopoulou et al., 2014).

Similarly, another cross-sectional study among 124,113 children according to IOTF BMI cut-off points, showed that the prevalence of overweight was 24.8%, and for obesity was 8.8%, the rates were similar for both sexes (Grigorakis et al., 2016).

In Thessaloniki, a cross-sectional study examined 1,250 preschoolers aged 2-6 years, and BMI was classified into weight categories based on the IOTF, WHO and CDC. The authors showed that the prevalence of overweight, according to the IOTF, WHO and CDC, was 21.2%, 32.6% and 30.5%, respectively. Obesity prevalence derived from the IOTF, WHO and CDC references was 5.8%, 5% and 13.5%, respectively (Hassapidou et al., 2015).

Manios et al. (2018) in the European ToyBox study in six European countries, namely Belgium, Bulgaria, Germany, Greece, Poland, and Spain examined 7,554 individuals 3.5-5.5 years. Based on IOTF references, the prevalence of overweight/obesity was found to be higher in countries from Southern/Eastern Europe compared to countries in

Central/Northern Europe. In Greece, the prevalence of overweight was 14.9%, and obesity was 5.7% (Manios et al., 2018).

In 2018 as well, the National Action for Children's Health (EYZHN) program studied 336,014 participants aged 4 to 17 years and the prevalence of overweight and obesity was 22.2% and 9.0% in boys and 21.6% and 7.5% in girls, respectively (Tambalis et al., 2018).

Findings from another study, among 1,000 children and adolescents who attended the Outpatient Clinic for the Prevention and Management of Overweight and Obesity in Childhood and Adolescence for 1 year, and according to IOTF references showed that 29.5% of participants were classified as overweight and 57.9% as obese (Genitsaridi et al., 2020). Similarly, in the same program, the National e-Health Program at the Outpatient Clinic for the Prevention and Management of Overweight and Obesity in Childhood and Adolescence, 2,400 children 2-18 years, 28.1% were classified as overweight and 57.1% as obese according to the International Obesity Task Force cut-off points. The findings indicated a reduction in the prevalence of overweight by 26.7% and of obesity by 32.1% in childhood and adolescence after one year of intervention (Tragomalou et al., 2020).

The Health Behaviour in School-Aged Children (HBSC) study in Greece conducted on 3,816 adolescents aged 11, 13 and 15. Based on the WHO growth charts classification, the prevalence of overweight was 19.4% in the total sample (24.1% for boys and 14.7% for girls), and obesity was 5.3% in the total sample (7.3% for boys and 3.4% for girls) (Makri et al., 2022). The prevalence of overweight and obesity in Greece based on studies conducted since 2010, is shown in Table 1.2.

Trying to draw a general conclusion about the prevalence of overweight/obesity, it is of note that this is difficult as there are quite a few differences. These differences are due to the age groups of the samples, the number, and the area where each study was conducted. The percentages of overweight/obesity in Greek children and adolescents are relatively close to those indicated in children and adolescents nationwide. Three studies are conducted in specific areas but in different populations. One study was carried out at the beginning of the economic crisis in Greece, so the results of the reduction in the prevalence are visible after three years. Furthermore, two studies exclusively involved overweight/obese children. Finally, another criterion that plays a role is the evaluation system of children's weight, which creates discrepancies when comparing the percentages.

In Greece, the prevalence of obesity for children 5-9 years was 21.2% for boys and 14.2% for girls in 2016 and it is predicted to rise to 22.8% by 2030. For adolescents 10-19 years the prevalence of obesity was 14.4% of boys and 8.8% of girls and it is predicted to rise to 16.2% by 2030 (World Obesity, 2019).

Table 1.2 Prevalence of overweight and obesity in Greece.

Studies	Sample	Age (years)	Place	Criteria	Overweight / Obese (%)
Hassapidou et al., 2017	n=5,701	7.0–7.9 9.0–9.9	Hellenic	IOFT, WHO	7 years *M 25.2 **F 25.3 9 years M 33.2 F 28.2
Farajian et al., 2011	n=4,786	10-12	Hellenic	IOFT	M 29.9 12.9 F 29.2 10.6
Jelastopulu et al., 2012	n=200	10-13	Patra	IOFT	M 39.1 13.0 F 25.9 8.3
Kleanthous et al., 2012	n=1,327	6-7 9-10 12-13	West Attica	IOFT	November 2009 M 43.0 F 33.4 May 2012 M 37.3 F 26.9
Grammatikopoulou et al., 2014	n=37,344	12-19	Hellenic	IOFT	M 27.9 8.9 F 19.4 6.0
Grigorakis et al., 2016	n=124,113	(9.9±1.1)	Hellenic	IOFT	24.8 8.8
Hassapidou et al., 2015	n=1,250	2-6	Thessaloniki	IOFT, WHO, CDC	IOFT 21.2 5.8 WHO 32.6 5.0 CDC 30.5 13.5
Manios et al., 2018	n=7,554	3.5-5.5	Europe	IOFT	14.9 5.7
Tambalis et al., 2018	n=336,014	4-11 12-17	Hellenic	IOFT	M 22.2 9.0 F 21.6 7.5
Tragomalou et al., 2020	n=2,400	2-18	Hellenic	IOFT	M 25.0 66.3 F 30.7 49.5
Genitsaridi et al., 2020	n=1,000	2-18	Hellenic	IOFT	29.5 57.9
Makri et al., 2022	n=3,816	11,13,15	Hellenic	WHO	19.4 5.3

*M, Male; **F, Female

1.3 Consequences of childhood obesity

According to the CDC, childhood obesity can have a serious impact on the body, including high blood pressure and high cholesterol (as risk factors for cardiovascular disease (CVD)), glucose intolerance, insulin resistance and type 2 diabetes, breathing problems such as asthma and sleep apnea, joint problems and musculoskeletal discomfort, fatty liver disease, gallstones and gastro-esophageal reflux. It is also related to psychological problems such as anxiety, low self-esteem, lower self-reported quality of life and depression and social problems such as bullying and stigma (Centers for Disease Control and Prevention, 2022c). Moreover, childhood obesity is strongly linked to adult obesity and its associated comorbidities (Serdula et al., 1993) and is also linked to a higher risk of premature death (Franks et al., 2010).

Hypertension is more frequent in children than might be expected. The prevalence ranges from 1% to3% in children to 3.2% in adolescents worldwide (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children, and Adolescents, 2004). A recognized risk factor for high blood pressure is excess body weight. Increases in body mass index (BMI) have been linked to increased blood pressure tracking from childhood to adulthood (Burke et al., 2001). There is a well-established association between overweight and high blood pressure in children, as documented in numerous studies. A comprehensive analysis combining data from 47 studies in children and adolescents <19 years old published between 1994 and 2018 shed light on the prevalence of childhood hypertension. This systematic review and meta-analysis revealed significant variations in hypertension prevalence depending on the measurement devices used. Interestingly, the analysis identified a positive secular trend, indicating a rise in childhood hypertension prevalence over the past two decades. Moreover, the study found a clear association between weight status and hypertension, with overweight and children with obesity exhibiting a higher likelihood of developing hypertension compared to their normal-weight peers (15.27%, 4.99% and 1.90%, respectively) (Song et al., 2019).

Moschonis et al. (2018) in the Healthy Growth Study, a cross-sectional study of 2,665 schoolchildren found that increased blood pressure in children was associated with body mass index (odds ratio (OR) 1.188, $p < 0.001$) (Moschonis et al., 2018; Souza et al., 2017). A cross-sectional study in Brazil investigated risk factors for overweight and high blood pressure in 1,868 students. The study found that 28.6% of the students were overweight, while 15.9% had high blood pressure. Males exhibited a higher susceptibility to both conditions. Notably, adolescents were 1.173 times more likely to have high blood pressure compared to children. Interestingly, adolescents appeared to be protective against overweight, as indicated by a relative risk (RP) of 0.754. Furthermore, the study revealed that increased waist circumference (WC) and poor cardiopulmonary fitness in children were associated with a 5.5-fold and 1.3-fold increase in overweight prevalence, respectively (Tornquist et al., 2016). This study was in agreement with another study in Brazil, which reported a link between high BMI, high waist circumference, and elevated blood pressure levels in schoolchildren. Overall, the reviewed studies suggested that children with excess weight were at an increased risk of developing high blood pressure, with the risk ranging from 1.5 to 4.9 times greater compared to their normal-weight counterparts (Costanzi et al., 2009).

Another study of 1,037 individuals born in 1972–1973 in New Zealand used systolic blood pressure data measured at ages 7, 11, 18, 26, 32 and 38 years. At age 38, they were having a high risk of developing hypertension, while related cardiovascular conditions (such as dyslipidemia) were found to have had high blood pressure as early as age seven. This finding highlighted the potential long-term influence of childhood health, as the study also revealed a positive association between BMI and blood pressure levels across the whole population (Theodore et al., 2015). Additionally, the Cardiovascular Risk in Young Finns Study launched in 1980 tracked 2,204 participants from childhood (ages 3, 6, 9, 12, 15, and 18) into adulthood (ages 30 to 45) over a 27-year follow-up period (2007). This long-term investigation revealed significant correlations between childhood risk factors and adult health markers in both sexes and across all age groups. Notably, correlation coefficients for blood pressure and triglyceride levels ranged from 0.21 to 0.32 ($p < 0.0001$), indicating a moderate association between childhood blood pressure and triglycerides and their corresponding values in middle age. Interestingly, the strength of these associations appeared to increase with advancing age at the time of measurement (Juhola et al., 2011). However, CASPIAN-IV conducted on 13,486 children and adolescents 6-18 years as well as Khan et al. (2010) showed no significant association between the consumption of junk foods and hypertension (Khan et al., 2010; Payab et al., 2015).

It is well known that children who are overweight/obese have higher blood pressure and more cardiovascular disease risk factors than their counterparts with normal weight because of endothelial dysfunction, early atherosclerosis, and an imbalance in the pro- and anti-inflammatory activities of adipocytes (Brady, 2017). According to these findings, regular blood pressure evaluations and risk factors are crucial for children (Oliveira et al., 2020). Diastolic blood pressure (DBP) is a stronger predictor of adult cardiovascular disease in adolescents than systolic blood pressure (SBP). Although no studies have found this association in children, it makes sense to believe that screening children for diastolic blood pressure could help prevent cardiovascular illnesses (Oliveira et al., 2020). Regarding cardiovascular health risks, several studies found that children and adolescents with severe pediatric obesity had a worse cardiovascular risk factor profile than their less obese counterparts. It has been shown that excessive consumption of processed foods high in sugar, trans fats and energy could contribute to several adverse health outcomes. These include heightened secretion of very low-density lipoproteins (Chong et al., 2007), increased lipogenesis (Parks et al., 2008), and reduced fatty acid oxidation leading to greater fat accumulation in tissues and the bloodstream (Kennedy et al., 2009). These metabolic alterations are associated with the formation of atheromatous plaques within blood vessel walls, which can lead to serious clinical consequences such as peripheral vascular disease, myocardial infarction (heart attack) and stroke (Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, National Heart, 2011). Interestingly, research suggests that dietary choices have a more pronounced effect on total and LDL cholesterol levels in children comparing other markers of abnormal blood lipid levels (Ho et al., 2012).

The Cardiovascular Risk in Young Finns Study, a longitudinal investigation launched in 1980, included 2,204 participants from childhood into adulthood in a 27-year follow-up (2007). This study revealed significant correlations between childhood risk factors and adult health markers across both sexes and all age groups. Notably, the correlation between cholesterol levels and BMI ranged from 0.43 to 0.56 ($p < 0.0001$), indicating a strong association between childhood lipid levels and BMI and their corresponding values in middle age. Interestingly, the strength of these correlations appeared to increase with advancing age at the time of measurement (Juhola et al., 2011). Further supporting the link between childhood health and adult health outcomes, another longitudinal study followed 770 children (aged 5-20 years old) for 26 years. The study found that children with persistently high triglycerides throughout the study period were more likely to experience CVD events as adults ($p = 0.0005$). Conversely, children maintaining a normal BMI throughout the study had a lower risk of CVD events in adulthood ($p = 0.02$). Interestingly, the study also revealed that children with persistently high blood pressure or high TG were more likely to develop type 2 diabetes as adults ($p = 0.0006$, $p = 0.003$) (Morrison et al., 2012).

A longitudinal study in China followed 649 children from childhood to adulthood (1989-2009). The study found that individuals who maintained overweight or obese status from childhood to adulthood exhibited an increased risk of negative cardiometabolic health outcomes in adulthood. This risk was also observed in individuals who only became overweight or obese as adults. Interestingly, the only elevated cardiometabolic risk identified in those with childhood overweight/obesity who normalized weight by adulthood was high levels of cholesterol (Huang et al., 2024). These findings align with a meta-analysis reporting an association between normal childhood weight and adult overweight/obesity, or overweight/obesity at both time points, with higher levels of cardiometabolic markers in adulthood. These markers included triglycerides, LDL cholesterol, lower HDL cholesterol levels and systolic and diastolic blood pressure (Juonala et al., 2011).

Freedman et al. (2007) in the Bogalusa Heart Study, a cross-sectional and longitudinal analysis, quantified cardiovascular and metabolic risk factors that included dyslipidemia, hypertension, and hyperinsulinemia among children and adolescents aged 5–17 years. In this study, it was shown that 70%, 39%, and 18% of obese children and adolescents had at least 1, 2, or 3 CVD risk factors, respectively (Freedman et al., 2007). Another cross-sectional study conducted on children aged between 2 and 18 years in Iran indicated that overweight and obese children were 3.176 times more likely to have high TG levels, 1.882 times more likely to have high TC levels and 2.236 times more likely to have high non-HDL-c levels in comparison with children who were of normal weight. The highest percentage of isolated TG dyslipidemia (23.1%) appeared in obese children, whereas the highest percentage of isolated HDL dyslipidemia (15.6%) appeared in underweight children (Habib et al., 2019). Moreover, a systematic review with longitudinal and cohort studies suggested that childhood obesity may be a risk factor for selected adult CVD risk factors. Findings showed that childhood obesity is significantly and positively associated with adult SBP, DBP, and TG and significantly and inversely associated with adult HDL (Umer et al., 2017). A study has shown that increased lipid concentrations follow a person from childhood to adult life because childhood lipoprotein and lipid profiles predict increased lipoprotein profiles in adults (Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, National Heart, 2011).

Costa et al. (2020) in a cohort study conducted on 540 children and adolescents aged 7 to 15 years, found that a 0.1 increase in the mean BMI Z-score was associated with an increase of 2.7 mg/dL in the triglycerides mean levels and a gain of 1.5 mg/dL in the total cholesterol mean levels after the follow-up period (Costa et al., 2020). Furthermore, a cross-sectional study in Brazil with 147 overweight and obese schoolchildren reported a positive association between elevated TC and the consumption of full-fat dairy products, as well as between elevated TG and the percentage of total energy obtained from saturated fat (Rinaldi et al., 2012). Finally, in a study in Denmark, among 276,835 schoolchildren, it was shown that BMI at 7 to 13 years was positively related to fatal and nonfatal coronary heart disease events later in adulthood (Baker et al., 2007).

Some of the consequences of severe obesity have been associated with hyperinsulinemia, insulin resistance, and prediabetes (Invitti et al., 2003; Reinehr et al., 2009; Singhal, 2010). Insulin resistance in childhood is the first step toward an increased risk of diabetes and, consequently, the development of a variety of cardiometabolic disorders in adulthood. Findings from a study of more than 700 severely obese children in the European Union showed that insulin resistance and insulin secretion were associated with 2-hour postprandial glucose levels (Invitti et al., 2003). Furthermore, research suggested that childhood insulin response during an oral glucose tolerance test could predict adult insulin response (Thearle et al., 2009). Adding to the evidence on the long-term influence of childhood health, a study following 770 schoolchildren (aged 5-20 years old) for 26 years found that those with persistently high blood pressure (BP) or triglycerides were more likely to develop type 2 diabetes (T2DM) as adults ($p = 0.0006$, $p = 0.003$). This finding was aligned with the observation of a link between childhood blood sugar levels and future T2DM risk (Morrison et al., 2012). Similarly, a report from the Bogalusa Heart Study supported this notion, demonstrating that even fasting blood sugar levels within the normal range during childhood can predict T2DM development in young adulthood (Nguyen et al., 2010).

The Healthy Growth Study, a Greek cross-sectional study among school children 9–13 years old, showed that there is a strong, positive association between waist circumference, trunk and visceral fat, fasting insulin and insulin resistance (Moschonis et al., 2016). In 2012, another cross-sectional study in adolescents aged 12–16 years found that there is a significant high correlation between the BMI and the HOMA2-IR values ($p < 0.001$) and insulin concentrations ($p = 0.001$). These correlations were stronger in obese compared to normal-weight adolescents (Aguilar et al., 2013). A systematic review and meta-analysis involving nine randomized controlled trials investigated the effects of low glycaemic index/load (GI/GL) diets in overweight children and adolescents or children and adolescents living with obesity. The analysis suggested that a low GI/GL dietary approach may be beneficial for these individuals compared to a high GI/GL diet. Specifically, findings indicated that children and adolescents on a low GI/GL diet exhibited lower serum triglycerides and HOMA index scores, indicating potential improvements in blood fat levels and insulin sensitivity (Schwingshackl et al., 2015). Nowadays, consequences of obesity such as type 2 diabetes mellitus, hypertension, and hyperlipidemia are more frequently observed in children with obesity than previously, which has been seen only in adults. Younger age at initiation of type 2 diabetes mellitus not only prolongs the duration of the disease but is likely to contribute to early presentation of adult-life consequences such as cardiovascular disease (Gungor et al., 2005) kidney failure, visual impairment, and limb amputations (Dean & Sellers, 2007).

Metabolic syndrome (MetS) is a cluster of risk factors that occur together and raise one's chance of developing chronic diseases like heart disease and stroke. These risk factors include central obesity (excess fat around the waist), high blood pressure, impaired blood sugar control (often diagnosed as prediabetes or type 2 diabetes), low levels of HDL cholesterol (HDL-C), and high levels of triglycerides (World Health Organization, 1999). There is growing evidence that metabolic syndrome can identified in young children, more so among children in Western countries (Dietz &Robinson, 2005). The concerning rise in childhood obesity and physical inactivity worldwide is contributing to a rapid increase in the prevalence of metabolic syndrome in younger populations (Kelishadi, 2007).

There are numerous intricate pathways involved in the pathophysiology of the MetS that are not yet completely understood. Whether the various components of MetS constitute unique pathologies unto themselves or are part of a larger, shared pathogenic process is still up for debate. Apart from genetic and epigenetic factors (Dizaji, 2018), certain lifestyle and environmental factors, like overindulging in food and inactivity, have been recognized as significant contributors to the development of Metabolic Syndrome. The majority of the MetS pathways have demonstrated to be activated by visceral adiposity, which suggests that high caloric intake plays a causal role in these pathways (Matsuzawa et al., 2011). Of the various mechanisms that have been proposed, the progression of MetS and its subsequent transformation into CVDs and T2DM appear to be largely dependent on insulin resistance, chronic inflammation, and neurohormonal activation.

Firstly, insulin, a peptide hormone released by the beta cells in the pancreas in response to elevated blood glucose levels, promotes the uptake of glucose in the liver, muscles, and adipose tissues while suppressing lipolysis and hepatic gluconeogenesis. Insulin-mediated inhibition of lipolysis is compromised when fat tissues develop insulin resistance. A vicious cycle is created when there is an increase in free fatty acids (FFAs) in circulation, which aggravates insulin resistance by altering the insulin signaling cascade in various organs (Boden & Shulman, 2002).

Furthermore, the recently identified endocrine function of adipose tissue and its roles as a thermoregulator and lipid storage organ offers further mechanistic insights into the development of MetS (Mohamed-Ali et al., 1998). The different adipokines that are released include hormones (like leptin and adiponectin), peptides (like angiotensinogen, resistin, apelin, and plasminogen activator inhibitor (PAI)-1), and inflammatory cytokines (like interleukin (IL)-6, tumor necrosis factor α (TNFα), chemerin, visfatin, and omentin). These adipokines are essential in the pathophysiology of insulin resistance and MetS (Trayhurn & Wood, 2004). Another pathway is leptinlevels, one of the hormones released, which has been demonstrated to be directly correlated with obesity and body fat levels (Considine et al., 1996). Leptin regulates glucose homeostasis and insulin sensitivity, suppresses food intake, and increases energy expenditure when body energy stores are sufficient (Berglund et al., 2012). Nevertheless, the idea of "leptin resistance," which refers to tissues with reduced sensitivity to leptin, was created because high leptin levels could not address the metabolic imbalance associated with obesity (Obradovic et al., 2021). Leptin is thought to play a vital role in the relationship between obesity, MetS, and CVDs because higher levels of the hormone are correlated with increased inflammation and cardiovascular risk (Patel et al., 2008). However, because adiponectin has been shown to be an anti-inflammatory, anti-atherogenic, and anti-diabetic adipokine, its effects are the opposite of those of leptin (Yamauchi et al., 2003). These characteristics result from adiponectin's actions on the inflammatory pathway of nuclear factor kappa-light-chain enhancer of activated B cells (NF-kB) (Wulster-Radcliffe et al., 2004), insulin sensitivity (Yamauchi, T. et al., 2001), inhibition of vascular smooth muscle cell (VSMC) proliferation (Ouchi et al., 2001), and stabilization of plaque formation.

The different pathogenic pathways that lead to the development of MetS result in a pro-inflammatory state, which explains why people with MetS have elevated levels of inflammatory markers like TNFα, C-reactive protein (CRP), and IL-6 (Kopp et al., 2003). One of the cytokines secreted by adipocytes and macrophages is IL-6 (Weisberg et al., 2003), and studies have indicated that obesity and insulin resistance raise IL-6 levels. It is known that IL-6 controls fat and glucose metabolism, mediating insulin resistance through various intricate mechanisms (Kanemaki et al., 1998). TNFα is the cytokine produced in adipose tissue, primarily by local macrophages. Its production is correlated with insulin resistance and varies proportionally with adipose tissue mass, both of which are essential characteristics of Metabolic Syndrome (Weisberg et al., 2003). By serine phosphorylating and inactivating insulin receptors and downstream signaling molecules, TNFα reduces insulin's metabolic effects in adipocytes and hepatocytes, thereby eliciting pathogenic effects (Hotamisligil et al., 1994). By causing hepatic lipolysis and raising FFA levels in the bloodstream, TNFα also plays a role in insulin resistance (Zhang et al., 2002).

A cross-sectional study included 51 obese and 30 normal-weight Danish adolescents aged 12–15 years, which showed that 14% of adolescents with obesity had metabolic syndrome. They had significantly higher blood pressure, insulin, homeostasis model assessment of insulin resistance, C-peptide, total cholesterol, low-density lipoprotein cholesterol (LDL), triglyceride, C-reactive protein (CRP), interleukin-6 and tumour necrosis factor-alpha and lower high-density lipoprotein cholesterol values, compared with normal-weight adolescents (Gøbel et al., 2012). Moreover, data from the NHANES 2001–2010 among 3,495 adolescents aged 12–19 years found that the prevalence of metabolic syndrome was 10.1%, with approximately 73.2% of the participants having at least one criterion. In males, the prevalence was higher than in females (13.0% vs. 6.4%) (Miller et al., 2014).

The Fourth and Fifth Korea National Health and Nutrition Examination Surveys among 1663 children and adolescents aged 10-19 years old examined the relationship between obesity measures and metabolic syndrome. The metabolic risk factors were high-density lipoprotein cholesterol, triglycerides, fasting blood glucose, and resting blood pressure. Obese children and adolescents, regardless of the obesity measures used, were more likely than their non-obese counterparts to exhibit clustering of metabolic risk factors: obesity based on WC (OR=1.917, 95% CI:1.066, 3.446, p=0.010), obesity based on WHtR (OR=2.160 and 95% CI:1.203, 3.878, p=0.003) and BMI (odds ratio, OR=4.151, 95% CI:2.763, 6.238, p<0.001). According to research, adolescents who were obese had a higher risk of developing metabolic syndrome compared to their counterparts who were not obese (Song et al., 2024). Another study, which included 353 students aged 10 to 14 years in Turkey, aimed to determine the rates of metabolic syndrome (MS) in children and investigate the association between MS components in this age group. Children's blood samples were collected for analysis of total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), very-low-density lipoprotein (VLDL), triglyceride fasting glucose level, and basal insulin. The average BMI was 20.57 ± 3.48 kg/m², with 10.4% (n=41) being overweight and 12.7% (n=50) obese. Metabolic syndrome was diagnosed in 0.85% of the whole study population, including 6% of obese children. The results indicated that there was a significant positive correlation (p<0.001) between BMI and the following measures: waist circumference, waist/hip ratio, systolic and diastolic blood pressure, basal insulin level, insulin resistance assessed by the homeostasis model, triglyceride value, total cholesterol level, LDL, VLDL level, and a significant negative correlation with HDL level (p<0.001). The study's findings demonstrated that metabolic syndrome affected children as well as adults and that this was a serious health issue. Children who are obese are more likely to have MS (Elitok et al., 2019). In March 2010, 60 obese children between the ages of 7 and 9 who were attending the Al-Zahraa Hospital Outpatient Clinic in Egypt were the subjects of a case-control study. The study aimed to determine the relationship between obesity and various components of metabolic syndrome in these children as well as the associated clinical and biochemical features. Of cases in which children were obese, 25% had MS. When comparing the values of insulin, HOMA-IR, LDL, systolic and diastolic blood pressure, waist-to-hip ratio, and other measurements to the lean controls, obese children demonstrated significantly higher values. Furthermore, in obese children, HDL levels were significantly lower than in controls. In comparison to obese children without MS, obese children with MS had significantly higher values of the body mass index standard deviation score (SDS), skinfold thickness, visceral fat thickness, waist circumference, systolic and diastolic blood pressure, HOMA-IR, insulin, and triglycerides; in contrast, HDL was significantly lower. Compared to children without MS, obese children with MS had higher rates of dyslipidemia and hypertension. The findings indicated that in obese children, visceral fat positively correlated with both insulin level and waist circumference ($P < .05$). The MS was notably more common in Egyptian children who were obese. The most common features of this syndrome in obese children were high HOMA-IR values and abdominal obesity (Zaki et al., 2012).

A systematic review and meta-analysis of 10 randomized controlled trials were carried out to evaluate the impact of a low-fructose diet on metabolic and anthropometric indicators. A low-fructose diet did not significantly affect weight, but it had a significant effect on waist circumference (SMD = -0.48; 95% CI: -0.67, -0.29, $P < 0.0001$) and body mass index (SMD = -0.2; 95% CI: -0.37, -0.04, $P = 0.017$). In addition, a low-fructose diet significantly impacted triglyceride, hemoglobin A1c, fasting blood glucose, and systolic blood pressure. On the other hand, it had no discernible impact on insulin levels, diastolic blood pressure, or insulin resistance as assessed by the homeostatic model. A low-fructose diet was more beneficial for healthy individuals over 50, according to subgroup analysis. According to the findings of the meta-analysis, low-fructose diets dramatically lower levels of triglycerides, hemoglobin A1c, systolic blood pressure, waist circumference, body mass index, and fasting blood glucose (Jafari et al., 2024). A systematic review of nine studies highlighted a concerning trend: a rising incidence of metabolic syndrome in children and adolescents with Type 1 diabetes (T1DM). The prevalence of MetS in this population ranged from 3.2% to 29.9%, adding to the existing challenge of weight management for these individuals. Notably, the studies also reported an average of 20.1% of children and adolescents with T1DM being overweight and 9.5% obese (Grabia et al., 2021). Additionally, another systematic review pinpointed the dramatic increase in childhood obesity rates within developing countries as a significant factor contributing to the high prevalence of pediatric metabolic syndrome in these regions (Kelishadi, 2007).

The exact causes of metabolic syndrome are still being investigated, but Al-Hamad and colleagues (2017) suggested a complex interplay between three major factors: obesity, insulin resistance, and inflammation (Al-Hamad & Raman, 2017)**.**

The health benefits of a Mediterranean diet, as opposed to the Western diet, have been documented in several studies. This diet is linked to lower risk of heart disease and cardiovascular mortality as well as a lower overall mortality. Findings from a multicenter trial in Spain conducted on participants at high cardiovascular risk found that those assigned to a Mediterranean diet supplemented with extra-virgin olive oil or nuts had a lower incidence of major cardiovascular events than those assigned to a reduced-fat diet (Estruch et al., 2018). However, it has been demonstrated in multiple models that dietary restriction without severe nutritional deprivation can increase lifespan (Ford et al., 2011).

1.4 Causes of obesity

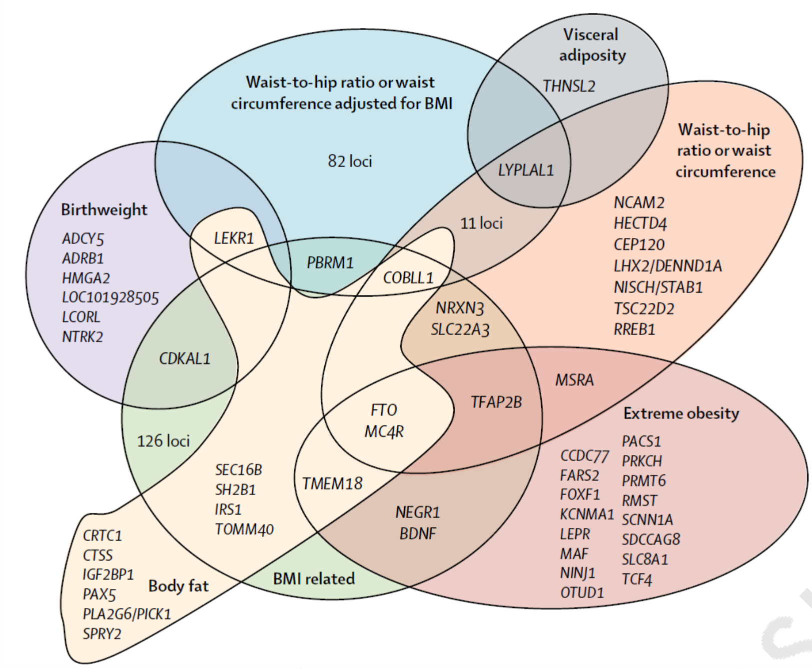
1.4.1 Genetics

A combination of causes and contributor factors, such as individual behavior and genetics, are the main reasons for obesity. According to NIH, 'The genome is the entire set of DNA instructions found in a cell. In humans, the genome consists of 23 pairs of chromosomes located in the cell's nucleus, as well as a small chromosome in the cell's mitochondria. A genome contains all the information needed for an individual to develop and function' (National Human Genome Research Institute, 2024b). Over the last 20 years, the identification and characterization of rare genetic abnormalities in individuals and families with extreme obesity has provided fundamental insights into the biological regulation of hunger, food intake, and weight gain. Mutations in genes encoding leptin, the leptin receptor, pro-opiomelanocortin, the melanocortin-4 receptor, and brain-derived neurotropic factor have all been found to be harmful (Ramachandrappa & Farooqi, 2011). Large chromosomal deletions are another cause of severe monogenic obesity, which is linked to hyperphagia and learning and behaviour impairments (Bochukova et al., 2010). Many of these breakthroughs in the genetics of obesity have come from studies of severely obese children with early-onset obesity, suggesting that these rare mutations have a greater impact on BMI growth in children than in adults (Stutzmann et al., 2008). Much more recently, advances in understanding the polygenic foundation of common obesity and normal variations in BMI have been made. Several common genetic variations are strongly related to adult BMI and obesity, according to genome-wide association studies in large-scale population-based investigations. In 2007, the FTO gene was discovered, followed by MC4R, TMEM18, SH2B1, KCTD15, MTCH2, NEGR1, BDNF, SEC16B, GNPDA2, and

ETV5 and 18 other genes (Speliotes et al., 2010). Several of these variations demonstrated substantial relationships with childhood BMI even though the research focused on BMI or obesity in adult populations (Willer et al., 2009; Speliotes et al., 2010). An insight into the genetics of common obesity has been provided by twin studies. The estimates for mean correlations for body mass index (BMI) based on data from over 25,000 twin pairs and 50,000 biological and adoptive family members are 0.74 for monozygotic ("identical") twins, 0.32 for dizygotic ("fraternal") twins, 0.25 for siblings, 0.19 for parent-offspring pairs, 0.06 for adoptive relatives, and 0.12 for spouses (Maes et al., 1997). The high link between BMI and monozygotic twins, as well as its attenuation with lower levels of shared genes, suggest that BMI has a strong genetic influence. This conclusion, however, is predicated on the premise that identical and fraternal twins share the same degree of shared environment, which may not be true in practice.

Genes instruct the body on how to respond to environmental changes. Several gene variants have been identified as potentially contributing to obesity by increasing hunger and food intake. Rarely does a specific mutation of a single gene cause a definite pattern of inherited obesity within a family (monogenic obesity). Most obesity cases, on the other hand, are most likely caused by complicated interactions between several genes and environmental factors that are yet poorly understood (multifactorial obesity) (Bouchard, 2010; Choquet, 2011). Figure 1.1 summarizes the set of genes associated with body status to date (Goodarzi, 2018).

Figure 1.1 Genes associated with body status (Goodarzi, 2018).



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1.4.2 Epigenetics

According to NIH, ‘Epigenetics (sometimes called epigenomics) is a field of study focused on changes in DNA that do not involve alterations to the underlying sequence. The DNA letters and the proteins that interact with DNA can have chemical modifications that change the degrees to which genes are turned on and off. Certain epigenetic modifications may be passed on from parent to daughter cell during cell division or from one generation to the next. The collection of all epigenetic changes in a genome is called an epigenome’(National Human Genome Research Institute, 2024a).

Excessive weight gain during pregnancy is more common now than in 1990. Furthermore, more women are beginning pregnancy, overweight or obese. One of the proposed developmental pathways to obesity is excessive energy intake during fetal and/or early postnatal life. Maternal hyperglycemia increases glucose transport across the placenta, which causes the fetal pancreas to secrete more insulin. Insulin is adipogenic in late fetal and infant life, increasing both the number and content of fat cells (Wu et al., 1999). Between 1989 and 2003, a population-based cohort study of sibling births in Michigan and New Jersey among 513,501 women and their 1,164,750 offspring found a consistent correlation between pregnancy weight gain and birth weight (Ludwig & Currie, 2010). Infants of women who gained more than 53 pounds during pregnancy were about 5 ounces heavier at birth and were twice as likely to weigh more than 8.8 pounds at birth compared to infants of women who gained 18-22 pounds during pregnancy (Harvard School of Public Health, 2022). Large cohort studies consistently showed a linear and positive relationship between birth weight and later-life BMI, which might be due to correlations with adiposity and lean mass (Rogers et al., 2006). Infants during this period of life gained approximately 6 kg in the first year in absolute terms, as well as triple their size during the first year relative to body size. Findings from randomized controlled trials suggested the existence of long-term "programming" effects of infant nutrition and weight gain on later obesity and obesity-related diseases. Consequently, an increased risk of childhood and adult obesity was associated with faster infant weight gain (Singhal, 2010).

Another epigenetic cause is the duration of breastfeeding in infants. Findings from a meta-analysis of 17 studies about breastfeeding duration showed that breastfeeding infants for an additional month was associated with a 4% lower risk of obesity later in life (Harder et al., 2005). Systematic reviews showed that breastfeeding was associated with a lower cholesterol level (Owen et al., 2008), lower blood pressure (Martin et al., 2005) and lower risk of type 2 diabetes mellitus (Owen et al., 2006) later in life. Higher intakes of milk and other sources of energy among formula milk-fed infants were positively associated with infancy weight gain and childhood BMI (Ong et al., 2006). However, the energy demands for growth were significantly higher during infancy than later childhood as a percentage of total energy intake (Lakshman et al., 2012).

Finally, long-term alterations in DNA methylation caused by nutrition in early life have an impact on an individual's health and age-related diseases for the duration of their lives (Lillycrop et al., 2014). Adults with a diet low in methyl have lower levels of DNA methylation; however, these effects can be reversed by restoring methyl to the diet (Tiffon, 2018). Furthermore, nutrients can directly inhibit epigenetic enzymes like DNMT, HDAC, or HAT or change the availability of substrate required for those enzymatic reactions. Consequently, this alters how important genes are expressed, affecting our overall health and lifespan (Davis & Ross, 2007). The metabolism of folate is associated with changes in phenotype via DNA methylation, and as a water-soluble vitamin, provides one carbon for the synthesis of AdoMet, which is necessary for DNA methylation (Kim et al., 2009). Calorie restriction can reduce inflammation by inhibiting critical genes, including NF-κB (Choi & Friso, 2010)

1.4.3 Environmental factors

In some cases, a genetic disorder may cause an imbalance in energy consumption and expenditure, but in most cases, it arises from living in an environment with large consumption of food, especially food rich in energy, low levels of physical activity and extended sedentary behaviour (World Obesity, 2022a).

Since adolescents develop lifelong eating habits that affect both their own health and the health of future generations, they are especially vulnerable to changes in the food system. Throughout the day, they share meals with a variety of people in a variety of social meal environments, including school and the house. Furthermore, other behaviours - like eating at the table during meals - and additional variables like television may have an impact on consumption patterns. Watching TV during meals has been linked to an increase in the consumption of unhealthy foods. However, eating meals with family may have promoted the consumption of healthful foods like fruits and vegetables (Barr-Anderson et al., 2009). As a result, it's critical to evaluate the relationship between different eating contexts and teenage consumption patterns, as well as determine the precise contexts that may promote or inhibit unhealthy eating behaviours. It is important to keep in mind that eating contexts are typically analyzed within social contexts that honor their unique norms and cultures. In the UK, lunch consists of quick and light foods like sandwiches, whereas the evening meal is the main meal of the day in terms of social occasion and meal content (Yates & Warde, 2017). The mealtime when multiple family members can share a meal together is known as dinner. These meals have a longer duration, indicating their social significance and impact on eating habits. Moreover, there is a higher daily intake of foods rich in added sugars, saturated fats and energy-dense among those who eat their meals alone in bed while watching television. The distraction that comes from watching TV during meals can cause internal satiety signals to decrease and normal mealtime satiation to be delayed (Blass et al., 2006), which can result in overconsumption. Adolescents are more likely to see commercials while watching TV, and these advertisements frequently promote highly processed foods. They may choose the promoted food after only a brief exposure to advertising, but repeated exposure to the same advertisements may strengthen this desire (Rey-López et al., 2008). A further drawback of eating in bed is that it takes the place of family dinners at the table, which takes away from the social aspect of eating. Frequent family meals are more likely to happen at the table and are crucial for developing healthy eating habits like consuming fresh foods (Larson et al., 2007). Children and adolescents generally eat fewer unhealthy foods when they are with their parents. Consequently, the setting created by family meals offers adolescents a significant chance to be introduced to healthy food options, supporting parental modeling of eating habits. The eating habits of adolescents are significantly influenced by their families and friends.

Nonetheless, the foods they eat with their families differ from those that they eat with their friends (Kelly et al., 2019). It was indicated that eating with friends at restaurants or at their homes was linked to consuming more unhealthy foods on a daily basis. While mealtimes spent with friends were a valuable opportunity for social interaction, eating habits could also be influenced by other factors. Individual eating behaviours were frequently modified according to the social group and the perceived norms to fit in and be accepted in the group (Yates & Warde, 2017). Another study found that dining with friends increased energy intake by 18% and that social facilitation had a selective effect on the consumption of sweets and high-fat foods (Hetherington et al., 2006). Finally, a stronger influence on eating behavior might come from the eating environment. In UK adolescents, eating out of the house, especially at food outlets, was also associated with higher energy intake from unhealthy foods (Toumpakari et al., 2019).

1.4.3.1 Family environment

Children are not rational, have inconsistencies in their preferences over time, and are influenced by the environment that their parents create. The important role of parental-created environmental factors in childhood obesity has been indicated by Anderson and colleagues (Anderson et al., 2007). In this study, they investigated the relationship between parental and child BMI and concluded that the relationship between mother's and child's BMI has grown over time, indicating the significance of shared environment in rising obesity rates.

East et al. (2019) assessed the home, family environments, and parenting - such as father absence, family stress, maternal depression, an unappealing unstimulating home, and low parental warmth/acceptance - at 1 and 10 years in 1,000 Chilean children and adolescents aged 5, 10, 15, and 21 years old. They found that a higher adult BMI or faster BMI growth was related to home and family characteristics indicative of less supportive environments. These factors indicate a lack of resources that promote children's engagement with and connection to their surroundings (East et al., 2019). Furthermore, the Early Childhood Longitudinal Study-Birth Cohort (ECLS-B) among children aged 2 to 4 years investigated the relationship between shifts in father involvement in childrearing and changes in early childhood obesity outcomes. Results showed that increases in fathers' caregiving were associated with lower odds of obesity in children living in two-parent, heterosexual households from ages 2 to 4 (Wong et al., 2017). Fathers who were absent during early childhood could deprive children of opportunities to model active play in later development as well as physically stimulating experiences (Berge et al., 2010).

According to cross-sectional and longitudinal analyses, children who live with a single parent typically weigh more or gain more weight than children who grow up in other types of family structures. Lack of quality time with their children is more common in single-parent households, which may also allow their kids to eat high-energy foods because they do not place as much emphasis on their diet. Furthermore, single parents might not have a lot of time to play with their kids or motivate them to be active (Chen & Escarce, 2010). Findings from a cross-sectional study with 421 adolescents showed a relationship between parent and child excess weight. Children would engage in less physical activity if both parents had a sedentary lifestyle. Moreover, the prevalence of childhood overweight is inversely correlated with parental education levels. In the same study, it was indicated that children from divorced or single-parent families were more likely to be overweight or obese. Finally, the same survey showed that 32% of parents understood their children's excess weight incorrectly, while 53% misjudged their own (Candel et al., 2021).

The nutritional status of children was highly correlated with the educational attainment of their parents, most likely because the more educated parents were more knowledgeable, aware of the issue, and engaged in more physical activity compared to the lower educational level or lower social classes that seemed to be risk factors for childhood obesity (Leech et al., 2014). Finally, a study in Greece among 1,728 primary-school Greek students and their parents assessed their adherence to the Mediterranean Diet with the KIDMED score. It was found that there were interactions between family structure and adherence to the Mediterranean Diet. In children from nuclear families, the KIDMED score was inversely associated with the likelihood of overweight/obesity compared to those from single-parent families. Consequently, the family structure plays an important role in the effect of healthy dietary habits on children's weight status (Kanellopoulou et al., 2021).

Even after accounting for individual and school influences, researchers found a clear link between family meal routines and dietary habits in teenagers. Adolescents who regularly shared meals with their families and had some rules around food choices tended to eat healthier (Kelly et al., 2019). This aligned with previous studies highlighting the importance of a supportive family atmosphere for healthy eating habits (Berge et al., 2014). Interestingly, this study suggested that supportive home environments had an even stronger influence on a teenager's healthy eating patterns and weight when combined with healthy neighborhood environments (Berge et al., 2014).

A cross-sectional study among 598 Greek children aged 1–19 years old investigated how different meal and snack patterns were related to micronutrient intakes and diet quality. The study revealed that four eating schemes were most commonly reported: breakfast (B), lunch (L), dinner (D), and two snacks (S); B, L, D, and 1S; B, L, D, and 3S; and B, L, and D. Interestingly, most of the recalled days (55.6 percent of the sample overall) included reports of eating all three main meals (breakfast, lunch, and dinner) every day (Mitsopoulou et al., 2019). There was a consensus that eating meals regularly led to better food choices and a higher nutrient density (Savige et al., 2007), and the most consistent finding is that skipping breakfast was associated with a lower intake of many nutrients (Leech et al., 2015).

It has been recommended that it is wise to encourage children and their families to follow a regular meal pattern that includes five meals a day with an appropriate composition, given the ongoing correlation between meal skipping and an increased risk of obesity in children. Frequent family meals have also been shown to protect against the risk of obesity. Farajian et al. (2014) in a cross-sectional study conducted on 4,552 Greek children aged10–12 years old and 2,225 of their parents, found that children who reported having meals with at least one family member five or more times a week had a 14% lower risk of being overweight or obese than children whose family meals were less frequent (Farajian et al., 2014). Findings from a meta-analysis revealed a similar decrease in the odds of being overweight, and children and adolescents who had family meals three or more times a week also had higher odds of eating healthily (Hammons & Fiese, 2011). It has been hypothesized that family meals encouraged social interaction, gave parents the opportunity to act as dietary role models, and provided them with control over the quality and quantity of their children's diet, even though the precise mechanisms by which family mealtimes influenced nutritional habits and guarded against childhood overweight are not fully understood (Hammons & Fiese, 2011).

In the international Health Behaviour in School-Aged Children (HBSC), a cross-sectional study in 2018, among 3,525 adolescents (51.5% girls) aged 11, 13, and 15 years old, it was found that a third of the sample reported eating breakfast rarely or only once a week (Benetou et al., 2020). Similar studies in Greece and other countries have found that skipping breakfast is a common occurrence (Tambalis et al., 2019). Furthermore, 80% of the sample's participants had a family meal nearly every day, compared to 20% who had one infrequently (Benetou et al., 2020). Consistent with previous research, eating less frequently with family was linked to a lower quality diet (Berge et al., 2017). It's possible that eating meals with the family leads to healthier food choices because better foods are consumed, and there are more opportunities for family conversations about diet and health (Rockett, 2007). However, recent studies in Greece have yet to investigate the relationship between family environment and the quality of children's main meals, such as lunch or dinner.

Reducing stress and negative emotions in the family environment could be the link between parental warmth and obesity. There is evidence that children's energy intake is influenced by emotional eating and stress (Hill et al., 2018), and that parenting behaviors like pressuring to eat (Stifter et al., 2011) and using food to soothe moods (Berge et al., 2017) are associated with parental stress. A cross-sectional study among 158 children 6-9 years old showed that in a home environment with lower energy intake and the availability of cognitive and emotional enrichment of children, there was a negative association between home environment and children's energy intake. Furthermore, these results account for a significant amount of variance in the percentage of overweight children. Aside from energy intake and carbohydrates, parental warmth and family integration explained an additional variation in children's overweight percentage. The same results were found about cognitive enrichment and family integration with an additional variation in children's overweight percentage, which was beyond sugar, protein and fat intake (Epstein et al., 2021).

Another factor of childhood obesity in the family environment is the parents' working hours. Findings showed that 10.4% of the increase in childhood obesity could be attributed to changes in labour force participation (Courtemanche, 2009). Parents are pushed to discover fast and convenient food consumption options as they spend more time at work and face tighter time constraints. Consequently, time-consuming healthy meals prepared at home are less convenient than ready-to-consume foods such as fast foods, snacks and soft drinks. This kind of food is appealing to both parents and children because of its convenience and low cost. According to Lakdawalla et al. (2009) lower food prices were attributed to 40% of the recent increase in body weight (Lakdawalla & Philipson, 2009).

Youths' perceptions of their weight in relation to desirable weight standards and social norms are influenced not only by their current socio-economic situation but also by the sociocultural setting they grew up (Baum & Ruhm, 2009; Thompson et al., 1997). As a result, it's likely that overweight children raised in obesogenic homes have higher ideal weights and social norms than children of normal weight (Papoutsi et al., 2013). In Greece, results from studies showed that the high prevalence of childhood obesity was associated with dietary, lifestyle and family environmental factors (Farajian et al., 2014; Magriplis et al., 2019; Kosti et al., 2008). An interesting cross-cultural difference emerged in studies examining the link between socioeconomic status and childhood weight. A US-based study found the highest prevalence of overweight among children from lower SES backgrounds. However, this trend appeared to be reversed in China, where children and adolescents from high-SES families exhibited a greater likelihood of being overweight or obese (Wang, 2001).

The effects of shared genetics and environment among close relatives are reflected in family health history. Families cannot change their genes, but they can modify the environment in which they live to promote a healthy diet and physical activity. These improvements have the potential to improve the health of family members as well as the health of future generations (Bouchard, 2010).

1.4.3.2 School

The rise of the snacking pattern in adolescents reflects a broader shift towards Westernized diets, which are high in processed foods, sweets, and fast food. These dietary patterns are unfortunately linked to an increased risk of developing chronic health outcomes like cardiometabolic co-morbidities. The influence of the school food environment on adolescent dietary patterns is crucial. The school environment significantly shapes their dietary choices, as they spend considerable time there. Schools provide an opportunity for teens to make independent food choices, fostering a sense of autonomy. It has been shown that the availability of healthy options like fruits and vegetables in school could promote healthy eating habits (Gonçalves et al., 2021). Conversely, easy access to fast food outlets near schools was linked to unhealthy dietary patterns among adolescents (Kelly et al., 2019). The Health Behaviour in School-aged Children (HBSC) study, involving 5,344 students found a connection between fast food restaurants near schools and students' eating habits. Students attending schools surrounded by more fast-food outlets reported eating less fruits and vegetables daily. The study also revealed a social disparity: students from lower socioeconomic backgrounds and disadvantaged schools were more likely to report having a less healthy diet overall (Kelly et al., 2019).

Another issue is that school tuck shops are often driven by profit and tend to stock unhealthy choices. These items are typically high in calories, saturated fat, and sugar, while lacking essential vitamins, minerals and fibre. Healthier options, rich in fibre and low in unhealthy fats and added sugar, are often less popular and less profitable for tuck shops to distribute. This easy availability of unhealthy options can negatively influence students' eating habits and make it harder for them to make healthy choices. A 2012 cross-sectional study in Brazil examined the link between cafeterias selling unhealthy food in schools and students' eating habits. The study involved ninth-grade students from both public and private schools. They found that regardless of whether the school was public or private, having a cafeteria that sold unhealthy food was associated with students consuming more of those unhealthy options (Azeredo et al., 2016). For instance, a large Australian study involving 196 schools found a connection between soft drink sales in school cafeterias and vending machines with a higher frequency of sugary drink consumption among teenagers (Scully et al., 2017). Interestingly, another study showed that students who purchased these drinks at school tended to consume more compared to those who bought them elsewhere (OR = 3.47, 95% CI: 2.74 to 4.39) (Gonçalves et al., 2021). Additionally, a Canadian study categorized schools into three groups based on the availability of unhealthy food options: unhealthy options within the school only, unhealthy options both inside and around the school and overall healthy food environments. Two years later, researchers followed up with the students and found that those who attended schools with the least healthy food options had a higher percentage of body fat compared to those with healthier food environments (Fitzpatrick et al., 2017).

However, the proximity, availability, and affordability of food options within schools play a major role. Mukanu et al. (2022) showed that school canteens and temporary food vendors had a stronger association with dietary patterns compared to supermarkets and fast-food restaurants (Mukanu et al., 2022). Their results showed that semi-permanent food vendors within urban schools could promote healthier eating habits among teenagers. They found that these vendors offered a greater variety, and more nutritious options compared to school canteens. Additionally, they were likely more affordable than supermarkets. This research highlighted the importance of the school environment, beyond individual choices, in shaping adolescent dietary patterns (Mukanu et al., 2022). Similarly, findings from a US study suggested that informal food vendors could encourage increased fruit and vegetable consumption among students (Tester et al., 2012). A systematic review of 20 studies examined the link between selling food in schools (or nearby) and body mass index in students. The analysis found a weak association between schools selling food and increased BMI (OR = 1.14, 95% CI: 1.01 to 2.06). However, it demonstrated that schools that offered healthy food options significantly decreased the risk of students becoming obese (OR = 0.89, 95% CI: 0.82 to 0.96). Interestingly, school nutrition policies or programs alone were not statistically associated with lower obesity risk (OR = 0.81, 95% CI: 0.57 to 1.16) (Gonçalves et al., 2021).

It has to be pointed out, however, that research findings are not always consistent. For instance, a US study found no link between the types of food outlets in a school's neighborhood and adolescent diets (Laska et al., 2010). Similarly, a study in the Netherlands offered limited evidence that the presence of food outlets influenced teenagers' consumption of snacks and sugar-sweetened beverages (van der Horst et al., 2008).

Beyond the choices offered by tuck shops, parents' attitudes can also play a role. Some parents view tuck shops as a place to treat their children, which can reinforce unhealthy eating habits. The contents of students' lunchboxes also contribute to their overall dietary intake during school hours (Sanigorski et al., 2005). Finally, limited knowledge about nutrition can also contribute to unhealthy eating habits. For instance, a study in Italy found a link between students with lower nutrition knowledge scores and consuming more snacks throughout the day (Grosso et al., 2013).

It is very important to investigate the impact of parental and school involvement on the management of childhood obesity. A community-wide pilot intervention investigated how primary school children's diet and physical activity changed after a three-year in London's second most deprived ward. To improve local environments, decrease the consumption of sugary snacks and beverages, increase the intake of fruits and vegetables, encourage healthy snacking, increase active play and travel, and decrease screen time, six co-created themes were the focus of the activities. Using data gathered yearly between 2016 and 2019 from 1,650 children aged 6 to 11 through six local schools - all of whom received the intervention - authors examined changes in the children's self-reported physical activity and diet. After three years of follow-up, there were increases in screen time (high versus moderate/low: OR 2.30, 95% CI: 1.36 to 3.90), but decreases in the consumption of fruit and vegetables (adjusted beta -0.22 portions, 95% CI: -0.44 to 0.001), sugar-sweetened beverages (adjusted beta -0·43 occasions/day, 95% CI: -0.55 to -0.32), and car travel to and from school (adjusted OR 0.19, 95% CI: 0.06 to 0.66). No statistically significant evidence of changes was found for the other behavioral outcomes. Although local governments have significant authority to positively alter the obesity-promoting environment, their programs are rarely assessed (Bijlani et al., 2024). Furthermore, a cluster-randomized controlled trial comprised 353 families with children aged 5 to 7 years old from 17 schools in underprivileged areas of mid-Sweden sought to prevent childhood obesity by encouraging parents to support their children's healthy eating and exercise habits at home. The primary outcomes were photographic measurements of the intake of selected healthy and unhealthy foods and beverages. Secondary outcomes included accelerometer measurements of physical activity and sedentary time, as well as weight and height measurements. All outcomes were evaluated at the beginning and end of the eight-month intervention. Linear multi-level regression revealed that the intervention had a significant positive effect on sweet beverage intake (b = - 0.17, p = 0.04), healthy food intake (b = 0.11, p = 0.04), and more time spent on moderate to vigorous physical activity during the week (b = 5.68, p = 0.02). Children from families with low levels of education showed an unfavorable sub-group effect of the intervention about weekend sedentary time (b = 23.04, p = 0.05). According to the results consistent with the program's two earlier trials, school-based parental support was an effective strategy for promoting young children's health in underprivileged communities (Norman et al., 2024).

A Victorian Government initiative called Healthy Together Victoria (HTV) aimed to lower the rate of overweight and obesity by focusing on risk factors for chronic diseases such as physical inactivity, poor diet quality, smoking, and excessive alcohol consumption. To provide system activation around health and well-being for individuals, families, and communities, the intervention involved a boosted workforce of over 170 local-level staff members working in 12 communities. HTV included an embedded cluster randomized trial (CRT) of a system thinking approach to obesity prevention. The authors report on the two-year changes in overweight and obesity and related behaviours in Grade 8 (13–15 years old) and Grade 10 (15–16 years old) secondary school students at participating schools. The students enlisted using an opt-out method between 2014 and 2016. In the final analysis, 4,242 children received intervention and 2,999 control children. After two years, there was a significant improvement in boys' waist circumference (difference in change: -2.5 cm; 95% CI: -4.6, -0.5) and daily consumption of sugar-sweetened beverages (<1 serve: 8.5 percentage points; 95% CI: 0.6, 16.5) between the intervention and control groups. For girls, the differences between the conditions were not statistically significant. Although there was no discernible effect on BMI, HTV appeared to positively alter boys' waist circumference and consumption of sugar-sweetened beverages. Despite the brief duration of the HTV intervention and the short time interval between data collection points, the HTV findings added to the mounting body of evidence supporting community-wide initiatives to combat childhood obesity (Strugnell et al., 2024).

The impact of parental involvement on the prevention and management of childhood obesity was examined in a systematic review and meta-analysis of 12 randomized controlled trials (RCTs) (a total of 5,573 participants), with a focus on outcomes like BMI z-score, percentage body fat, dietary self-efficacy, exercise levels and screen time. The meta-analysis found a significant decrease in BMI z-score, a non-significant increase in exercise levels, and a substantial decrease in screen time. Additionally, there was a significant improvement in dietary self-efficacy. Parental participation in childhood obesity interventions had a significant effect on screen time, exercise, BMI z-score, and dietary self-efficacy, but not on body fat percentage (Aleid et al., 2024). Finally, a meta-analysis encompassing 24 studies assessed the effectiveness of diverse interventions for children suffering from obesity, with an average age range of 6-12 years. For children with obesity, interventions like exercise without parental supervision (E w/o P), diet with parents (D w/P), and diet, exercise, and lifestyle with parents (D+E+L w/P) proved to be significantly more effective than no intervention at all. The P-score for E w/o P was the highest; P-scores for D w/P and D+E+L w/P were 0.7486 and 0.5464, respectively. Furthermore, in comparison to no intervention, the results showed that E w/o P, D w/P, and D+E+L w/P were significantly effective treatments for children with obesity (Bae & Lee, 2021).

1.4.3.3 Neighborhood

Throughout the world, play is an essential part of childhood. Adults who reflect on their favorite playing memories frequently recall outdoor play, particularly in natural settings, as a source of creativity, freedom, skill, fun and confidence development (Brunelle et al., 2016). Numerous advantages have been found for kids' growth, health, and well-being. One of the strongest results is that children who play outside are more physically active and less sedentary than those who play indoors (Ferreira et al., 2007). It is because playing outside increases physical activity levels. Outdoor play contributed 36 minutes per day to physical activity, compared to 40 minutes per day for organized sports, 26 minutes per day for curriculum-based physical activity and 17 minutes per day for active travel, according to a study of children and adolescents aged 10 to 13 (Borghese & Janssen, 2019). Additionally, outdoor play has been linked to socioemotional learning, mental health, and the development of motor, visual and cognitive skills (Gibson et al., 2017). Public health experts and pediatricians have also acknowledged the advantages of outdoor play and emphasized the significance of regular opportunities for outdoor play (Yogman et al., 2018).

In particular, it is well known that a child's physical activity and other health behaviors that affect their weight status can be significantly influenced by their built environment at home (Daniels et al., 2021). Proximity to fast food restaurants, a dearth of public recreation options, and a poorly walkable neighborhood are examples of built environment characteristics that have been linked to childhood overweight or obesity (Daniels et al., 2021). Historically, resources for the built environment have been disproportionately distributed to wealthy neighborhoods. This has led to persistent differences in childhood overweight and obesity by race and ethnicity as well as by income (Komro et al., 2011). It has been demonstrated that a child's weight status is influenced by elements of the social and built neighborhood environments (Suglia et al., 2016). In particular, the built environment of a neighborhood is made up of both positive and negative components, referred to as neighborhood amenities and detractors, respectively (Cronin & Gran, 2018). Aspects of the built environment that make it simple to engage in physical activity, like parks and playgrounds, sidewalks, and recreation centers, are examples of neighborhood amenities. Abandoned buildings and signs of criminal activity or vandalism are examples of neighborhood detractors, also known as detracting neighborhood conditions or neighborhood disorder. The term "neighborhood social environment" refers to the "relationships, groups, and social processes that exist between individuals who live in a neighborhood" in addition to the sociodemographic makeup of the neighborhood and its inhabitants (Carroll-Scott et al., 2013). Researchers measure neighborhood cohesion, safety, and support, among other domains, to assess the neighborhood social environment (Kepper et al., 2019). Neighborhood support is linked to a lower prevalence of chronic health conditions and a longer life expectancy. It is defined as the reciprocity and trust that exist among community members (Quinn et al., 2019). It is believed that fear of crime in a neighborhood, which is strongly linked to neighborhood drawbacks, directly discourages physical activity because of worries about one's physical safety. It can also cause chronic activation of stress responses linked to obesity (Richardson et al., 2017).

A cross-sectional study that involved 96,858 kids between the ages of 10 and 17 in 2016 and 2021 examined the relationships between neighborhood features (safety, amenities, distractions, and support) and childhood overweight/obesity. Of the children, 66.5% had a healthy weight, 16.8% were overweight, and 17.2% were obese. The weight status of the child was correlated with all four neighborhood factors. With fewer amenities and more detractions, the odds of being overweight or obese generally increased; the highest adjusted odds ratio was observed when there were no amenities and all three potential detractions [1.71; 95% confidence interval (1.31, 2.11)] (Worsley et al., 2024). Similarly, the National Survey of Children's Health, a cross-sectional study conducted on 40,730 children and adolescents, examined the relationships between neighborhood features, such as safety and support, and childhood and adolescent overweight and obesity. When age, sex, race/ethnicity, parent's education, poverty, asthma, physical activity, and sedentary behavior were taken into account, children and adolescents living in non-supportive neighborhoods had a 21% (95% CI: 1.10-1.33) higher probability of being obese than their counterparts living in supportive neighborhoods. Furthermore, there was a 1.30 (95% CI: 1.08-156) and 1.18 (95% CI: 1.01-1.38) probability of obesity associated with neighborhood safety and support, respectively. Overweight and obesity in US children and adolescents might be related to living in unsafe and unsupportive neighborhoods (Borrell et al., 2016).

Public neighborhood parks are important places in cities where kids can play outside safely (Huang et al., 2020). Parks have qualities and features that can be crucial in promoting physical activity across a range of age groups. According to the literature, one of the parks' features that appeals to children the most is the existence of playgrounds (Huang et al., 2020). A playground is typically an outdoor space found in parks or other public open spaces that is intended for kids to play. Playgrounds and public parks can significantly lower childhood obesity and physical inactivity rates worldwide (Ortegon-Sanchez et al., 2021).

The findings of a systematic review evaluating relationships between neighborhood environment features and childhood obesity were evaluated in a comprehensive review of 39 studies published between 2011 and 2019. Walking distance to grocery stores, parks, and leisure centers, crime, sense of safety and social cohesiveness were among the neighborhood environment metrics. Ninety percent of the studies were cohort studies, and the median follow-up period was six years. Studies comparing weight changes to neighborhood changes were less common than studies examining baseline neighborhood environment measures in relation to weight trajectories or obesity incidence. Fast-food restaurants showed the most evidence of negative effects in the food environment domain, but this effect was only noticeable in girls. The findings indicated that parks, green areas, and recreational facilities might be good for weight loss. While not all studies were consistent, there may be a link between increased crime, a lower sense of safety, and an increase in weight (Daniels et al., 2021). The Built Environment and Active Children study, a cross-sectional study carried out in Spain on 83 children aged 6 to 12, examined the association between physical activity and the availability and proximity to parks and playgrounds. Additionally, the body mass index and accessibility to parks and playgrounds were examined, as well as their relationship to active commuting to and from school. Using information from the geographical information system, the availability and distance to parks and playgrounds were determined at several buffer sizes (250, 500, 1000, and 1250 m). The number of playgrounds and parks was positively correlated with both total physical activity and moderate to vigorous physical activity (MVPA); this included light physical activity and MVPA on weekdays, in varying buffer sizes. On weekdays, a negative correlation was observed between total physical activity and the distance to the closest playground. Furthermore, while park land area was negatively correlated with the BMI percentile, the number of playgrounds was positively correlated with active commuting to and from school in various buffer sizes. This study emphasized how crucial it was to evaluate the accessibility and presence of parks and playgrounds in kids' communities when examining physical activity behaviour and weight status (Molina-García et al., 2021).

1.4.3.4 Stress

Stress in early life is associated with childhood obesity. It may be related to increased rejection sensitivity as children enter into adolescence. Several studies suggested a connection between following a Western-style diet high in unhealthy fats and sugars and an increased risk of depression, anxiety or mental health symptoms (Jacka et al., 2010). Animal research offers a possible explanation: a Western diet may lead to a rapid decrease in brain-derived neurotrophic factor (BDNF) levels (Molteni et al., 2002). BDNF is a critical molecule that supports the health and function of brain cells (Castrén et al., 1998). Molteni et al. (2002) examined a potential mechanism through which the regulation of neurotrophins could affect brain structure and function in response to a diet that is similar to the typical Western industrialized diet, which is high in refined sugar and saturated fat (HFS). They also demonstrated that animals with higher hippocampal levels of brain-derived neurotrophic factor (BDNF) mRNA and protein learn a spatial memory task more quickly. The HFS diet was found to be effective in lowering hippocampal BDNF levels and spatial learning performance in just two months. In the hippocampal regions of rats fed the HFS diet for two to twenty-four months, downstream effectors for the action of BDNF on synaptic plasticity were diminished correspondingly to BDNF levels as a result of the protein's impact on synaptic function. Specifically, animals fed the HFS diet had lower levels of the following: (i) synapsin I mRNA and protein (total and phosphorylated), which is essential for neurotransmitter release; (ii) cyclic AMP-response element-binding protein (CREB) mRNA and protein (total and phosphorylated); BDNF regulates the levels of CREB, which is necessary for different types of memory; and (iii) growth-associated protein 43 mRNA, which is important for neurite outgrowth, neurotransmitter release, learning, and memory (Molteni et al., 2002). The Western diet might also increase the production of inflammatory molecules that hinder BDNF production. Therefore, a diet rich in processed foods, sugary drinks, and fast food could potentially increase vulnerability to mental health problems or negatively impact mental well-being. These physiological processes may influence both physical and mental health, even in healthy individuals (Ruano et al., 2013).

This can activate behavioral and physiological changes that lead to higher adolescent BMI (Gooding et al., 2015) as well as the course of faster weight gain (Wickrama et al., 2013). A Spanish study involving over 11,000 participants examined the link between dietary choices and self-reported quality of life. The study identified two distinct dietary patterns: a Western pattern high in red meat, processed pastries and fast food, as opposed to a Mediterranean pattern rich in vegetables, fruits, and olive oil. Interestingly, people who followed a Western diet at the beginning of the study (baseline) reported a lower quality of life four years later. Conversely, those who adhered more closely to a Mediterranean diet at baseline reported better quality of life scores after four years. These findings suggested a potential link between dietary choices and well-being (Ruano et al., 2013).

Multiple underlying processes may contribute to the associations between early life stress and BMI. For example, stress in early life is linked to changes in the biological systems, such as those that control the homeostatic regulation of hunger and metabolism (Murphy et al., 2017). Furthermore, these biological alterations are associated with hormones that regulate hunger and satiety (e.g., ghrelin, leptin) (Yam et al., 2015). Lee et al. (2024) found that female adolescents with low rejection-provoked anger and higher early life stress had higher BMI for their age (Lee et al., 2024).

Growth, both mental and physical is vulnerable to a variety of outside influences during the crucial period of childhood and adolescence. Several studies indicated that exposure to stress has been associated with an increased risk of obesity and metabolic syndrome, among other detrimental effects on a child's development (Pervanidou & Chrousos, 2018; Pervanidou & Chrousos, 2011). A Norwegian cross-sectional study investigated the link between diet and mental health in over 5,700 men and women aged 46-49 and 70-74 years old. The study found that those who adhered more closely to a healthy dietary pattern were less likely to experience depression or anxiety. This association was particularly strong for women. Interestingly, a traditional Norwegian dietary pattern was also linked to a lower risk of depression in women and anxiety in men. Conversely, a Western-style diet was associated with increased anxiety in both men and women. It is important to note that these associations with anxiety lessened somewhat after accounting for total calorie intake (Jacka et al., 2011). However, a large study investigated how diet quality, stress, neuroticism, and mental health relate to each other. Over 121,000 adults aged 18-93 years old were followed for nearly four years, with researchers assessing past-year stress exposure, four neuroticism traits (anger-hostility, self-consciousness, impulsivity, vulnerability), depression, and anxiety. They also examined participants' overall diet quality. The study found that high stress and high neuroticism scores were weakly linked to an unhealthier diet. However, poor diet quality itself was not associated with an increased risk of depression or anxiety. Ultimately, diet quality did not play a mediating role in the connection between stress/neuroticism and mental health problems (Schweren et al., 2021).

A study following nearly 3,000 adolescents over two years (2001-2003) found a link between unhealthy eating habits and mental health problems. The study involved adolescents aged 11-12 or 13-14 years old (Jacka et al., 2013). Emerging research in epidemiology suggests a connection between people's usual dietary patterns and common mental health conditions like depression and anxiety (Jacka et al., 2013). A meta-analysis consisting of twenty-two studies with cross-sectional, prospective, or retrospective designs with data from 143,603 children who were ≤18 years old, collected from the general population or community settings, indicated that girls who were obese had 44% higher odds of depression than children who were normal weight. Conversely, there was no significant correlation found between being overweight or obese as a child and depression, nor between male or obese subgroups and depression (Calcaterra et al., 2024).

Another serious issue is bullying at school between classmates. Bullying is defined as persistent abuse, either physical or verbal, in which the aggressor exhibits greater dominance than the victim (Olweus, 1994). A meta-analysis of 16 articles demonstrated that youths who were overweight or obese had a higher likelihood of becoming victims of bullying (van Geel et al., 2014).

1.4.3.5 Sleep

Another key to maintaining a healthy weight is a good night's sleep. The sleep-wake cycle is the most noticeable circadian rhythm. A good night's sleep is essential for the brain's proper functioning, memory, growth, maturation and metabolic regulation. Furthermore, to maintain optimal physical, mental, and emotional functioning, sufficient sleep is required. Evidence from The National Health and Nutrition Examination Survey (NHANES) indicated an association between a higher incidence of obesity and insufficient sleep duration each day (Gangwisch et al., 2005). Similarly, it has been found that people who got too little sleep were more likely to gain weight and become obese than those who got seven to eight hours of sleep per night. Findings from a British study of more than 8,000 children from birth showed that children who slept less than 10 and a half hours a night at the age of three had a 45 percent higher risk of becoming obese by the age of seven, compared to those who slept more than 12 hours per night (Reilly et al., 2005). Over time, the younger population has shown a tendency toward sleep deprivation, which could be contributing to the burden of short sleep-mediated outcomes like obesity and overweight (Magee et al., 2014). Findings from longitudinal analyses among 10,000 Swedish children showed a relationship between sleep and BMI Z-scores. This indicated that poor sleep habits from the first year of age increase the risk of being overweight and obese 8 years later. Every hour of less sleep increased the child's BMI Z-score by 0.09 units on average (Danial et al., 2023). A systematic review and meta-analyses of 22 longitudinal studies indicated that sleep duration may have an inverse relationship with children's and adolescents' later BMI. In comparison to those who sleep longer, children and adolescents who sleep for shorter periods of time have roughly twice the odds of overweight/obesity (Fatima et al., 2015). Furthermore, insufficient sleep may cause changes in the hormones that regulate hunger (Taheri et al., 2004). Reduced sleep duration has been shown to stimulate the hormones leptin and ghrelin, which in turn increases appetite and hunger, especially cravings for salty snacks (Spiegel et al., 2004). St-Onge et al. (2004) found that irregular sleep patterns caused a hormonal state that increased the risk of overeating and preceded or followed notable changes in energy homeostasis (St-Onge et al., 2011). Research has linked disturbed sleep and increased food intake to the hormones leptin and ghrelin (Knutson et al., 2007). Adipocytokine leptin is primarily produced by white adipose tissue and functions by sending signals of satiety to the appetite control centers in the hypothalamic region of the brain (Ahima et al., 2000). Ghrelin, on the other hand, is an orexigenic hormone that increases appetite by sending signals from the stomach to the brain (van der Lely et al., 2004). According to a small study, young men who lacked sleep had higher levels of the appetite-stimulating hormone ghrelin and lower levels of the satiety-inducing hormone leptin, increasing hunger and appetite, particularly for foods high in carbohydrates and fat (Spiegel et al., 2004).

Tajiri et al. (2023) in a 3-day randomized crossover trial with a control sleep condition (CS; 8 hours of sleep) and a sleep restriction condition (SR; 5 hours of sleep) among 13 women and 11 men with a mean age of 21.4 ± 1.0 years examined changes in subjective psychological factors and dietary intake during sleep restriction. There were two conditions on days three and four: living in freedom and a laboratory (in the morning). A visual analog scale (VAS) measuring 0.0–10.0cm was used to measure subjective psychological factors (hunger, appetite, desire for sweets and fatty foods, sleepiness and fatigue) every hour on day 3 and at 8:00 a.m. on day 4. On day three, the food that was bought and consumed was used to calculate dietary intake. On the fourth day, fasting blood samples were taken at 8:00 a.m. On day 4, the amount of food consumed during the ad libitum breakfast was measured. On day 3, there was a significant difference ($P < 0.05$) between the SR and CS in the areas under the curve for hunger, desire for fatty foods, sleepiness, and fatigue, measured from 0 to 16 hours after waking. Day 3 total dietary intake did not differ between the conditions ($P > 0.05$), but energy and carbohydrate intakes from snacks (daytime and nighttime) were higher in the SR than in CS ($P < 0.05$). Although there was a difference in the 2-arachidonoylglycerol level between the conditions ($P < 0.05$), it was not related to dietary intake, preference for sweet tastes, or the level of active ghrelin on day 4 ($P > 0.05$). In conclusion, under free-living conditions, ratings for subjective psychological factors, as well as energy and carbohydrate intakes from snacks, increased in correlation with sleep restriction (Tajiri et al., 2023).

A crossover design study among 37 children aged 8 to 11 years of age completed a 3-week study three-week period aimed to investigate the impact of varying the duration of the children's sleep on food reinforcement, self-reported food intake, hormones that regulate appetite and weight measurements. After one week of sleeping at home as usual, the children were randomized to spend 1.5 hours more or less each night in bed, with the alternate schedule completed on the third week. The 24-hour dietary recall test, food reinforcement (i.e., points accrued for a food reward), and fasting levels of ghrelin and leptin were the main outcomes. The weight of the children was the secondary result. In the increased condition, children showed lower fasting morning leptin values ($P < 0.05$) and reported consuming an average of 134 kcal/day less than in the decreased sleep condition ($P < 0.05$). Weight measurements showed a 0.22kg decrease in the increased sleep condition compared to the decreased sleep condition ($P < 0.001$). Neither the fasting ghrelin nor the food reinforcement varied. Increased sleep duration in school-age children was associated with lower reported food intake, lower fasting leptin levels, and lower weight as compared to decreased sleep (Hart et al., 2013).

Furthermore, a cohort study in the US examined the relationships between sleep quantity and quality and children's appetitive traits, as well as eating in the absence of hunger (EAH), involving 86 preschool-aged children (4.0 ± 0.8 years). Less satiety responsiveness was linked to shorter sleep duration, as reported by parents (standardized ß = 0.14, 95% CI: 0.01, 0.26; $p = 0.03$). Moreover, there was a negative association between satiety responsiveness and EAH (Pearson's $r = -0.35$, $p = 0.02$). Both the sleep measures and the appetitive traits were not found to be correlated with any accelerometer-measured sleep parameters or EAH (Zhang et al., 2024). Another study, which involved 134 33-month-old low-income children, looked at the possible relationships between various sleep health parameters (duration, timing, and quality) and eating behaviors related to obesity in toddlers, such as emotional overeating, food responsiveness, enjoyment of food, satiety responsiveness, and eating in the absence of hunger (EAH). Greater Emotional Overeating and greater Food Responsiveness were linked to poorer child sleep quality. Children who slept for shorter periods at night consumed more EAH kcal. Enjoyment of Food and Satiety Responsiveness were not linked to any child sleep variables, nor were any eating behaviors associated with a child's bedtime delay (Miller et al., 2019).

A systematic review with 43 studies examined the relationship between chronotype and eating patterns, meal timing, energy and macronutrient intakes, and obesity in relation to dietary habits. Of the included studies, about 95% demonstrated a correlation between eveningness and at least one unhealthy eating habit. Regular consumption of fresh and minimally processed foods was linked to morninginess. Furthermore, a higher correlation between late types and obesity was observed in approximately 47% of the studies. Early types were more likely to have protective and healthy eating habits, such as eating early and consuming mostly fresh or minimally processed foods, whereas late types were more likely to exhibit unhealthy eating habits, such as eating late at night, skipping breakfast, and eating processed or ultra-processed foods. Regarding eating and health, intermediate types typically resembled early types more than late ones. Compared to early or intermediate types, late types were also more likely to exhibit higher weight and body mass index (Teixeira et al., 2022). Another systematic review comprising 50 randomized controlled trials (RCTs) sought to investigate the association between sleep duration and energy intake, food consumption, anthropometric traits, and hormones that regulate appetite. Of these, 7 RCTs were conducted on children or adolescents, and 43 RCTs were conducted on adults. The results indicated that while protein and carbohydrate consumption, total energy expenditure, and respiratory quotient were unaffected by sleep restriction, it might result in a significant increase in energy intake, fat intake, body weight, appetite, hunger, eating occasions, and portion size. Additionally, the amount of sleep did not affect the cortisol, ghrelin, or serum leptin concentrations. It has been suggested that in order to address disordered eating, it might be necessary to pay closer attention to sleep duration. Inadequate sleep has been linked to energy imbalance, weight gain, and metabolic disorders (Soltanieh et al., 2021).

The purpose of another systematic review and meta-analysis of 24 intervention studies was to assess how adults' dietary intake impacted by their sleep health. Dietary outcomes included food types, diet quality, energy intake, and intake of fat, carbohydrates, and protein. A partial sleep restriction lasting no more than 5.5 hours per day increases the amount of energy, fat, protein, and carbohydrates consumed daily (Fenton et al., 2021). A meta-analysis of 33 articles examined the relationship between 57,848 children and adolescents' obesity and sleep duration. The results of the overall analyses showed that there were statistically significant relationships between obesity and both short (adjusted RR = 1.57, 95% CI: 1.36 to 1.81, $P < 0.001$) and long (adjusted RR = 0.83, 95% CI: 0.75 to 0.93, $P < 0.001$) sleep durations. The body mass index z-score significantly changed with short sleep duration (mean difference = -0.06; 95% CI: -0.09 to -0.04; $P < 0.001$). On the other hand, lengthy sleep duration has been linked to a decreased risk of childhood obesity. Short sleep duration was found to be significantly linked to obesity in preschool-aged (3-5 years), school-aged (6-13 years), and toddlers (1-2 years) in dose-response analyses (Deng et al., 2021).

1.4.3.6 Sedentary behaviour

Research indicates that the duration of sedentary behaviour, regardless of physical activity level, is associated with increased health risk (Tremblay et al., 2010). The term "sedentary behavior" refers to screen-based sedentary behaviors, such as watching television, playing video games, and using computers (Must & Tybor, 2005) collectively referred to as screen time (ST) (Lanningham-Foster et al., 2006). Children are spending a great deal of time sitting down thanks to current technological trends, and many of these activities only need a small amount of energy (Rinderknecht & Smith, 2004). New generations spend more time using gadgets like PCs, video games, tablets, and mobile phones than watching television. According to Fang et al. (2019) increased screen time for TV or other devices is associated with obesity and overweight in children, and this relationship was stronger when only PC use was taken into account (Fang et al., 2019).

According to the American Pediatric Association, the recommended level of screen time is less than 2 hours per day (Daniels et al., 2015). Bawaked et al. (2020) found that time spent watching TV was a strong indicator of obesity and abdominal obesity (Bawaked et al., 2020). This study was in agreement with the findings of other study from 12 countries in children aged 9–11 years, where there was a positive relationship between TV time and obesity (Katzmarzyk et al., 2015). According to a 2015 meta-analysis, the risk of obesity in children increased by 13% for every extra hour spent watching TV each day (Zhang et al., 2016).

In a cluster-randomized clinical trial (ToyBox-study) of 718 children from six European countries, childhood overweight/obesity was investigated according to diet quality, screen time and physical activity. Findings from this study showed strong positive correlation between a sedentary lifestyle, which included playing video games on the computer and watching television and the risk of being overweight or obese (Miguel-Berges et al., 2023). Furthermore, results from a meta-analysis of 16 cross-sectional studies regarding ST activities merged as an important modifiable risk factor for childhood obesity, indicated a 13% increase in the risk of obesity for every hour or day of TV watching, and a linear dose-response association between TV watching and obesity in children (Fang et al., 2019). The European Childhood Obesity Project (CHOP) among 526 children aged 3-6 years investigated if playing outside and screen time at 4 years had an effect on anthropometric measures at age 6 years. The results showed that daily ST was associated with increased BMI ($p = 0.002$) and waist-to-hip ($p = 0.001$) at 6 years old. For every extra hour of average ST over the course of the four years, there was a 66% increased risk of having a BMI score over one ($P<0.001$) and a nearly twofold (94% higher risk) of having a BMI score over two ($P<0.001$) at the six-years (Schwarzfischer et al., 2020). When the relationship between the sedentary activity variable - which was defined as "consist of reading, doing courses, drawing, puzzles, etc." - and BMI or WC z-scores was evaluated, no association was found (Bawaked et al., 2020). Furthermore, a Spanish study among children found no association between TV time and obesity and abdominal obesity (Schroder et al., 2017).

It has been shown that children's screen time reduces their level of physical activity (Rey-López et al., 2008). However, there were no significant associations for time spent playing outside (Schwarzfischer et al., 2020).

An explanation of the relationship between screen time and childhood obesity could be that increased television viewing has been associated with a higher energy intake (Miguel-Berges et al., 2017). Findings from a cross-sectional among 532 toddlers who watched more TV per day were more likely to consume junk food, sugar-sweetened beverages (SSB) and fast food, compared to those who watched less TV and were more likely to consume fruits and vegetables. Furthermore, toddlers who watched TV during mealtimes had higher odds of consuming more junk food [OR 4.25 (95% CI: 2.71-6.65)], SSB [OR 3.72 (95% CI: 2.16-6.43)] and fast-food [OR 2.83 (95% CI: 1.54-5.20)] (Lutz et al., 2023). Mushtaq et al. (2011) found that Pakistani children aged 5–12 years old with a sedentary lifestyle and less healthy dietary practices such as fast-food had higher odds of being overweight/obese (Mushtaq et al., 2011). Another study of 6,431 European preschoolers (5–12 years of age) showed a positive association with energy-dense foods and beverages and a negative association with the consumption of fruit and vegetables (Miguel-Berges et al., 2017). Anderson et al. (2009) in a longitudinal study conducted on 564 middle school students and 1,366 high school students investigated the relationship between television viewing habits and dietary intake after five years. Participants in the first phase of this cohort, who watched more than five hours of television a day in high school, reported eating less healthily, such as lower intakes of fruits, vegetables, calcium-rich foods, whole grains, higher intakes of snacks, fast-food, fried foods, trans fat and sugar-sweetened beverages. Conversely, five years later, watching television in middle school only predicted a decrease in fruit consumption and an increase in sugar-sweetened beverage intake. Consequently, watching television during adolescence was a longitudinal predictor of worse dietary patterns five years later. The patterns were stronger and more stable when the individual moved from high school to young adulthood than when moving from middle school to high school (Barr-Anderson et al., 2009).

Another factor that plays an important role in ST and childhood obesity is parents and their practices. In 2009-2012, a study conducted among 252 children aged 2–5 years found that children's waist circumference, BMI z-score, and weekly TV viewing were all found to decrease with increased parental control and monitoring of their ST (Neshteruk et al., 2021). Furthermore, a study that included Italian children (6-7 years of age) indicated that a lack of physical activity and excessive screen time contribute to overweight and obesity. It is noteworthy that excessive screen time was found to be the most significant risk factor for childhood overweight/obesity, while higher parental education levels were protective against adopting unhealthy lifestyles with respect to the amount of time spent on physical and sedentary activities. Moreover, the results indicated that participants who engaged in sedentary activities for longer periods of time had more odds of developing unhealthy eating habits (Paduano et al., 2021). Kontochristopoulou et al. (2024) conducted a study among 7,397 children aged 4-12 years from families with low socio-economic status in six European countries to identify correlations between various parental practices and lifestyle indices and childhood overweight/obesity. They found that the risk of being overweight or obese was related to be higher in children who consumed high amounts of fresh fruit juice, had irregular breakfast consumption, had no daily physical activity with their parents, and had higher daily ST (Kontochristopoulou et al., 2024). Furthermore, it was highlighted that children who watch a lot of television were more likely to acquire weight, according to studies conducted over extended periods of time (Rey-López et al., 2008; Boone et al., 2007), Harris et al. found that children who watched cartoons with food advertisements consumed 45% more snack food than children who watched cartoons without food advertisements (Harris et al., 2009).

1.4.3.7 Physical activity

Physical activity has a lot of health benefits. Despite that, people around the world are less active at work and at home, with one in three people getting little if any, physical activity. Physical inactivity is a major contributor to the global obesity epidemic and, thus, to rising rates of chronic diseases worldwide. For children and adolescents, physical activity in family, school, and community activities includes play, games, sports, transportation, chores, recreation, physical education or planned exercise. Cardiorespiratory and muscular fitness, bone health, cardiovascular and metabolic health biomarkers are improved with physical activity. To achieve these goals, it is necessary to incorporate i) at least 60 minutes of moderate-to vigorous-intensity physical activity daily and ii) vigorous-intensity aerobic activities at least 3 days per week (World Health Organization, 2020b).

The IDEFICS study, a longitudinal analysis across eight European countries (Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden) conducted on 16,000 children aged 2–9.9 years showed that children with at least 45 or 60 min moderate-to vigorous-intensity physical activity daily at baseline and follow-ups had less likelihood of becoming overweight, compared to less active children (Carlson et al., 2012; Sprengeler et al., 2021). Similarly, another study investigated an array of dietary and physical activity factors about weight status and indicated that only vigorous physical activity was associated with weight in adolescent boys and girls (Patrick et al., 2004). Wijnhoven et al. (2015) in a cross-sectional study among 15,643 aged 6–9-year-olds, examined the relationship between physical activity and overweight/obesity in five European countries. They found that less favourable physical activity behaviours were positively associated with obesity (Wijnhoven et al., 2015). Furthermore, Mladenova and Andreenko (2015) showed that less physically active girls were more likely to be obese, whereas no such differences were observed among boys. In contrast, they were more likely to be overweight. These gender disparities most likely result from the fact that girls were typically less physically active, whereas boys had higher levels of physical activity across all age groups. It is also well recognized that eating foods high in calories and engaging in less physical activity raises the risk of obesity and overweight (Mladenova & Andreenko, 2015). Additionally, a systematic review that compared the levels of physical activity and sedentary time between obese and non-obese children and adolescents showed that the time spent in MVPA was generally less than the recommended 60 minutes per day in obese participants, and ST was frequently highly independent of age or gender. However, levels of MVPA in non-obese participants were also below recommendations, and there were no differences in ST compared to obese peers (Elmesmari et al., 2018).

In the South-East Asian Nutrition Survey (SEANUTS) among 1,143 children 6-12 years old, it has been shown that participants with low PA had a higher risk of being overweight compared to children who had high PA (Harahap et al., 2018; Wilkie et al., 2016). Another cross-sectional study conducted on 826 children aged 8-11 years showed that time spent at MVPA was inversely associated with the risk of overweight/obesity. However, few participants met the physical activity recommendations (Aragón-Martín et al., 2022; Keane et al., 2017). A systematic review on the relationship between physical activity, physical fitness, and overweight in adolescents showed that overweight and obesity were inversely associated with PA. Furthermore, the same review highlighted that all studies showed physical fitness to be inversely associated with overweight (Rauner et al., 2013). Kambas et al. (2015) showed that normal and obese children aged 4–6 years had significant differences in step counts on weekdays ($p < 0.001$), weekend days ($p < 0.05$), during school ($p < 0.001$), after school ($p < 0.005$) and in weekly steps ($p < 0.005$) (Kambas et al., 2015).

Findings from a four-year randomized trial among 945 participants 12 years old showed that in non-overweight adolescents, increasing physical activity through a multilevel program prevented excessive weight gain (Simon et al., 2008). A meta-analysis of randomized controlled trials about the efficacy of exercise in weight loss among overweight and obese adolescents indicated that BMI, body fat percentage, and waist circumference decreased with exercise intervention (Stoner et al., 2016). On the other hand, Gorely et al. (2011) found that while the intervention initially resulted in positive changes in physical activity levels and body composition, these changes did not last after the end of the intervention period (Gorely et al., 2011).

In order to investigate the relationships between weight loss, exercise enjoyment, obstacles to physical activity, and the perceived importance of MVPA and MVPA engagement, this study conducted a secondary analysis of data obtained from individuals recruited in the US between 2014 and 2016 for a long-term behavioral weight loss (BWL) trial. An 18-month BWL intervention was completed by adults (N = 301) who were overweight or obese. An additional 18 months were spent in a follow-up without any intervention. Participants ranked the significance of six weight control strategies at baseline, six months, eighteen months (i.e., post-treatment), and thirty-six months (i.e., follow-up): food journaling, MVPA, light PA, self-weighing, small portions and low-calorie diet. Regardless of the weight control goal (weight loss vs. maintenance), most participants viewed MVPA as a primary weight control strategy throughout the intervention, ranking it as the first, second, or third most important strategy. In comparison to those who did not, those who ranked MVPA as their primary weight control strategy at concurrent time points engaged in significantly more MVPA at post-treatment had greater weight loss at follow-up, endorsed fewer barriers to PA at post-treatment and follow-up, and reported enjoying exercise more both at baseline and post-treatment. In a long-term BWL intervention, weight loss, adherence to MVPA, and subjective experiences with MVPA were all correlated with the perceived importance of MVPA (Ehmann et al., 2023). Another study with participants from a larger randomized controlled behavioral weight-loss trial examined the relationship between MVPA and aspects of negative affect (e.g., average levels of negative affect, variability in negative affect) in people trying to reduce their weight behaviorally by trying to raise MVPA. In the sixth month of a year-long behavioral weight loss program, 139 participants submitted data. The average negative affect and the variability in negative affect over the assessment period were lower in those who participated in MVPA more frequently and for longer periods of time. Less variability in negative affect than one's average level also predicted more time spent in MVPA the following day; lower negative affect on one day predicted more time spent in MVPA the following day. On a single day, greater MVPA engagement than one's mean did not predict mean or affect variability. Over time, practicing

MVPA might lessen negative effects, and less negative effects might boost one's motivation to practice MVPA. Significantly, daily effects revealed affect to be a significant acute predictor of MVPA behavior. Programs that recommend physical activity may benefit from including skills to manage negative affect, especially for individuals who have higher negative affect or variability in negative affect (Kerrigan et al., 2020).

A cross-sectional study of 1,200 children 6-10 years old from eight public schools in Brazil examined the association between physical activity (PA) environment at schools and age, sex, and obesity in children. There were observed positive correlations between BMI and the following: duration of breaks (0.564), indoor sports courts (0.662), physical education teacher (0.349) and physical education classes (0.847). Sex (-0.212), age (-0.387), extracurricular PA (-0.492) and playground (-0.557) all showed negative correlations. Furthermore, the centrality indicators showed that BMI had the highest closeness (2.239) and strength (1.230) values, while extracurricular PA (1.789) was the variable with the highest betweenness values. The presence of playgrounds in schools and extracurricular PA was linked to a healthier weight in children from low-income families (Souza Filho et al., 2024). In five major Chinese cities (Beijing, Shanghai, Xi'an, Nanjing, and Chengdu), a cohort study comprising 5,535 schoolchildren was carried out in 2015, 2016, and 2017. The study examined the physical activity and sedentary behavior of the participants and examined their associations with the weight status of the participants as well as pertinent gender differences. From 2015 to 2017, these kids had high rates of central obesity (28.1%, 95% CI: 26.9%-29.3%) and obesity (12.4%, 95% CI: 11.6%-13.3%). Individuals who took less than five minutes on their typical daily walk to school had a higher probability of being obese (OR: 1.96, 95% CI: 1.03-3.73) compared to those who walked for at least fifteen minutes. Individuals who watched screens for longer periods of time had higher odds of being obese (OR: 1.13, 95% CI: 1.06-1.21) and having central obesity (OR: 1.05, 95% CI: 1.02-1.09). In urban Chinese children, less walking time and more screen time were associated with a smaller likelihood of obesity (Sun et al., 2021). A cross-sectional study carried out in the US in 2019 on 39 children aged 3 to 6 examined the viability of tracking daily caloric intake and physical activity. Pertaining to daily screen time (1.5 ± 0.8 vs. 1.7 ± 0.8, P = 0.442) and mean daily calories (1403.9 vs. 1406.1 kcal/day, P = 0.980), there was no statistically significant difference observed between children who were overweight or obese and those who were not. When comparing children who were overweight or obese to those who were not, their mean daily steps were lower (8038 ± 2685 vs 10038 ± 2599, P = 0.051). The results showed that preschool overweight/obesity was more closely correlated with decreased physical activity than calorie intake and that pedometer activity tracking could be used with children ages 3 to 6 (Bedell et al., 2022).

The European Youth Heart Study that was conducted on 487 children and 274 adolescents showed that 37.5% of 9-year-old normal-weight and 34.0% of 9-year-old overweight/obese children, and 16.4% and 27.3% of normal-weight and overweight/obese adolescents met the recommendations of 60 min of MVPA daily (Laguna et al., 2013). Similarly, Raistenskis et al. (2016) in a cross-sectional study of 532 Lithuanian adolescents aged 11-14 years, found that obese and overweight participants had lower physical activity levels and lower physical fitness than normal-weight children (Raistenskis et al., 2016). A systematic review for physical activity among overweight and obese adolescents reported that PA was significantly and beneficially associated with changes in fat percentage, waist circumference, insulin, systolic blood pressure, total cholesterol and low-density lipoprotein cholesterol, as well as with small non-significant changes in glucose, diastolic blood pressure, and high-density lipoprotein cholesterol (Vasconcellos et al., 2014). A meta-analysis of 28 articles included 1,010 patients evaluated the impact of exercise training on children who were overweight or obese by looking at markers related to inflammation and glucose metabolism. Findings showed that in children who were overweight or obese, exercise therapy improved glucose metabolism by lowering levels of FBG, FINS, and HOMA-IR. It also improved inflammatory status by lowering levels of IL-6, CRP, leptin, and adiponectin. The relationship between exercise training and TNF-α levels was not statistically significant (Li et al., 2024).

The I.Family study included families from Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden. This study examined sibling pairs with 1) all same-sex sibling pairs with a maximum 4-year age difference, 2) sibling pairs discordant for overweight and 3) twin pairs, found that MVPA was associated with lower BMI z-score within all 3 groups of sibling pairs. Authors indicated that within sibling and twin pairs growing up in the same home, MVPA and energy intake were related to BMI differences, independent of family-level confounding factors (Bogl et al., 2019).

A healthy weight status may influenced by behaviours best adopted during childhood, such as physical activity (Jones et al., 2013). However, the prevalence of physical activity among schoolchildren aged 6-10 years old has significantly declined, and many do not follow PA recommendations (Wu & Chang, 2019). Furthermore, because there are fewer environments conducive to physical activity, PA opportunities are even worse for students from low-income families (World Health Organization, 2016). Therefore, given its greater flexibility for structural changes and the potential to implement a transversal health promotion program that could impact multiple schoolchildren at once, the school setting may be a potential setting for promoting PA. Similarly, it plays a crucial role in offering healthy opportunities, particularly in low-income communities where schools are the only setting where students can participate in PA (Di Cesare et al., 2019). In a study, the physical activity levels of 42 students in years 5 (10–11 years) and 6 (11–12 years) during a sports education season were evaluated using the phases of the model, adjusted for body mass index. The students had a mean age of 10.68 ± 0.69 years. Lessons in physical education from the same school were consented to take part. Through sport education, students in both groups completed a team handball learning unit consisting of 14 lessons. The findings demonstrated no statistically significant difference between the overweight/obese group's scores for moderate to vigorous physical activity and sedentary time and the normal-weight group. In order to help overweight and obese children attain moderate-to-vigorous physical activity and sedentary scores comparable to their classmates who were normal weight, sports education might be deemed an appropriate pedagogical framework (Rocamora et al., 2024).

A Greek cross-sectional study conducted on 3,195 children aged 10 to 12 years indicated that boys had higher levels of total, light-to-moderate intensity and vigorous-intensity PA (VPA) than girls. Non-overweight boys had higher levels of total PA and VPA compared with overweight and obese boys (Tambalis et al., 2013). Similarly, the National Health and Nutrition Examination Survey 2007-2012 among adolescents aged 12-19 years showed that boys had more MVPA than girls. Lack of PA in girls was not associated with obesity, but a significant relationship was observed in boys. Normal-weight boys had more MVPA than their obese peers. Consequently, obesity was significantly related to less physical activity in boys (Basterfield et al., 2014; Carson et al., 2015; Glinkowska and Glinkowski, 2018). In Greece, Farajian et al. (2014) in the GRECO study, a cross-sectional study of 690 children aged 10–12 years old, found no association between physical activity and the likelihood of being overweight or obese (Farajian et al., 2014; Hong et al., 2016). Similarly, a cross-sectional study in Italy among 690 children found no association between BMI and physical activity level (PAL) (Rosi et al., 2017). Physical activity and healthy lifestyle habits that form during childhood and adolescence are more likely to be sustained throughout life. As a result, increasing physical activity levels among children and adolescents is critical for everyone’s future health.

1.4.3.8 Nutritional habits

An adequate diet from a nutritional perspective means that it is balanced and that there are no excessive amounts of trans fats, sugars, or saturated fats, among other foods linked to childhood diseases that are very common, like obesity, hypercholesterolemia, or dental caries. Therefore, proper child feeding practices and a diet rich in variety and adequate nutrients will directly impact a child's growth and development. In recent years, there has been a surge of interest in studying dietary patterns within nutritional epidemiology (Trichopoulos & Lagiou, 2001). This shift acknowledges that people consume foods and nutrients as part of a whole dietary approach rather than in isolation. Additionally, it recognizes that interactions between foods and nutrients can amplify or diminish their health effects. The impact of a single nutrient might be too subtle to measure, but the combined effect of multiple nutrients within a dietary pattern can be substantial enough to influence health outcomes (Ruano et al., 2013). Over the past three decades, the food environment has undergone a significant transformation, marked by a surge in the ease of obtaining food and a decrease in its relative cost (Cohen, 2008). The rapid rise in obesity rates over the past three decades cannot be attributed to biological changes within humans themselves. Since we have observed no significant mutations, metabolic shifts, or physiological alterations in individuals, the cause likely lies outside our bodies. This points to environmental factors. Indeed, the past 30 years have witnessed a dramatic transformation in how we access food and engage in physical activity. These environmental shifts could be the key drivers behind the behavioral changes linked to obesity (Cohen, 2008). A healthy diet and physical activity can assist children in growing and maintaining a healthy weight throughout their childhood. Balancing the energy or calories consumed from foods and beverages with the calories burned through activity helps to prevent excessive weight gain (Centers for Disease Control and Prevention, 2022a).

Childhood obesity may be linked to food groups or nutrient intake levels. However, it is possible that general dietary intake patterns are more pertinent and closely related to assessing weight status, and that this will yield more precise information about how to decrease the increasing rates of obesity (Nicklas et al., 2001). In Growing Up Today Study (GUTS) II, a cohort study, 10,918 participants aged 8-15 years were examined according to their adherence to the Mediterranean dietary pattern and BMI change. This study showed that a higher score in KIDMED, an index of adherence to the Mediterranean diet in children, was independently related to a lower BMI. Consequently, there was an inverse association between the KIDMED score, and the BMI (Martin-Calvo et al., 2016). Similarly, Metro et al. (2018) in a cross-sectional study among 337 children, using Mediterranean Adequacy Index (MAI), a diet quality indicator, showed that normal weight participants scored 2.67 MAI mean value while overweight participants scored 1.27 MAI mean value. This result highlighted a decreased adherence to the Mediterranean diet in overweight children compared to their normal weight counterparts (Metro et al., 2018). Another cross-sectional study, «EYZHN» during 2014-2015 with 174,209 students aged 6-18 years showed that participants who had high adherence to the Mediterranean lifestyle according to the Mediterranean lifestyle index (MediLIFE-index) compared to those who had low adherence were associated with lower odds of being overweight, obese or abdominal obese, by 6% (OR 0.94, 95% CI: 0.92, 0.98), 30% (OR 0.70, 95% CI: 0.67, 0.75) and 20% (OR 0.80, 95% CI: 0.77, 0.83), respectively (Katsagoni et al., 2020). Furthermore, in Italy, 1,643 adolescents 11-16 years were included in a cross-sectional study about Mediterranean diet adherence and body composition. The authors found that boys and girls with good adherence to the Mediterranean diet had 30% decreased odds of being overweight or obese. Consequently, there was an inverse association between the KIDMED score and the BMI, waist circumference and fat mass (Mistretta et al., 2017).

Kozioł-Kozakowska et al. (2020) compared dietary behaviours, quality of diet, and nutrient intake among 2 groups of 105 children aged 7-15 years who were obese and normal weight. They showed that in comparison to children of normal weight, obese participants consumed an average of 73.42 ± 19.60 kcal per body weight when normal-weight counterparts consumed 49.89 ± 12.20 ($p < 0.01$), with fat providing more energy than carbohydrates. Furthermore, both groups had low intake of vitamins A, D, folic acid, iron, iodine and calcium. According to the HDI, nearly 40% of obese children had a poor diet high in highly processed and high-fat foods, as well as low in whole grains, fruits, and vegetables (Kozioł-Kozakowska et al., 2020). While energy imbalance plays a major role in the development of childhood obesity, there has not been much research done on the relationship between various dietary components as indicated by diet quality scores and children's weight status. In a cross-sectional study of 1,700 children 9-10 years old, it was found that measures of children's weight status are linked to the Diet Quality Index (DQI) and Diet Indicator (HDI), regardless of energy density, physical activity, and other significant variables linked to childhood obesity. This suggested that, in addition to energy balance, dietary profiles could help prevent childhood obesity. In this sample, the Mediterranean Diet Score (MDS) showed no correlation with any of the weight status measures considered (Jennings et al., 2011). In the US, a cross-sectional study conducted on 156 children aged 4–9 years showed that overweight and obese participants who mentioned lower consumption of an energy-dense diet also mentioned eating a higher quality diet, as measured by the HEI. Particularly, higher HEI scores for fruits, vegetables, and saturated fat were linked to a lower energy-dense diet, which was measured with all foods and beverages consumed or just food consumed (Poole et al., 2016). Furthermore, in the ZOOM8 Study, both the prospective and cross-sectional analyses, there was an inverse relationship between high adherence to a frequency-based Mediterranean Diet Score and waist circumference or waist-to-height ratio, as well as overweight, obesity and fat mass. Modern dietary habits that involve consuming energy-dense fast foods and beverages may be the cause of the low adherence rate to the Mediterranean diet and the high prevalence of overweight and obesity (Roccaldo et al., 2014). This study's findings about the high intake of fat, fast-food, sweets, and sugar-sweetened beverages combined with the low consumption of vegetables were consistent with the observation that people were generally shifting from a traditional to a Westernized diet, especially as urbanization increases (Grosso et al., 2016).

Concerning eating patterns, a cross-sectional study among 1,549 children aged 11–13 years showed that those with a high-frequency consumption of fast-food diet, as well as low physical activity, had 2.22 times higher chance of central obesity than children with a low-frequency consumption of fast-foods, sweetened beverages, energy drinks and sweets. These findings emphasized health-promoting dietary habits and active lifestyle to decrease adiposity risk (Wadolowska et al., 2018). Similarly, Shang et al. (2014) in 630 children (8-10 years) during 2005-2008, found that higher scores on the fast-food pattern related to different indices of adiposity such as BMI, waist circumference and percentage of body fat mass (Shang et al., 2014). Likewise, the population-based birth cohort Generation XXI with 3,473 children evaluated at both 4 and 7 years of age highlighted that even if the dietary pattern high in energy-dense foods persisted across the two ages in both sexes, it was positively related with later BMI only in girls at 4 years of age ($\beta=0.075$, 95% CI: 0.009, 0.140, $p = 0.046$) (Durão et al., 2017). Moreover, a cross-sectional study among 892 school children aged 7–14 years examined the nutritional behaviors of insufficient consumption of vegetables, fruit, whole grain products, dairy products, and fish in relation to weight status. The authors found that the frequency of consumption of vegetables and fruit is significantly reduced with an increase in a child’s BMI ($G = -0.110$, $p < 0.05$ and $G = -0.114$, $p < 0.05$) (Zadka et al., 2018). Katsa et al. (2018) among 480 participants 5–12 years old, showed that meat consumption was positively correlated with both BMI ($p = 0.038$) and WC ($p = 0.023$) (Katsa et al., 2018). Similarly, Sun et al. (2020) in 2,224 individuals, showed that children who skipped breakfast and ate unhealthy food had a higher risk of being overweight or obese (OR 1.507, 95% CI: 1.116-2.035 and OR 1.571, 95% CI: 1.170-2.110, respectively) (Sun et al., 2020).

Portion size is another parameter associated with BMI. Findings from the UK National Diet and Nutrition Survey in 2008–2011 to 636 participants aged 11–18 years showed that the portion sizes of several high-energy-dense foods such as high-fibre breakfast cereals, cream and high-energy soft drinks were associated with higher BMI in all participants (Albar et al., 2014). A cross-sectional study among 748 young French children found a positive association between overweight and the portion size of croissant-like pastries and other sweetened pastries. On the other hand, the portion sizes of liquid dairy products were negatively correlated with overweight (Lioret et al., 2009).

Interestingly, one study examining portion sizes observed that children unconsciously took larger bites when served more food, automatically widening their mouths to accommodate it (Orlet Fisher et al., 2003). This aligned with research by Libet and colleagues who demonstrated that motor actions could precede conscious awareness of them (Libet et al., 1991). Despite this, people mistakenly believed they had complete conscious control over their behaviors (Wegner & Wheatley, 1999). Moreover, weight gain, in many cases, is a gradual and subtle process. People accumulate weight incrementally, often just a few kilograms at a time. A seemingly small daily calorie surplus, as low as 20 extra calories, can lead to a significant weight gain over time. For an average person, this could translate to roughly 0.91kg gained per year, accumulating to 4.54kg in just 5 years. The subtlety of these changes makes it challenging for people to detect or monitor their calorie intake, especially in an environment brimming with readily available calories and constant cues to eat (Cohen, 2008).

Roll et al. (2024) measured preschoolers' intakes in two randomized crossover trials, to determine the relationship between meal energy intake and meal energy dense. They also examined the relationship between meal portions, eating occasions, and menus in 6,355 meals that were served to 94 children between the ages of three and five. For five days in a row, they nourished the children with everything they needed to eat and drink in their regular daycare. The results of this investigation demonstrated that energy intake during meals was connected to both the energy-dense and the weight of food consumed (all $P < 0.0001$), as well as to the portions of food served. The type of meal and the items offered on the menu had a big impact on how much energy was consumed. Higher energy-dense foods were served in smaller portions than lower energy-dense foods, and children ate them selectively. The results demonstrated that while children's energy intake generally increased with increasing energy-dense, it curvilinearly decreased with higher energy-dense meals, lacking a distinct breakpoint. More meal-related variables, like the serving size, may account for this decrease in intake at higher ED than sensitivity to meal energy content (Rolls et al., 2024). The effects of changing the portion size and energy-dense of lunches served to children in their regular eating environment were evaluated in a crossover design involving 120 children ages 3-5 years. Lunch was provided once a week in three childcare centers for six weeks.

Every item was served at two levels of energy-dense (100% or 142%) and three levels of portion size (100%, 150% or 200%) for each of the six meals. The lunch menu included macaroni, ketchup, chicken, vegetables, cheese, milk, and applesauce in both lower- and higher energy-dense versions. The foods that kids rated showed that both the higher energy-dense and lower energy-dense meals were equally popular. Serving larger portions at meals increased the total weight of food and milk consumed ($P<0.0001$) but changing the energy-dense had no effect ($P=0.22$). On the other hand, energy-dense and portion size had an independent impact on meal energy intake (both $P<0.0001$). Energy intake rose by 24% when portions were doubled and by 40% when meal energy-dense increased by 42%. When compared to the lower energy-dense meal with the smallest portions, these effects increased intake by 175±12kcal, or 79%, at the higher energy-dense meal with the largest portions. Applesauce, macaroni and cheese and chicken were the foods that contributed the most to this increase. Parental assessments of the eating behaviour of their child had a significant impact on the effects of meal portion size and energy-dense on intake, but neither child age nor body size had any influence (Kling et al., 2016). Finally, another study examined the relationship between the portion size of the most energy-dense foods and body composition. A total of 1,889 adolescents from the HELENA-CSS study were included. Most energy-dense foods (for example, cheese) were chosen because they contained more fat and/or sugar and had less fiber and water. PS from "breakfast cereals" had a significant positive correlation (β = 0.012; 0.048) with BMI in males. While "sweet bakery products" were linked to a lower probability of obesity (OR = 0.996; 95% CI: 0.991, 0.999) in females, PS from "carbonated soft drinks" in males (OR = 1.001; 95% CI: 1.000, 1.002) and "bread and rolls" in females (OR = 1.002; 95% CI: 1.000, 1.004) was associated with a higher probability of developing obesity. The current study indicated a link between obesity in European adolescents and portion size of energy-dense foods (Flieh et al., 2021).

Dietary habits also play a role. Specifically, breakfast - the first meal of the day - is essential for maintaining a healthy energy balance and controlling diet. One plausible explanation could be that children who eat breakfast every day are more likely to meet the recommended intake of micronutrients and have a better-quality diet with higher intakes of healthy food groups like dairy, fruit and dietary fibre. On the other hand, children who miss breakfast typically eat more high-energy foods, like fast-food, which can cause overeating and excess hunger (Vereecken et al., 2009). Furthermore, a systematic review that was published in 2010 and included observational studies gathered data regarding the relationship between breakfast consumption and body weight in the European population. Authors indicated that the risk of being overweight or obese is lower for children and adolescents who eat breakfast, and their BMI is lower than that of those who skip it (Szajewska & Ruszczynski, 2010).

Another cross-sectional study of 2,163 children 7,5-9,5 years old reported that 68.64% had breakfast in the morning, 5.9% skipped breakfast and 33.5% of those had a mid-morning snack. Authors highlighted that breakfast, and more specifically, adequate breakfast has a protective role against obesity (Troiano et al., 2018). Similarly, Wadolowska et al. (2019) in a sample of 1,566 individuals (11–13 years), reported that 44% of Polish adolescents usually skipped both breakfast and a meal at school a few times per week with a higher risk of being overweight/obese (OR 1.37, 95% CI: 1.06, 1.78) (Wadolowska et al., 2019). Moreover, a cross-sectional study with 5,332 primary school children aged 6 to 12 years and 3,000 secondary school children aged 13 to 17 years showed that among children, only boys who skipped breakfast had a higher mean BMI-for-age z-score than regular breakfast eaters. Among adolescents, the BMI-for-age z-score was higher for breakfast skippers than regular breakfast eaters (Tee et al., 2018). On the other hand, in Brazil, the prospective cohort study (ELANA) among 809 students aged 10 to 16 years enrolled in 2010 and followed for 3 years reported that baseline breakfast consumption related to low BMI and % body fat (BF) among girls. During follow-up, regular breakfast consumption was associated with an increase in %BF. Consequently, the authors found no consistent relationship between breakfast consumption and adolescent adiposity trajectory (Hassan et al., 2019).

Interestingly, a Japanese cohort study investigated the link between meal skipping and weight gain in university students. The study involved 17,573 male and 8,860 female students. Interestingly, skipping dinner was linked to a significantly higher risk of gaining at least 10% of body weight and becoming overweight or obese (BMI ≥ 25 kg/m2) for both men and women. This association was stronger for dinner skippers compared to those who skipped breakfast. Researchers suggested that skipping dinner might lead to weight gain by increasing appetite later in the day, causing participants to consume more calories overall (Yamamoto et al., 2021). Additionally, a systematic review included 56 studies aimed to examine the relationship between body weight and metabolic outcomes in pediatric children who skipped breakfast and demonstrated that those who skipped breakfast were at higher risk of being overweight/obese. Skipping breakfast was linked to worse blood pressure, metabolic syndrome, lipid profile and insulin resistance (Monzani et al., 2019). In Greece, data from a cross-sectional study among 177,091 boys and girls aged 8–17 years old examined anthropometric and lifestyle factors. The main conclusions drawn from this study were that nearly 23%of school-age children skipped breakfast, individuals who skipped breakfast had worse anthropometric and lifestyle profiles, and skipping breakfast was significantly related to unhealthy eating habits (Tambalis et al., 2019).

The link between skipping breakfast and obesity has been explained by several theories. An insufficient breakfast may result in less energy for physical activity, lowering energy expenditure (Rosato et al., 2016). Additionally, it has been suggested that skipping breakfast increases daily energy intake because people overeat to make up for it later in the day—for instance, by consuming more sugary or high-fat breakfast snacks (Ashwell, 2010). In conclusion, it appears that skipping breakfast raises the risk of being overweight or obese, as well as other cardiometabolic risk factors. Additionally, for those who eat breakfast, the nutrient profile of the foods they eat may have an impact on their weight. Although the exact mechanisms underlying the potential benefits of breakfast on the risk of obesity and other cardiovascular and metabolic diseases are not well understood, it is likely a result of a complex interplay between a number of factors, such as timing, circadian rhythm, general dietary patterns, and the effects of breakfast type on satiety and appetite regulation. Furthermore, a number of environmental, genetic, psychosocial, and socioeconomic factors may increase the risk of obesity in addition to these physiological factors (Gibson-Moore et al. 2023). According to the Childhood Determinants of Adult Health study, skipping breakfast as a child tends to carry over into adulthood and is linked to higher waist circumference, BMI, total cholesterol, low-density lipoprotein cholesterol concentrations, homeostatic model assessment index, and fasting insulin (Smith et al., 2010).

The eating context, which is the setting in which people eat, is a crucial factor in determining the type of food consumed as well as its immediate aspects for each eating occasion. This is the outcome of how crucial context is when making meal decisions. The variety of food options reflects the complexity of eating occasions and locations, which are linked. In this way, research has examined where and how people eat their meals in addition to what they eat. While some studies examined the home food environment (Pearson et al., 2017), others concentrated on the accessibility and availability of unhealthy foods in built environments, such as neighborhoods and schools (Shareck et al., 2018). Additionally, it has been established that different eating environments influence the kinds of meals that adults eat (Liu et al., 2015), whereas exposure to various eating environments encourages children to eat a variety of fruits and vegetables (Mak et al., 2012). In 2013-2014, a cross-sectional study among 406 schools in low socioeconomic status regions of Greece with 16,652 children aged 5–11 and 14,747 adolescents aged 12–18 was designed to investigate the effect of household food insecurity on dietary patterns. Research revealed that children from food-insecure households were more likely than their counterparts from food-secure households to eat unhealthy, high-energy foods like chips, fast food, sweets, sugar-filled drinks, French fries and mayonnaise sauce (Kastorini et al., 2021). These findings were in accordance with economic analyses that showed that lower energy density diets, which were primarily defined by consuming fruits, vegetables, lean meat, fish and whole grains, were generally linked to higher food costs than higher energy density diets, which were defined by consuming refined grains, added sugars, and added fats (Drewnowski & Darmon, 2005). Energy-dense foods are primarily consumed by people with lower socioeconomic status because they are not only affordable to buy but also have longer shelf lives and satisfy hunger (Kastorini et al., 2021). Higher educated and wealthier people tend to provide better nutrition information, which could be a mediating factor in the positive relationship they have with food quality and healthy eating habits. Parental education about nutrition has been linked to a healthier home environment, which has improved adolescents' diet quality (Tabbakh & Freeland-Graves, 2016). It can potentially improve children's and young adolescents' eating habits in particular (Grosso et al., 2013). Nonetheless, scant information exists regarding the correlation between adolescents’ consumption of unhealthy foods, especially during mealtimes, and eating patterns that take into account various dining settings and social contexts (Rauber et al., 2022).

Findings from a cross-sectional study among 881 children aged 8 to 15 years reported that children who eat one time per day were significantly more frequently obese than those who had three or more meals per day ($p < 0.05$) (Mladenova & Andreenko, 2015; Stea et al., 2015). In the Chinese Health and Nutrition Survey (2006, 2009 and 2011), a longitudinal study included 2,277 individuals aged 2–13 years, the consumption of snacking in relation to BMI was examined. It was reported that snacking dominated by fruit consumption was associated with decreased BMI in overweight/obese children and increased BMI in underweight children in China (Taillie et al., 2016).

A study among 6,247 Finnish adolescents aged 16 years old examined associations of three meal patterns on weekdays - five meals including breakfast, ≤ four meals including breakfast and ≤ four meals without breakfast - with overweight/obesity and MetS factors. Findings indicated that the five-meal daily pattern was strongly linked to lower risks of overweight and obesity in both sexes, as well as lower risks of abdominal obesity in boys (Jääskeläinen et al., 2013). When assessing the nutritional status in relation to weight status, one factor that was highly significant was the frequency of food intake. Another study conducted on 881 Bulgarian children and adolescents aged from 8 to 15 years found a significant positive association between overeating and BMI in both genders and a negative association between meal frequency and BMI in boys ($p<0.05$). When children who overeat were compared to their counterparts who eat normal or smaller quantities of food, their BMI values were significantly higher ($p<0.05$). Furthermore, children who eat one or two times a day were significantly more likely to be obese than those who eat three or more meals daily ($p<0.05$) (Mladenova & Andreenko, 2015). These findings were in agreement with the findings of Mota et al. (2008), who showed an authentically higher frequency of overweight and obese cases when the frequency of meals was less than three times per day (Mota et al., 2008).

There is high interest in the connection between highly processed foods and meal timing, a key aspect of chrono-nutrition that remains largely unexplored. A recent study suggests a link between individuals who follow an ‘early eating’ (morning) pattern consuming less artificial sweeteners, seasonings, sweets and unhealthy fats (Rosi et al., 2022). Existing research also highlights the potential benefits of chrono-nutrition, with late meals potentially contributing to lower basal metabolic rate and obesity (Al Abdi et al., 2020). Disrupted eating patterns may also lead to hormonal imbalances, impacting leptin, cortisol, adiponectin, and other hormones that regulate weight, potentially promoting weight gain (Rodríguez-Muñoz et al., 2021).

The tendency to gain weight during the first year of college is a widely recognized phenomenon. This transition from high school to college often involves significant changes in students’ environments and access to resources, which can influence health behaviours. A longitudinal study in the US examined weight changes, dietary habits, and other health behaviours in 159 first-year college students (aged 18 years old). The study revealed that nearly a quarter of participants gained significant weight during their first semester. Students who gained at least 5% of their body weight reported lower activity levels in college compared to high school. Interestingly, this group also reported eating breakfast more often and sleeping more than those who maintained weight (Wengreen & Moncur, 2009). In addition, a study investigated the dietary changes of Greek students, focusing on the impact of living away from home and the influence of the surrounding environment. The researchers compared students who remained at home in Greece (n=43) with those who moved away, either within Greece (n=37) or to Glasgow, Scotland (n=55). The study found that living away from home for the first time, regardless of location, led to generally unhealthier eating habits for Greek students. This suggested that taking responsibility for food preparation, rather than simply location, played a significant role in these dietary changes. These findings aligned with a previous study by Papadaki et al. (2007), which showed that Greek students living away from home made poorer dietary choices compared to those who remained at home (Papadaki et al., 2007). Their research also suggested that managing food purchases and preparation impacted student diets significantly. The present study went a step further by revealing a location-specific effect. While both groups living away from home decreased their intake of raw and cooked vegetables, students in Glasgow exhibited a steeper decline compared to those in Greece. This suggested an 'additive Glasgow effect, implying that the city's environment further contributed to unhealthy dietary choices among these students (Kremmyda et al., 2008).

Other factors in the quality of nutrition are high total energy intake as well as higher consumption of sugars, fats and salt. The National Health and Nutrition Survey 2012, a cross-sectional study among 2,203 Mexican adolescents aged 12–19 years showed a positive association between energy intake and the BMI-for-age z-score ($\beta = 0.347$ 95% CI: 0.101, 0.594, $p = 0.006$) (Arango-Angarita et al., 2019). Furthermore, an Australian study conducted on 2,460 participants aged 5-17 years found that children with a higher BMI z-score or WC consumed significantly more energy than their normal-weight counterparts (Elliott et al., 2011). Adults with lower energy-dense diets tended to consume more fruits, vegetables, whole grains, legumes and fiber and less energy from fat and sugar-sweetened beverages and desserts, according to findings of a study (Raynor et al., 2011). However, only one observational study examined the relationship between dietary energy density and quality in children aged 2–8 years. The findings showed that individuals in the lower energy-dense diet ate more fruits, vegetables, and dairy products and less fat and sugar than those in the higher energy-dense diet (Poole et al., 2016).

A study of a total of 105 children aged 7- 15 years old showed that in terms of sugars, the amount of sucrose consumed by the obese children in the study should be taken into consideration. On average, children who were obese consumed twice as much sucrose as children who were of normal weight. Sweets were another source of sucrose in the diets of obese children, in addition to the use of sugar to sweeten meals, beverages, and flavoured water (Kozioł-Kozakowska et al., 2020). A meta-analysis examining the intake of sweetened beverages in the pediatric population found that over 80% of adolescents regularly consume these types of drinks (Dereń et al., 2019). The scientific literature on beverages varies regarding the effects of consuming carbonated soft drinks (as opposed to low-energy drinks) in relation to obesity. Evidence for the theory that increased energy from sweetened beverages causes an increase in weight has been presented in several reviews (Albar et al., 2014). A cross-sectional study with 946 children aged 3–7 years showed that those who consumed more sugar-sweetened beverages (SSB) had higher BMI-for-age Z-score ($P<0.05$). Further, there was an association between SSB consumption and a higher risk of being overweight or obese (Yu et al., 2016). The UK Millennium Cohort Study, a longitudinal study of 13,170 individuals 7–11 years old had the same findings. Daily consumption of SSB increased the percentage of body fat between ages 7 and 11 (+0.57%). The artificially sweetened beverage was also associated with increased BMI and percentage of body fat in children (Laverty et al., 2015). In addition, the Hellenic National Nutrition and Health Survey (HNNHS) among 1,165 children and adolescents aged ≥2–18 years showed that after adjusting for food groups and macronutrient intakes, the likelihood of being overweight or obese was 2.57 ($p = 0.002$) and 1.77 ($p = 0.047$) times higher for intakes of ≥10% of total energy from added sugars compared to less than <10%, respectively (Magriplis et al., 2021).

Findings from a cohort study, the Avon Longitudinal Study of Parents and Children (ALSPAC), among 521 (5 and 9 years) and 682 (7 and 9 years) participants showed that an energy-dense, low-fibre, high-fat diet was related to increased fat mass and an increased risk of childhood obesity (Johnson et al., 2008). Wang et al. (2020) in the China Health and Nutrition Survey, an ongoing open-cohort study conducted on 23,859 adults aged 20–60 years from 1991 to 2015, found that fat intake, percentage of energy intake from fat and a high-fat diet were associated with increased body weight, BMI and the risk of overweight and obesity in both sexes (Wang et al., 2020). Kozioł-Kozakowska and colleagues found that children who were obese used excessive amounts of energy compared to their ideal weight. Considering their appropriate weight age, the average difference in energy intake between the obese group and the normal-weight children was 1000 kcal, or 30% more than they needed. When the individual nutrient intake that contributed to the excess energy in obese children was analyzed, fats were found to be the primary cause, followed by carbohydrates. The average amount of fat consumed by obese children was twice that of their counterparts with normal body weight (Kozioł-Kozakowska et al., 2020). Interestingly, it was found that 38% and 45% of the obese children in the Spanish population who were the subject of the study consumed more fat and carbohydrates than what was considered by the Acceptable Macronutrient Distribution Range (AMDR) (López-Sobaler et al., 2017). These results were in agreement with those of Greek children who were overweight and showed similar trends, consuming more fat and less carbohydrates for energy (Manios et al., 2008). Since fat has the highest calorific value, it is the primary source of excess energy in children's diets. Both the type and quantity of fat delivered to the children vary statistically significantly. Compared to children with normal body weight, obese children consumed nearly twice as much saturated and monounsaturated fatty acids on average. These fatty acids are primarily found in sweets, salted snacks and meat products. Additionally, children living with obesity ate these foods more frequently (Kozioł-Kozakowska et al., 2020).

Moreover, in the same study, the group of obese children consumed an excess of protein; on average, they exceeded the daily standard for body weight by 7%, while the normal weight children did not exceed it (Kozioł-Kozakowska et al., 2020).

Insufficient fiber intake, which is also present in whole grain cereal products, has been linked to excessive body weight and can raise the risk of developing a number of chronic conditions, such as cardiovascular disease, type 2 diabetes and some cancers (Emmett & Jones, 2015). Poole et al. (2016) indicated that more than half (57.7%) of obese children did not consume the recommended amount of dietary fibre in their diet, while the percentage in the normal weight group was nearly two times lower (30.2%). Consuming dietary fiber from fruits, vegetables, and whole cereal grains lowers the risk of obesity and improves diet quality by adding low-energy, high-nutrient foods (Poole et al., 2016).

Overconsumption of salt and high consumption of highly processed foods high in sodium, like bread and other salty snacks like chips and crisps, lead to an excessive intake of sodium. Consuming a lot of salt raises the likelihood of hypertension, which is a side effect of obesity (Yang et al., 2012). The UK National Diet and Nutrition Survey 2008/2009 with 458 children aged 10±4 years and 785 adults aged 49±17 years showed that each 1 g/d increase in salt intake was associated with an increase in the risk of obesity by 28% in children and 26% in adults. Higher consumption was also significantly associated with higher body fat mass in both children ($P = 0.001$) and adults ($P = 0.001$) (Ma et al., 2015). Similarly, in Korea, authors studied the relationship between sodium intake and obesity among 1,467 Korean children and adolescents aged 10-18 years. They found that daily Na intake was significantly related to BMI and WC (Lee & Kim, 2016). Another study indicated that compared to children who were of normal weight, their counterparts who were obese had diets that were statistically significantly higher in sodium (Kozioł-Kozakowska et al., 2020). These findings regarding the overconsumption of salt were in agreement with the findings of NHANES 2003–2008 among 6,235 children and adolescents aged 8 to 18 years, where sodium intake was found to be positively associated among those who were overweight or living with obesity (Yang et al., 2012). In addition, in Greece, children's and adolescents' diet was found to be high not only in sodium (Magriplis et al., 2011) but also in nitrates and nitrites (Kotopoulou et al., 2022)

One of the primary issues with industrial food processing is the high Na content; lowering blood pressure is linked to consuming less of this micronutrient. As a result, reducing salt intake in food is advised for everyone, not just those with hypertension. In the ELSA-Brasil population, the results showed higher than recommended average consumption of Na (4.6g/d of Na, equivalent to 11.5g/d of salt intake), despite the World Health

Organization's recommendation that Na consumption be limited to 2g/d (Rezende-Alves et al., 2021).

1.5 Conclusion

In conclusion, the prevalence of obesity among individuals aged 5-19 years has risen dramatically from 1975 to 2016. Childhood obesity, as well as associated non-communicable diseases, are mostly preventable. The most fundamental causes are imbalanced diets, the lack of physical activity and individual behaviour. Our food choices and eating habits are influenced by a complex interplay of factors, often happening subconsciously. These factors shape how people eat across entire populations. Furthermore, throughout history, humankind has relentlessly pursued labor-saving devices and other shortcuts to simplify daily life. This relentless pursuit has resulted in a significant decrease in the overall energy expenditure required for survival. The quest for convenience shows no signs of abating and continues at a steady and unstoppable pace. Changes in these contributors are of high priority for preventing the childhood obesity epidemic and non-communicable diseases later in life.

1.6 Systematic review in Overweight and Obesity among Children Aged 9-12 Years in Europe and the Nutritional and Environmental Factors of Child Obesity

In light of the foregoing, a significant question arises regarding how the future obesity rate will change if children alter the contributing factors in their daily lives. The following systematic review was designed to evaluate randomized control trials to assess the prevalence of childhood obesity and the factors that have contributed to it in Europe over the past ten years, as well as to look into the pattern of weight loss in children based on their new lifestyle. This unpublished systematic review is the result of research conducted in the course "Advance Nutrition/Dietetics Workshops/Seminars" of the University of Nicosia's doctoral program in Nutrition and Dietetics. The main body of the article is presented below, with the entire unpublished manuscript in Appendix 1.

Introduction

The global prevalence of obesity has nearly tripled between 1975 and 2016. Over 340 million children and adolescents aged 5-19 were overweight or obese in 2016, a significant rise from 4% in 1975 to over 18% population (World Health Organization, 2024). Less than 1% of children and adolescents aged 5-19 were obese in 1975, whereas more than 124 million were obese in 2016 (World Health Organization, 2024). European statistics show that the prevalence of overweight ranged from 18% to 57% for boys and from 18% to 50% for girls, while 6-31% of boys and 5-21% of girls were obese (Wijnhoven et al., 2014). The highest obesity rates were observed in girls from Malta and boys from Greece, estimated at 11.3% and 16.7%, respectively (World Health Organization, 2017). Countries around the Mediterranean Basin, such as Greece, Italy, Spain, Malta, and Portugal, have the highest prevalence of childhood overweight and obesity (Wijnhoven et al., 2014).

The World Health Organization has identified the prevention of childhood obesity as a public health priority for preventing chronic diseases (World Health Organization, 2016). The steady increase in overweight and obesity among children and adolescents has become a major public health problem, reaching epidemic proportions in most low/middle-income countries over the past two decades (Ng et al., 2014; de Onis et al., 2010; Wang et al., 2006). Moreover, excess weight in early life is associated with physical and mental health disorders in both childhood (Franks et al., 2010; Sánchez-López et al., 2009) and adulthood (Franks et al., 2010; Herva et al., 2006; Baker et al., 2007).

As a multifactorial disease, obesity results from the complex interaction of genetic, hormonal, physical, nutritional, environmental, and social factors (Chan & Woo, 2010). A multicomponent intervention model that includes nutritional aspects, physical activity, sedentary time reduction, and behavioral changes can yield better outcomes than isolated interventions (Rajmil et al., 2017; Kumar & Kelly, 2017).

The Mediterranean Diet (MD) is a well-known and nutritionally balanced dietary pattern. It has been associated with a reduced risk of mortality and the incidence of chronic diseases such as cancer, type 2 diabetes, metabolic syndrome, obesity, neuropsychological diseases, and cardiovascular diseases by decreasing risk factors and improving health and quality of life (Serra-Majem et al., 2004; Sofi et al., 2010; Romaguera et al., 2010; Trichopoulou, et al., 2009). In the Go4it study, an 18-month follow-up showed that healthier dietary changes had a significant long-term effect on SDS-BMI compared to regular care in obese adolescents (Hofsteenge et al., 2014).

Few interventions have considered changes in diet quality and nutrient adequacy. Studies have shown that lifestyle interventions can improve diet quality and reduce BMI-

SDS in children and adolescents with abdominal obesity (Waling et al., 2010; Waling & Larsson, 2012; Ojeda-Rodríguez et al., 2018). Higher diet quality scores were linked to lower nutrient inadequacy (Ojeda-Rodríguez et al., 2018).

Regular physical activity is crucial for healthy growth and development in children (Biddle et al., 200; Stanner, 2004). However, many young people do not meet the physical activity guidelines of 60 minutes on most days (Stanner, 2004). The GreatFun2Run program (GF2R) demonstrated short-term changes in physical activity and body composition through an intervention primarily focused on physical activity (Gorely et al., 2011).

Children from families with limited resources are more likely to be obese, have poor dietary patterns and face greater health risks compared to children from more affluent families (Barnes, 2012). The Eat Mediterranean Program (EM program) showed a positive effect, with 76.0% of participants reporting optimal adherence to the MD (Rito et al., 2019). Socioeconomic and lifestyle factors, such as parental occupational status, maternal education level, and income, significantly influence children's eating habits (Lissner et al., 2016; Arriscado et al., 2014; Taylor et al., 2005; Fauquet et al., 2016). Higher socioeconomic status and mother's educational level positively impact diet quality (Rito et al., 2019). A multidisciplinary, family-based lifestyle intervention can lead to positive lifestyle changes in both children and adolescents with overweight or obesity (Ranucci et al., 2017).

Objective

This systematic review seeks to evaluate the impact of nutritional and environmental factors on the Body Mass Index (BMI) of overweight and obese children aged 9–12 years across Europe from 2010 to 2019. We aim to explore how variations in daily contributing factors, including dietary and environmental influences, may affect future trends in obesity rates among this age group. Specifically, our research focuses on understanding how these factors influence obesity rates, considering gender differences, country-specific contexts, and distinct nutritional and environmental elements.

Research Questions and Main Objectives

Our primary research question is: *How do changes in daily nutritional and environmental factors influence future obesity rates among European children?*

To address this question, the study's main objectives are to:

1. Identify Contributing Factors: Investigate the various nutritional and environmental factors contributing to obesity in this population, including dietary habits, physical activity levels, and other relevant lifestyle elements.
2. Evaluate Obesity Levels: Analyze the extent of childhood obesity using BMI as a measure, differentiating by country and gender to provide a comprehensive view of the issue.
3. Examine Weight Loss Outcomes: Evaluate the effectiveness of interventions and lifestyle changes on weight reduction, assessing how modifications in diet and environment impact children's weight management.

By fulfilling these objectives, this review aims to provide valuable insights into the factors driving childhood obesity and guide future public health strategies and interventions.

Methods

Overview

This systematic review, guided by the Cochrane Handbook and the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P), aims to collate and synthesize empirical evidence according to predefined eligibility criteria to address a specific research question (Higgins & Thomas, 2019). The review follows rigorous systematic methods to provide reliable findings and draw robust conclusions (Higgins & Thomas, 2019). The PRISMA checklist has been utilized to design and structure this review (Moher et al., 2009).

A meta-analysis, which statistically synthesizes and recalculates results from individual studies, was considered. However, due to the limited number of studies, a meta-analysis could not be conducted.

Eligibility Criteria

Inclusion Criteria:

1. Studies involving healthy children aged 9-12 years with no additional health issues, specifically focusing on obesity.
2. Randomized Controlled Trials (RCTs).
3. Studies assessing interventions related to environmental and nutritional factors, including nutrition, physical activity, and behavior.
4. Outcomes measured included BMI, dietary intake, and physical activity.
5. Studies published in the last 10 years.
6. Full-text articles available and written in English.

Exclusion Criteria:

1. Studies involving populations with morbidities related to weight, such as diabetes or incorrect body posture.
2. Non-RCT studies.
3. Studies published before 2010.
4. Interviews, reviews, and meta-analyses.

Information Sources and Search Strategy

The literature search was conducted using three scientific databases: PubMed, Cochrane Library, and Scopus. Results from each database were exported to RefWorks for further evaluation. Keywords used with Boolean operators included: “child obesity” AND BMI, “child obesity” AND “nutrition”, and “child obesity” AND “nutrition” AND (“European Union” OR EU). Additionally, reference lists of retrieved publications were reviewed for further relevant studies, systematic reviews, and meta-analyses.

Selection of Studies and Data Extraction

Two independent reviewers screened titles and abstracts to determine eligibility for this systematic review. Full-text articles were retrieved and reviewed for inclusion. Disagreements were resolved through consensus, with a third reviewer consulted if necessary. The PRISMA flow diagram (Figure 1.6.1) illustrates the selection process. Data extraction was performed using the Cochrane data form for RCTs and included: authors' names, title, country, study design, sample size, participants, study period, intervention, follow-up, outcomes assessed, and findings. Risk estimates and quality scores were also recorded. Disagreements were resolved by consensus.

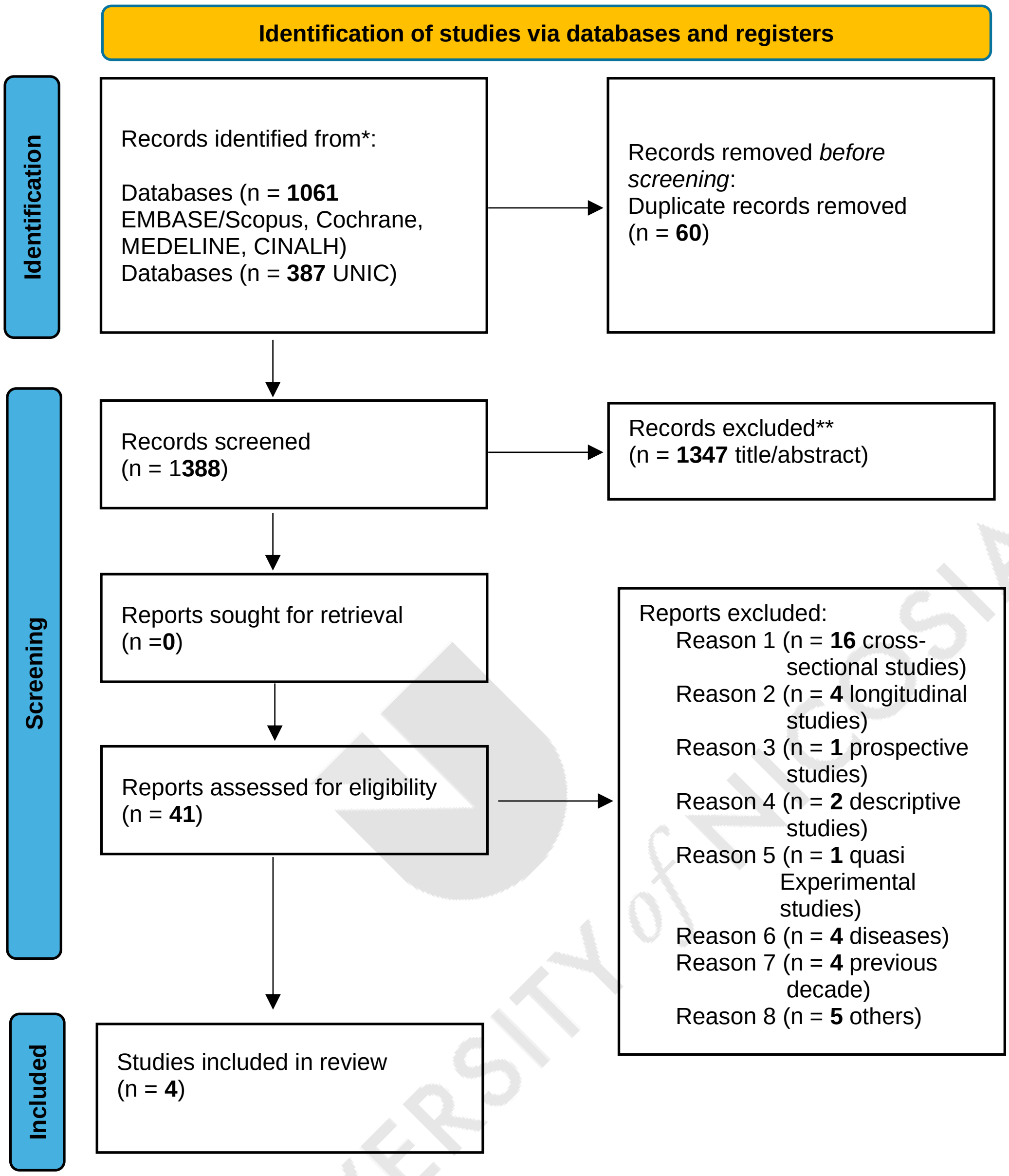
Risk of Bias

The risk of bias for included studies was assessed using the Jadad score for RCTs (Jadad et al., 1996). The Jadad score evaluates the quality based on: (1) randomization (2 points), (2) double-blinding (2 points), and (3) withdrawals (1 point). Points could be deducted for inadequate randomization and blinding (-1 point each). Scores ranged from 0-5 points: 5 points indicate high quality, scores above 3 denote good quality, and below 3 suggest poor quality. Quality assessments facilitated comparison and evaluation of study results. Disagreements were resolved by consensus.

Statistical Analysis

Due to the small number of studies meeting the inclusion criteria, a meta-analysis was not feasible. The limited number of studies prevented the aggregation of data for statistical synthesis, which is typically necessary for meta-analysis to derive more precise and generalizable conclusions.

Figure 1.6.1 PRISMA 2020 Flow Diagram.



Results

Study Selection and Characteristics

The PRISMA flow diagram (Figure 1.6.1) summarizes the study selection process. Out of the full-text articles reviewed, four RCTs met the inclusion criteria and were included in the systematic review (Hofsteenge et al., 2014; Ojeda-Rodríguez et al., 2018; Gorely et al., 2011; Halberstadt et al., 2017). These studies were conducted in the UK (Gorely et al., 2011), the Netherlands (Hofsteenge et al., 2014; Halberstadt et al., 2017) and Spain (Ojeda-Rodríguez et al., 2018) encompassing a total of 848 children aged 9-12 years. The studies were published between 2009 and 2019, with sample sizes ranging from 30 to 589 participants (Table 1.6.1).

Risk of Bias

The risk of bias was evaluated using the Jadad scale (Jadad et al., 1996). All studies were categorized as having good quality: two studies scored 3 (Gorely et al., 2011; Halberstadt et al., 2017), one study scored 4 (Hofsteenge et al., 2014), and one study scored 5 (Ojeda-Rodríguez et al., 2018). None of the studies met the criteria for double blinding, indicating limitations in reliable measurement (Table 1.6.2).

Interventions

The four included studies evaluated interventions on BMI through: (i) nutrition, (ii) physical activity, or (iii) multicomponent behavioral interventions. Intervention durations ranged from 8 weeks to one year. While three studies reported a successful decrease in BMI during the intervention phase, weight was subsequently regained post-intervention. The results suggest that behavioral modification may be necessary for sustained outcomes.

Data Synthesis

Dietary Intake Intervention

Three studies assessed BMI changes related to dietary intake. Two studies showed a reduction in SDS-BMI during the intervention, but an increase was observed during the 6-12 months follow-up period (Hofsteenge et al., 2014; Ojeda-Rodríguez et al., 2018). For instance, Hofsteenge's et al. (2014) study reported a decrease in SDS-BMI from 2.96 at baseline to 2.81 at 6 months and 2.86 at 18 months (95% CI, $P<0.05$) (Hofsteenge et al., 2014). Halberstadt and colleagues' study showed a decrease from 3.44 at baseline to 3.03 after one year and 3.18 after two years (P<0.001) (Halberstadt et al., 2017). The study by Ojeda-Rodríguez et al. (2018) specifically measured nutrient adequacy and diet quality with obesity indices. A calorie restriction varied from 10% to 40% had an improvement for SDS-BMI (a difference of -0,5, 95% CI, P<0,001) between baseline and after eight weeks (Ojeda-Rodríguez et al., 2018).

Physical Activity Intervention

One study examined the impact of physical activity on weight loss activity. The intervention included a comprehensive approach with a CD-ROM for teachers, an interactive website for pupils, teachers, and parents, a local media campaign, a summer activity planner, and two major physical activity events (1-mile school runs/walks). At the 20-month follow-up, the BMI of the intervention group increased from 17.9 at baseline to 18.8, indicating no significant weight loss despite the increased physical activity (Gorely et al., 2011).

Behavior Intervention

Another study investigated the effects of a behavioral intervention on weight loss. This intervention combined nutrition, exercise, and behavioral strategies aimed at improving self-regulation. It addressed various themes including disordered eating behavior, self-worth, self-efficacy, and parental feeding styles. The only statistically significant result was related to the 'control over eating' subscale of the Parental Feeding Style Questionnaire, showing a change (β= −0.0022; CI 95%= −0.0041, –0.0004; P=0.023) after one year of treatment (Halberstadt et al., 2017).

Table 1.6.1 Summary of Included Studies.

Authors	Title	Country	Study Design	Sample Size	Participants	Study Period	Intervention	Follow-Up	Outcome Assessed / Adjustments	Findings	Quality Score
Gorely 2011	Physical activity and body composition outcomes of the GreatFun2Run intervention at 20-month follow-up	UK	RCT	589 (287 boys, 302 girls) (7-11 years)	Intervention group (n=310) Control group (n=279)	Not specified	Physical Activity	10 months/ 20 months	BMI, Physical Activity	Significant increase in BMI (17.8 with CI 17.3-18.2). Both groups increased physical activity but no group-by-time interaction (control: +2726 steps/day; intervention: +3404 steps/day, p > .05). Increases in body fat, skinfolds, waist circumference, and BMI with age.	3
Hofsteenge 2014	Long-term effect of the Go4it group treatment for obese adolescents: A randomised controlled trial	Netherlands	RCT	122 (54 boys, 68 girls)	Intervention group (n=71) Control group (n=51)	2006-2008	Diet, Physical Activity	3 months / 6 months / 18 months	SDS-BMI	Significant decrease in SDS-BMI from 2.96 ± 0.6 to 2.86 ± 0.7.	4
Halberstadt 2017	The association of self-regulation with weight loss maintenance after an intensive combined lifestyle intervention for children and adolescents with severe obesity	Netherlands	RCT	30 (8-13 years) 90 (13-19 years)	Severe obese 8-13 years 13-19 years	2009-2013	Behaviour	1 year / 2 years	SDS-BMI	Average SDS-BMI decreased from 3.44 to 3.03 during treatment; slight weight regain to 3.18 at 2 years. Average weight loss of 0.41 SDS-BMI points during treatment; 0.26 SDS-BMI points at 2 years follow-up.	3

Authors	Title	Country	Study Design	Sample Size	Participants	Study Period	Intervention	Follow-Up	Outcome Assessed / Adjustments	Findings	Quality Score
Ojeda-Rodriguez 2018	Improved diet quality and nutrient adequacy in children and adolescents with abdominal obesity after a lifestyle intervention	Spain	RCT	107 (37% boys, 63% girls)	Usual care group (n=26) Intensive care group (n=81)	2018-today	Nutrient Adequacy, Diet Quality, Lifestyle Intervention	8 weeks / 22 months	Body Weight, SDS-BMI	Significant decrease in body weight and SDS-BMI in both groups.	5

Note: RCT-like indicates that while the methodology used was similar to RCT, a randomized version was not ultimately feasible.

Table 1.6.2 Quality Assessment of RCTs Using the Jadad Scale.

Jadad Score Calculation	Gorely 2011	Hofsteenge 2014	Halberstadt 2017	Rodriguez 2018
Was the study described as randomized (e.g., randomly, random, randomization)?	1	1	0	1
Was the method used to generate the sequence of randomization described and appropriate (e.g., table of random numbers, computer-generated)?	1	1	0	1
Was the study described as double blind?	0	0	0	0
Was the method of double blinding described and appropriate (e.g., identical placebo, active placebo, dummy)?	0	0	0	0
Was there a description of withdrawals and dropouts?	0	1	1	1
Deduct one point if the method used to generate the sequence of randomization was inappropriate (e.g., patients allocated alternately, according to date of birth)?	1	1	1	1
Deduct one point if the study was described as double blind but the method of blinding was inappropriate (e.g., comparison of tablet vs. injection without double dummy)?	0	0	1	1
Total Score	3	4	3	5

Note: RCT-like indicates that while the methodology used was similar to RCT, a fully randomized version was not ultimately feasible.

Discussion

This systematic review evaluated the effects of nutritional, physical activity, and behavioral interventions on BMI in children. The findings underscore the importance of lifestyle changes for reducing BMI, although the results show that many children experienced weight regain after the intervention period.

The quality of the studies was assessed using the Jadad score, and all included studies were considered of good quality, with scores ranging from 3 to 5. Specifically, Gorely et al. (2011) and Halberstadt et al. (2017) scored 3 (Gorely et al., 2011; Halberstadt et al., 2017), Hofsteenge et al. (2014) scored 4 (Hofsteenge et al., 2014), and Ojeda-Rodriguez et al. (2018) scored 5 (Ojeda-Rodríguez et al., 2018), indicating generally robust methodologies.

Two studies demonstrated that improvements in diet quality can positively impact BMI. Ojeda-Rodríguez et al. (2018), despite having a moderate risk of bias, reported reductions in weight and BMI during an 8-month intervention. However, the lack of a long-term follow-up limits the ability to evaluate the sustainability of these outcomes (Ojeda-Rodríguez et al., 2018). Hofsteenge and colleagues although presenting a high risk of bias and being conducted before 2010, showed initial weight loss but a return to baseline BMI levels after 18 months (Hofsteenge et al., 2014). Another intervention study was carried out to assess the efficacy of the school nutrition program (SNP), which combined nutrition education and a healthy school canteen environment with BMI-for-age. This study among 523 Malaysian children aged 7 to 11 years old showed that after 3-month follow-up, the intervention group had a lower BMI than the control group ($p < 0.05$) (Teo et al., 2021). However, a clustered randomized control trial of 245 Taiwanese schoolchildren examined the effects of an intervention program adapted from NASA's Mission X (MX) program on children's Healthy Eating Active Living (HEAL) knowledge and behaviours, as well as their anthropometry. The intervention was an eight-week program. The authors demonstrated that while the BMI did not change for the intervention group, it increased for the control group from 18.4 to 18.6 ($p < 0.05$) (Lin et al., 2019).

Collado-Soler et al. (2023) proposed that school-based nutrition intervention programs have a significant influence on children’s eating habits because the primary aim of their systematic review was to determine how well these programs affected participants’ knowledge and behaviour related to nutrition. As they have demonstrated, these programs, increase students' understanding of healthy diets and encourage positive attitudes and behaviours in their daily lives (Collado-Soler et al., 2023). Promoting healthy habits and changing dietary behaviours requires the support of families and school environments (Schlechter et al., 2016). However, since attitude, which is influenced by motivation

(Sabramani et al., 2015), mediated eating behaviours (van Stralen et al., 2011), it is more crucial to incorporate enjoyable and engaging activity-based nutrition sessions (Sharif Ishak et al., 2016).

In terms of physical activity, Gorely and colleagues observed that while increased physical activity led to initial improvements in BMI, these benefits were not sustained over a 10-month follow-up period, and BMI increased subsequently. This indicates that without continuous engagement in physical activity, short-term improvements may not be maintained (Gorely et al., 2011). A randomized clinical trial was conducted in Granada among 92 overweight or obese children aged 8 to 11 years to examine the effects of a 20-week exercise program on cardiometabolic health. For 20 weeks, the exercise program consisted of 3 to 5 aerobic and resistance training sessions per week (90 minutes each). Findings showed that a combination of aerobic and resistance exercise resulted in a significant decrease in body mass index [-0.59 (95% CI, -1.06 to -0.12)] in the intervention group compared to the control group. Additionally, kids in the exercise group lost visceral and total body fat, improving their body composition (Migueles et al., 2023). These findings about the decreases in body mass index and fat mass are consistent with earlier research on obese children (Feng et al., 2017). Similarly, findings from a network meta-analysis showed that in children and adolescents who were overweight or obese, aerobic or combined aerobic and resistance training effectively reduced adiposity outcomes with a similar magnitude (Kelley, Kelley & Pate, 2019). A cluster randomized clinical trial involving 1,392 eligible children aged 8 to 10 years was carried out over a single school year. A multimodal intervention supported children's behavioral changes by involving families, schools, and the community in addition to encouraging children to eat a healthy diet and exercise regularly. The intervention group's mean BMI decreased from baseline to the trial's closing, while the control group's mean BMI increased. The multimodal intervention successfully lowered the average body mass index and enhanced dietary, sedentary, and physical activity habits as well as knowledge about obesity; however, it had no effect on physical fitness or moderate-to-intense physical activity (Liu et al., 2022). Furthermore, a systematic review that assessed the association between physical fitness, physical activity, and overweight in adolescents found that overweight and obesity had an inverse relationship with physical activity (Rauner et al., 2013).

The study by Halberstadt et al. (2017) focused on behavioral interventions aimed at enhancing self-regulation. It found that the only statistically significant factor associated with weight loss maintenance was parental control over eating behaviors. This highlights the limited efficacy of behavioral changes alone in maintaining weight loss, suggesting that other factors might also be crucial (Halberstadt et al., 2017). A Victorian Government initiative called Healthy Together Victoria included an embedded cluster randomized trial of a system thinking approach to obesity prevention among adolescents aged 13–15 years and 15–16 years old. In the final analysis, 4,242 children received intervention and 2,999 control children. After two years of intervention, the authors found no discernible effect on BMI between the intervention and control group (Strugnell et al., 2024). Furthermore, a systematic review and meta-analysis of 12 randomized controlled trials assessed the effect of parental involvement on the management and prevention of childhood obesity, with an emphasis on outcomes such as BMI z-score. The BMI z-score significantly decreased, according to the meta-analysis. Subsequently, parental involvement in programs aimed at reducing childhood obesity significantly affects the BMI z-score (Aleid et al., 2024). According to the "4 your family" intervention study, family-based interventions can lead to positive changes in dietary and behavioral habits, as well as body weight and fat status. Personalized family-based interventions were found to be the most effective approach overall. Two factors could account for this: general health guidelines are given to all children regardless of their underlying problem(s) and time constraints parents may have for maximum engagement. This result implies that public health intervention programs ought to be tailored to the specific requirements and attributes of a given population. More planning is needed for certain eating habits, even though fundamental lifestyle factors like screen time and physical activity are simple to understand and change. Screening and categorizing parents and kids based on shared traits, eating habits, behaviors, and preferences may help adjust the intervention plan. This will tailor the intervention to the unique needs of the family (Varagiannis et al., 2021).

Family participation is especially crucial for kids under the age of twelve (Ho et al., 2012). Families have not always been included in school-based obesity interventions. For instance, two cluster RCTs in the UK attempted to lower BMI by implementing school-based obesity interventions but were unsuccessful (Adab et al., 2018; Lloyd et al., 2018). The low level of family involvement in these earlier interventions may have contributed to their failure (Okely, Hammersley, 2018). According to a review, family-based interventions have demonstrated significant effects right away at the finish of the intervention (Oude Luttikhuis et al., 2009). It is widely acknowledged that early health habits are shaped by the family and home environments and that parents are critical in helping their children develop healthy eating and physical activity habits. Parents choose what kinds of foods to keep in the house and give opportunities for physical activity (Karmali et al., 2019), so these environments play a significant role in the cause and prevention of childhood obesity.

Furthermore, a recent systematic review suggests that parents who participated in interventions that involved education sessions on nutrition and physical activity could successfully improve the lifestyle of their children (Chai et al., 2019).

This review provides evidence that interventions promoting better diet quality, increased physical activity, and parental control over eating can lead to weight loss. However, achieving lasting weight loss requires sustained lifestyle changes. Healthcare providers should emphasize the importance of continuous lifestyle modifications to ensure long-term weight management.

Overall discussion of the four studies

Gorely 2011: The study found a significant increase in BMI (17.8 with CI 17.3-18.2) over the study period. Both the intervention and control groups increased their physical activity, but there was no significant group-by-time interaction (control: +2726 steps/day; intervention: +3404 steps/day, $p > .05$). Additionally, increases in body fat, skinfolds, waist circumference, and BMI were observed with age.

Hofsteenge 2014: The study reported a significant decrease in SDS-BMI from 2.96 ± 0.6 to 2.86 ± 0.7 in the intervention group.

Halberstadt 2017: The study observed an average decrease in SDS-BMI from 3.44 to 3.03 during treatment, with a slight weight regain to 3.18 at 2 years. The average weight loss was 0.41 SDS-BMI points during treatment and 0.26 SDS-BMI points at 2 years follow-up.

Ojeda-Rodriguez 2018: The study found a significant decrease in body weight and SDS-BMI in both the usual care and intensive care groups.

Challenges and Observations

The findings from these studies highlight a critical issue: while interventions can lead to weight loss, maintaining these outcomes over time is challenging. This is a common theme in the literature, suggesting that interventions often achieve initial success but struggle with long-term adherence and sustainability. The need for ongoing support and sustained lifestyle changes is evident.

Limitations in Current Research

A significant limitation observed across the studies is the variability in study quality and the broad age ranges of participants. The inclusion of both younger children and adolescents complicates the interpretation of results, as their growth patterns and nutritional needs differ. Future research should aim to target more homogeneous age groups and address these limitations.

Future Directions

Future studies should focus on extending the duration of interventions and follow-ups to better understand how lifestyle changes impact long-term weight management. Additionally, exploring how interventions can be adapted to ensure continued engagement and support for children and their families is crucial.

Conclusion

Gorely 2011: The GreatFun2Run intervention led to increased physical activity in both groups, but it did not significantly impact BMI or other body composition measures compared to the control group.

Hofsteenge 2014: The Go4it group treatment for obese adolescents was effective in reducing SDS-BMI over the study period, indicating a positive impact on obesity management.

Halberstadt 2017: The intensive combined lifestyle intervention was effective in reducing SDS-BMI in children and adolescents with severe obesity, although some weight regain was noted at the 2-year follow-up.

Ojeda-Rodriguez 2018: The lifestyle intervention improved diet quality and nutrient adequacy, leading to significant reductions in body weight and SDS-BMI in children and adolescents with abdominal obesity.

Overall Conclusions

The findings of this review, despite the limitations, suggest that lifestyle changes, including improved nutrition, increased physical activity, and parental control over eating, can contribute to weight loss in children. Enhancing lifestyle habits can positively influence weight management, but for sustained results, these changes need to be enduring. Future research should extend the duration of interventions and follow-ups to better understand how long-term lifestyle modifications affect weight and to develop strategies that promote lasting behavioral changes in children.

CHAPTER 2 LITERATURE REVIEW: INTAKE OF ULTRA-PROCESSED FOOD AND ASSOCIATIONS WITH BODY WEIGHT AMONG CHILDREN AND ADOLESCENTS

2.0 Introduction

National dietary guidelines, traditionally based on food groups and nutrients, emphasize maintaining a healthy weight and preventing weight gain. Traditionally, the impact of diet on health has focused on individual nutrients. Concerns centered around excessive intake of total fat, saturated fat, cholesterol, calories, sugar, or salt, and a lack of fiber, vitamins and minerals. In recent years, research has broadened this perspective by highlighting the health effects of entire dietary patterns, such as the Mediterranean patterns are often measured using scoring systems like the Alternative Healthy Eating Index (AHEI) or the Dietary Approaches to Stop Hypertension (DASH) diet. However, recent research offers new perspectives on the diet-obesity connection. A key factor missing from this conversation is the level of processing and formulation in foods. It is of great importance to understand that the quality of the dietary pattern is determined not only by its content of specific nutrients or food items but also by other important factors such as its content in processed foods. Over the last few decades, in several countries, traditional foods and freshly prepared dishes and meals have been displaced by ultra-processed foods (UPFs).

One significant environmental change is the shift in the food landscape, marked by a rise in the physical availability in our environment and consumption of ultra-processed foods. This has altered the types of food and beverages people have access to and consume. The growing popularity of ultra-processed foods aligns with several aspects of modern life, including increased longer eating windows, eating out more often, snacking, and the ease and affordability of UPFs (Kac & Pérez-Escamilla, 2013). Furthermore, the global UPF market is flourishing, particularly in developing countries with emerging markets and developed nations with established ones. This widespread availability is fueled by the growing presence of supermarkets and fast-food chains (Popkin & Barry, 2017). Since the 1990s, sales of UPFs have risen dramatically, particularly in low- and middle-income countries (Srour et al., 2022). Consumption data reveals significant global variations in the proportion of ultra-processed foods within diets. The United States leads the way with 58% of daily energy intake coming from these foods, while Colombia boasts the lowest intake at just 16% (Srour et al., 2022). Even within Europe, intake varies considerably, ranging from 15% of total calories in Romania to 57% in the UK (Mertens et al., 2022). These disparities reflect a complex interplay of economic, cultural, political, legal, and commercial factors influencing our food systems. These factors shape the availability, affordability, and desirability of UPFs, ultimately impacting consumption patterns across the globe.

It is suggested that beyond just their nutritional content, the production and formulation of these foods raise concerns about potential negative health consequences for populations. Decades of weight-loss advice have not yielded significant results, prompting a shift in focus. A new theory indicates that the obesity epidemic stems primarily from the way food is processed rather than simply the nutrients it contains or how people choose to eat it (Monteiro, 2009). Studies have shown a positive correlation between UPF intake and an increased risk of weight gain, overweight/obesity, and a greater risk of cardiovascular diseases, specific cancers, and even overall mortality during adulthood (Srour et al., 2019; Juul et al., 2021; Fiolet et al., 2018). From a public health perspective, this trend warrants a precautionary approach. Consequently, it is crucial to understand the association between UPF consumption with obesity and cardiometabolic co-morbidities in children and adolescents since many studies in adults indicate a strong correlation.

2.1 Ultra-processed foods

2.1.1 Definition of ultra-processed foods

The importance of industrial processing is widely accepted. More specifically, techniques and ingredients developed or created by modern food science and technology are based on the nature of food and the state of human health (Food and Agriculture Organization of the United Nations, 2015). The concept of ultra-processing was first proposed in a Public Health Nutrition commentary in 2009 by a team at the University of Sao Paulo (Monteiro, 2009). Monteiro et al. (2009) highlighted that 'The most important factor now, when considering food, nutrition and public health, is not nutrients, and is not foods, so much as what is done to foodstuffs and the nutrients originally contained in them, before they are purchased and consumed. That is to say, the issue is food processing or to be more precise, the nature, extent and purpose of processing, and what happens to food and to us because of processing' (Monteiro, 2009).

It is useless to criticize foods as being "processed" because almost all foods are processed, even if merely for preservation. A variety of food classifications have been developed, with particular emphasis on types of processing. According to a systematic review, NOVA is the most specific, coherent, clear, comprehensive, and workable of these (Moubarac et al., 2014). NOVA (which is not an acronym) defines food processing as using of physical, biological, and chemical procedures to prepare food for consumption or preparation as dishes and meals after it has been removed from its natural state (Monteiro, et al., 2018). All foods and food products are divided into four categories by NOVA. An overview of the types and purposes of the industrial processes that constitute each of the four NOVA groups is: a) unprocessed or minimally processed, b) processed culinary ingredients,

c) processed foods and d) ultra-processed foods, which makes it simple to understand the distinct characteristics of ultra-processed foods and the health risks associated with their consumption (Monteiro et al., 2019). The term “ultra-processed” was coined to refer to non ‘real food’. They are formulations of food substances that are often modified chemically before being assembled into ready-to-eat or heat-up hyper-palatable food and drink products with emulsifiers, colors, flavors, and many other cosmetic additives. In addition, they are high in fat, salt, or sugar and low in dietary fibre, protein, micronutrients and other bioactive substances. Industrial formulations normally have 5 chemicals or more and frequently several more. Most are produced and advertised by multinational companies and other enormous businesses. Because of their ultra-processing, they are highly profitable, intensely appealing, and inherently unhealthy (Monteiro et al., 2018; Monteiro et al., 2019). Table 2.1 contains definitions and examples for each of the four NOVA groups according to Monteiro et al. (2019) (Monteiro et al., 2019).

The NOVA classification is now used globally. Description of population dietary patterns, evaluations of changes in the proportion of ultra-processed foods in diets over time, and investigations of the relationships between this proportion and the nutrient profile of diets and health outcomes are some of the uses now being made of this concept (Monteiro et al., 2018). However, it differs fundamentally from all prior methods of establishing healthy eating patterns in that it is based on the degree to which foods are processed rather than any nutritional parameters (Gibney, 2018).

"What is the relationship between consumption of dietary patterns with varying amounts of UPFs and growth, size, body composition, risk of overweight and obesity, and weight loss and maintenance?" is one of the questions to be addressed during the 2025–2030 Dietary Guidelines for Americans process. How identifying UPFs will be one of the issues that the upcoming Dietary Guidelines Advisory Committee will encounter in conducting a review on this topic (Hess et al., 2023). Studies have consistently linked high consumption of UPFs with a greater risk of obesity and related health problems like heart disease, type 2 diabetes and certain cancers. However, the reasons behind this link are debated. Some argue that the process itself might be harmful, while others believe that UPFs are simply less nutritious. People who eat more UPFs tend to eat fewer fruits, vegetables, legumes, and seafood. This raises the question of whether the negative health effects of UPFs are due to simply consuming more calories or following an unhealthy dietary pattern overall. If so, adjusting for overall dietary quality might eliminate the connection between UPFs and health issues (Dicken & Batterham, 2021). The global food system has experienced a significant technological and food processing revolution in the last few years. The global food profile has shifted significantly in favor of the consumption of highly processed industrial goods due to factors like consumer appeal, industrial competitiveness, and economic convenience (Monteiro et al., 2013). Due to all these factors, UPF is now widely available and consumed worldwide, irrespective of economical status.

Table 2.1 NOVA food groups: definition according to the extent and purpose of food processing, with examples* (Monteiro et al., 2019).

NOVA group	Definition	Examples
1) Unprocessed or minimally processed foods	Unprocessed: edible parts of plants (fruits, seeds, leaves, stems, roots, tubers) or of animals (muscle, offals, eggs, milk), and also fungi, algae and water, after separation from nature. Minimally processed: unprocessed foods altered by industrial processes such as removal of inedible or unwanted parts, drying, crushing, grinding, fractioning, roasting, boiling, pasteurisation, refrigeration, freezing, placing in containers, vacuum packaging, non-alcoholic fermentation, and other methods that do not add salt, sugar, oils or fats or other food substances to the original food. The main aim of these processes is to extend the life of unprocessed foods, enabling their storage for longer use, and, often, to make their preparation easier or more diverse. Infrequently, minimally processed foods contain additives	Fresh, squeezed, chilled, frozen, or dried fruits and leafy and root vegetables; grains such as brown, parboiled or white rice, corn cob or kernel, wheat berry or grain; legumes such as beans, lentils, and chickpeas; starchy roots and tubers such as potatoes, sweet potatoes and cassava; fungi such as fresh or dried mushrooms; meat, poultry, fish and seafood, whole or in the form of steaks, fillets and other cuts, fresh or chilled or frozen; eggs; fresh or pasteurized milk; fresh or pasteurised fruit or vegetable juices (with no added sugar, sweeteners or flavours); grits, flakes or flour made from corn, wheat, oats, or cassava; tree and ground nuts and other oily seeds (with no added salt or sugar); herbs and spices used in culinary preparations, such as thyme, oregano, mint, pepper, cloves and cinnamon, whole or powdered, fresh or dried; fresh or pasteurized plain yoghurt; tea, coffee, and drinking water. Also includes foods made up from two or more items in this

NOVA group	Definition	Examples
	that prolong product duration, protect original properties or prevent proliferation of microorganisms.	group, such as dried mixed fruits, granola made from cereals, nuts and dried fruits with no added sugar, honey or oil; pasta, couscous and polenta made with flours, flakes or grits and water; and foods with vitamins and minerals added generally to replace nutrients lost during processing, such as wheat or corn flour fortified with iron and folic acid.
2) Processed culinary ingredients	Substances obtained directly from group 1 foods or from nature by industrial processes such as pressing, centrifuging, refining, extracting or mining. Their use is in the preparation, seasoning and cooking of group 1 foods. These products may contain additives that prolong product duration, protect original properties or prevent proliferation of microorganisms.	Vegetable oils crushed from seeds, nuts or fruits (notably olives); butter and lard obtained from milk and pork; sugar and molasses obtained from cane or beet; honey extracted from combs and syrup from maple trees; starches extracted from corn and other plants, and salt mined or from seawater, vegetable oils with added anti-oxidants, and table salt with added drying agents. Includes products consisting of two group 2 items, such as salted butter, and group 2 items with added vitamins or minerals, such as iodised salt.
3) Processed foods	Products made by adding salt, oil, sugar or other group 2 ingredients to group 1 foods, using preservation methods such as canning and bottling, and, in the case of breads and cheeses, using non-alcoholic fermentation. Processes and ingredients here aim to increase the durability of group 1 foods and make	Canned or bottled vegetables and legumes in brine; salted or sugared nuts and seeds; salted, dried, cured, or smoked meats and fish; canned fish (with or without added preservatives); fruits in syrup (with or without added anti-oxidants); freshly made unpackaged bread and cheeses.

NOVA group	Definition	Examples
	them more enjoyable by modifying or enhancing their sensory qualities. These products may contain additives that prolong product duration, protect original properties or prevent proliferation of microorganisms.	
4) Ultra-processed foods	Formulations of ingredients, mostly of exclusive industrial use, that result from a series of industrial processes (hence 'ultra-processed'), many requiring sophisticated equipment and technology. Processes enabling the manufacture of ultra-processed foods include the fractioning of whole foods into substances, chemical modifications of these substances, assembly of unmodified and modified food substances using industrial techniques such as extrusion, moulding and pre-frying, frequent application of additives whose function is to make the final product palatable or hyper-palatable ('cosmetic additives'), and sophisticated packaging, usually with synthetic materials. Ingredients often include sugar, oils and fats, and salt, generally in combination; substances that are sources of energy and nutrients but of no or rare culinary use such as high fructose corn syrup,	Carbonated soft drinks; sweet or savoury packaged snacks; chocolate, candies (confectionery); ice-cream; mass-produced packaged bread and buns; margarines and other spreads; cookies (biscuits), pastries, cakes, and cake mixes; breakfast 'cereals', 'cereal' and 'energy' bars; 'energy' drinks; milk drinks, 'fruit' yoghurts and 'fruit' drinks; 'cocoa' drinks; 'instant' sauces; infant formulas, follow-on milks, other baby products; 'health' and 'slimming' products such as meal replacement shakes and powders. Many ready to heat products including pre-prepared pies and pasta and pizza dishes; poultry and fish 'nuggets' and 'sticks', sausages, burgers, hot dogs, and other reconstituted meat products, and powdered and packaged 'instant' soups, noodles and desserts.

NOVA group	Definition	Examples
	hydrogenated or interesterified oils, and protein isolates; cosmetic additives such as flavours, flavour enhancers, colours, emulsifiers, sweeteners, thickeners, and anti-foaming, bulking, carbonating, foaming, gelling, and glazing agents; and additives that prolong product duration, protect original properties or prevent proliferation of microorganisms. Processes and ingredients used to manufacture ultra-processed foods are designed to create highly profitable products (low cost ingredients, long shelf-life, emphatic branding), convenient (ready-to-consume) hyper-palatable snacked products liable to displace all other NOVA food groups, notably group 1 foods.	

* Alcoholic drinks are not immediately classifiable by NOVA. By analogy with the nature of processed and ultra-processed foods, they may be counted in group 3 if they are produced by fermentation of group 1 foods, such as beer, cider, and wine, and in group 4 if they are produced by fermentation of group 1 foods and distillation of the resulting alcohol, such as whisky, gin, rum, and vodka. Another option, depending on why NOVA is being used, is to treat alcoholic drinks separately.

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2.1.2 Consumption of ultra-processed foods

2.1.2.1 Ultra-processed foods and nutrient profile

It is well known that environmental factors like food quality, availability, convenience, advertising, accessibility and price influence food choices in addition to physiological needs. Under these circumstances, replacing unprocessed and minimally processed foods with UPFs is increasingly popular. A systematic review of the consumption of UPF in different countries highlighted the large differences in UPF intake. This review showed that the United States and the United Kingdom had the highest percentage of energy intake from UPFs (about >50%), whereas Italy had the lowest (about 10%) (Marino et al., 2021). It is noteworthy that a nationally representative study across eight middle- and high-income countries that examined the sociodemographic characteristics and diet quality with consumption of UPF showed higher energy density (≥2.25 kcal/g), free sugars (>10% of total energy intake), saturated fats (>10% of total energy intake) and fibre (<25g/2000 kcal) among the population (Martinez Steele et al., 2022). Additionally, another study found high levels of UPFs consumption, which aligns with previous research in other wealthy countries. For instance, studies in Canada, Australia, the United Kingdom, and the United States reported UPF intake ranging from 42% to 58% of total energy intake (Machado et al., 2019; Martínez Steele et al., 2016; Rauber et al., 2019; Moubarac et al., 2017). Interestingly, the Canadian Community Health Surveys conducted with 33,924 participants for the 2004 survey and 20,080 for the 2015 survey aged two or older showed that children and adolescents consumed more than half of the total daily energy intake from UPFs. The fact that UPF consumption remained consistently high across all ages and genders in Canada, especially among children and teenagers, is a cause for concern. A growing body of evidence suggests that diets high in UPFs are linked to several negative health outcomes. These include poorer overall diet quality, weight gain, and an increased risk of various diet-related health problems (Polsky et al., 2020). Similarly, a cross-sectional study with a sample of 364 adults aged 25–64 years in 2012–2013 indicated that 40.5% of mean energy intake came from UPFs. A significantly higher proportion of calories from UPF were consumed by younger persons (25–44 years) compared to older ones (45–64 years) (Harris et al., 2021). Moubarac et al. (2017) in a cross-sectional study conducted on 33,694 individuals aged ≥2 years old from the 2004 Canadian Community Health Survey, investigated the relationship between the consumption of ultra-processed foods and the diet's nutrient profile. The percentage of energy consumed by UPFs (including soft drinks and packaged juices, chocolate, cookies, and cake, mass-produced packaged bread and pastries, as well as fast-food dishes) was 48%, and it was high in all socioeconomic groups, especially in children and adolescents. The consumption of UPFs was significantly positively associated with the content of energy density, carbohydrates, total and saturated fats and free sugars. On the other hand, a negative association was found with the dietary content in protein, fiber, vitamins A, C, D, B6, and B12, riboflavin, thiamine, niacin, zinc, potassium, iron, phosphorus, magnesium and calcium (Moubarac et al., 2017). Furthermore, a cross-sectional study among 1,936 Italian adults aged ≥18 years old examined their nutrient profile and dietary quality. Authors found that 8.7% of total energy intake came from the NOVA group of unprocessed or minimally processed foods, 5.7% from processed culinary ingredients, 38.3% from processed foods, and 17.9% from UPFs (fast-food and sweets provided the most energy contribution). Furthermore, it was found that while UPF consumption was lower in those who met the recommendations for total fats, fiber, sodium, potassium, and vitamin C, it was significantly higher in those who met the European and Italian dietary recommendations for carbohydrates, vitamin B12, vitamin D, and vitamin E. Lastly, participants with higher adherence to either the Mediterranean diet, the Dietary Approaches to Stop Hypertension, the Alternate Diet Quality Index and the Diet Quality Index-International, consumed more unprocessed/minimally processed foods, and less UPFs (Godos et al., 2022). A study in Barbados investigated the dietary habits of 364 adults between the ages of 25 and 64. The research found that UPFs made up a significant portion of their daily energy intake, averaging around 40.5% (or 838 calories per day). Sugar-sweetened beverages were the biggest contributor of energy within the UPF category. Interestingly, the study revealed an age difference in UPF consumption. Younger adults (25-44 years old) consume a considerably higher proportion of their calories from UPFs compared to older adults (45-64 years old). Furthermore, a quarter of the participants derived at least half (50%) of their daily energy intake from UPFs, with this trend being more pronounced among younger individuals. The study also compared the nutrient profile of UPFs to non-ultra-processed foods. They found that the UPF diet fraction contained roughly six times more free sugars on average while offering significantly less dietary fiber (around 0.8 times the amount) compared to its non-ultra-processed counterpart (Harris et al., 2021). In the US, researchers examined the trends in UPFs consumption and diet quality from 1991 to 2008 among 2,893 adults and found that over 17 years of follow-up, their intake decreased from 7.5 to 6.0 servings/d, and while minimally processed food intake decreased from 11.9 to 11.3 servings/d (P trend < 0·001). These trends were similar across BMI. Furthermore, there was an increase in the DGAI-2010 score from 60.1 to 61.5, P < 0·001 for diet quality (Juul et al., 2021).

In 2020, the NHANES (2015–2018) conducted on 9,758 adults ≥20 years old and 5,280 children 2–19 years old estimated the relationships between UPF consumption and overall dietary quality. The authors found that increasing consumption of UPFs was related to lower diet quality. Furthermore, the percentage of children with a low-quality diet increased from 31.3% to 71.6% and 18.1% to 59.7% among adults when assessed across quintiles of UPF intake. According to this study, the consumption of unhealthy foods increased while the consumption of healthy foods decreased as the calories from UPFs increased (Liu et al., 2022). Similarly, the NHANES 2009–2010 among 9,317 participants aged 1+ years indicated that energy consumption from UPFs was 57.9%, which contributed to 89.7% of the energy intake from added sugars. Each 5% increase in proportional energy intake from UPFs increased 1% the proportional energy intake from added sugars (Martínez Steele et al., 2016). In addition, Steel et al. (2017) indicated that carbohydrate, added sugar, and saturated fat contents increased across quintiles of the UPFs consumption while protein, fibre, vitamins A, C, D, and E, potassium, phosphorus, calcium, magnesium and zinc decreased significantly (Martínez Steele et al., 2017). Moreover, in Spain, a cross-sectional study (The SENDO project) among 806 preschoolers found that the energy intake from UPF was 37.6% and increased odds of inadequate intake of ≥3 micronutrients in childhood are linked to high consumption of UPF (García-Blanco et al., 2023). Another cross-sectional study in Brazil among 444 adolescents (10-13 years) indicated an increase in total energy from UPFs consumption from 21.4% in 1st tertile to 61.5% in 4th tertile, and more than 80% increase in the rates of inadequate intake of vitamin D, vitamin E, folate, selenium and calcium (Falcão et al., 2019)**.** These results agreed with researchers in Brazil conducting a cross-sectional study to examine the eating habits of school children. The study involved 797 children aged 8-12 years old. On average, the children consumed around 2050 calories per day, with UPFs contributing about a quarter (25.8%) of their total calorie intake. The study found a negative association between the amount of ultra-processed foods that children ate and their intake of important nutrients like protein, fiber, vitamin A, iron, and zinc. In simpler terms, the more ultra-processed foods they consumed, the less of these essential nutrients they got. Conversely, higher UPFs consumption was linked to a positive association with total energy intake, fat intake, and sodium intake. In other words, children who ate more ultra-processed foods tended to consume more calories overall, more fat, and more sodium. This study concluded that a higher intake of UPFs was linked to a poorer nutrient profile in the diets of school children (de Lacerda et al., 2023). Moreover, Martini et al. (2021) in a meta-analysis of nationally representative samples, indicated a significant consumption of UPFs in the countries investigated, with an important increase in free sugars and total and saturated fats, as well as a decrease in fiber, protein, potassium, magnesium, and zinc, niacin and vitamins A, C, D, E and B12 (Martini et al., 2021).

Several studies have indicated similar results regarding the relationship between the nutrient profile associated with non-communicable diseases (NCDs) (Rauber et al., 2018; Costa de Miranda et al., 2021; Cediel et al., 2021; Araya et al., 2021). The U.K. National Diet and Nutrition Survey (2008–2014) among 9,364 participants aged ≥1.5 years showed that mean energy intake was 1764 kcal/day, with 30.1% coming from unprocessed or minimally processed foods, 4.2% from culinary ingredients, 8.8% from processed foods, and 56.8% from UPFs. As the UPFs intake increased, so did the dietary content of carbohydrates, free sugars, total fats, saturated fats, and sodium, while protein, fiber, and potassium levels decreased. Consuming more UPFs had an important impact on the average amount of free sugars, which rose from 9.9% to 15.4% of total energy from the lowest to the highest quintile. Furthermore, across these quintiles of UPFs, there was an 85% and 55% increase, respectively, in the prevalence of individuals exceeding the recommended upper limits for free sugars and sodium, which contribute to the prevention of diet-related NCDs (Rauber et al., 2018). Furthermore, in Portugal, a cross-sectional study conducted on 3,102 adults and 750 elderly examined the relationship between the nutrient profile associated with non-communicable diseases and the dietary share of UPFs. Results indicated that for adults and older people, about 24% and 16% of daily energy intake came from UPFs, respectively. Either in adults or in the elderly the dietary content of total fats, saturated fats and free sugars rose as UPFs consumption increased, while the dietary content of protein reduced. When comparing the consumption of UPFs in the lowest and highest quintiles, the prevalence of individuals exceeding the recommended upper limits for free sugars and saturated fats increased by 544 and 153% in adults and 619 and 60% in elderly people (Costa de Miranda et al., 2021). Another cross-sectional study conducted on 4,920 Chilean population aged ≥2 years old found that UPFs provided 28.6% of the total energy intake. As their contribution increased across quintiles the three remaining NOVA food groups and most of their subgroups declined. Additionally, they demonstrated the numerous unhealthy aspects of ultra-processed foods when comparing their nutritional composition to that of the three other NOVA food groups combined for NCD-protective nutrients (vitamin K and fiber) and NCD-promoting nutrients (total fats, trans fats, saturated fats, free sugars and energy) (Cediel et al., 2021). Finally, Araya et al. (2021) in a cross-sectional study among 960 preschoolers in Chile, examined the association of the intake of UPF with the nutrient composition of the diet. They found that 49% of the total energy intake came from UPFs. Participants with higher consumption of UPF increased the content of energy, saturated and monounsaturated fats, carbohydrates, total sugars, and vitamin D compared to their counterparts in the lowest quintile. On the other hand, there was a negative correlation ($p < 0.05$) between UPF intake and the consumption of proteins, fiber, zinc, vitamin A, and polyunsaturated fats. Consequently, the nutrient composition of a diet was related to the amount of UPF consumed (Araya et al., 2021).

Although most studies consistently showed that consuming UPF leads to higher intakes of nutrients of concern (apart from sodium) and lower intakes of fiber, the information currently available regarding micronutrient intake is still up for debate. The latter could be attributed to variations in micronutrient fortification regulations across nations as well as the quality (i.e., dietary diversity) of diets based on food groups with less processing (i.e., NOVA groups 1-3). A study in France associated several categories of ultra-processed foods with a higher risk of being overweight or obese. These included drinks (sugary and artificially sweetened beverages), dairy products, fats and sauces, processed meats, and fish or egg products. Interestingly, ultra-processed starchy foods and breakfast cereals were linked only to overweight, not obesity. It's important to note that the unprocessed versions of most of these food groups did not show the same association with excessive weight gain, except for processed meats like smoked meats or ham. Unsurprisingly, ultra-processed salty snacks and sugary products were not linked to weight issues in this French study (Beslay et al., 2020). Similar findings emerged in research in Brazil, suggesting that the negative effects of UPFs on weight might not be solely due to sugary drinks (Canhada et al., 2020). Additionally, a study across nine European countries found that while UPFs were linked to weight gain, soft drink consumption failed to fully account for this association (Cordova et al., 2021). There has been a positive trend in the U.S. - a decrease in sugary drink consumption among young people over the past two decades (Gidding et al., 2005). This decline might be due to increased public health initiatives aimed at curbing sugary drinks and growing awareness of their negative health effects on youth. However, a different study revealed a rise in the consumption of sweet bakery goods and snacks. These treats, including cakes, cookies, and ice cream, are the second biggest source of added sugars in the American youth diet, contributing between 21% and 31% of their total added sugar intake (Bailey et al., 2018). This highlights the need for public health efforts to target added sugar reduction in processed sweet snacks and bakery items during manufacturing. There is a current gap in research – a lack of studies that analyze data by subgroups or directly compare the health effects of the same food across different processing levels. Regularly incorporating subgroup analyses in cohort studies would be highly beneficial to understanding the variations in how UPFs impact weight gain.

2.1.2.2 Ultra-processed foods and diet quality

A cross-sectional study of 790 Brazilian adolescents 14-19 years old assessed relationships between food consumption and eating environments (such as meal frequency, location, and whether they are eaten in company and with attention) according to the level of processing. Three clusters were identified: cluster 1 referred to as "appropriate eating contexts at breakfast, lunch, and dinner" because it reflected a more balanced set of healthy contexts for the three main meals; in contrast, clusters 2 and 3 referred to as "inappropriate eating context at breakfast" and "inappropriate eating context at dinner" because they reflected inadequacies at breakfast and dinner. Authors showed that inappropriate eating patterns either at breakfast or at dinner were associated with an increase in the energy consumption from UPFs $\beta = 2.55\%$ (95% CI: 0.50, 5.05) and $\beta = 4.18\%$ (95% CI: 1.21, 7.14), respectively, compared to their counterparts in cluster 1. Furthermore, adolescents who consumed more UPFs at breakfast had a decrease in energy consumption from unprocessed or minimally processed foods and culinary preparations $\beta = -3.61\%$ (95% CI: -6.40, -0.82) (Neves et al., 2022). In Brazil, a cross-sectional study among 326 schoolchildren aged 7–9 years old found that 69.6% of the total energy intake came from UPFs and was associated with unhealthy dietary habits. Following adjusted analyses, eating UPFs was linked to skipping breakfast, mid-afternoon snacks and dinner, consuming unhealthy foods, and being physically inactive. On the contrary, consuming unprocessed or minimally processed foods was linked to being older as well as eating lunch, dinner, a mid-afternoon snack, and healthy foods. As a result, the eating environment (skipping breakfast, mid-afternoon snacks, and eating dinner) is crucial in determining and increasing the type of food consumed depending on the degree of processing (Fonseca et al., 2023). Da Rocha et al. (2021) in a cross-sectional study among 386 children with a mean age of 5.3 years old, found an inverse association between adherence to the traditional MedDiet and energy intake from UPF. Children with medium and high adherence reported 5.0% and 8.5% lower energy intake from UPF, respectively, compared to those with low adherence to MedDiet (da Rocha et al., 2021). Additionally, several cross-sectional studies among children and adults showed an inverse association between the percentage of energy from UPF and dietary patterns such as packed lunches or dinners when watching TV alone. Furthermore, higher consumption of UPFs was related to lower consumption of fruit, vegetables, legumes, lean meat and poultry, nuts and water and higher consumption of foods with saturated fats and added sugars such as SSBs (Marchese et al., 2022; Parnham et al., 2022; Rauber et al., 2022). UPFs are likely to be high in packed lunches because they have been designed to be preferable for time- and budget-constrained families who require inexpensive and quick food that young children will accept (Hayter et al., 2015). It is well known that packed lunches tend to have low nutritional quality. A cross-sectional study with 1,895 children aged 4-11 years old and 1,408 adolescents 11-18 years old from the UK was conducted in 2008–2017. Regression models were used to examine the relationship between lunchtime UPF intake and the type of meal (school meal or packed lunch). Findings demonstrated that either in primary or secondary school students, the average UPF intake was high (72.6% total lunch kcal and 77.8% total lunch kcal, respectively). Consumers of packed lunches, secondary school students and members of lower-class households were found to consume higher levels of UPFs. It is crucial to highlight that school lunches still had high levels of UPFs, even though they were lower than packed lunches (Parnham et al., 2022). For numerous reasons, including new exposures, social circuits, food insecurity, inadequate cooking abilities, migration, product attributes, and an energy-dense option if a main meal skipped due to busy schedules and classes, UPF's distinct profile might also make them "attractive" food choices for university students (Theodoridis et al., 2018).

In Spain, as a Mediterranean country, the share of UPFs was around 24%, probably since the Mediterranean diet includes cooking at home. The estimation of UPF intake in an adult sample of Italians showed results that were consistent with these data in Spain, where consumption of UPF was 24% of total energy intake (Blanco-Rojo et al., 2019) but significantly lower than that reported in general populations from non-Mediterranean countries (Rauber et al., 2018). On the other hand, these assumptions were opposed to results from a Belgian cohort that indicated that children's and adolescents' total energy intake from UPF was 33.3% and 29.2%, respectively (Vandevijvere et al., 2019). Higher UPF intake was linked to a lower-quality diet that was higher in fat, sodium, and fibre and inversely correlated with the Mediterranean diet, as previously observed in both adults and children/adolescents (da Rocha et al., 2021). The inverse relationship between the Mediterranean diet and UPF, which emphasizes home cooking and unprocessed or minimally processed foods, might help to explain why Italian's UPF intake was significantly lower than those reported in other, particularly non-Mediterranean, nations (Ruggiero et al., 2021). Among dietary habits, eating main meals outside the home was linked to a higher intake of UPF in adults, whereas eating breakfast outside the home was linked to a higher intake of UPF in children, indicating that the main foods Italian children eat for breakfast are highly processed. Adults' consumption of UPF was directly correlated with screen time during meals, which is consistent with earlier research suggesting that watching TV may lead to an increase in the consumption of high-density and attractive foods (Blass et al., 2006), however, there was no such relationship seen in children or adolescents (Ruggiero et al., 2021).

Interestingly, Hess et al. (2023) investigated the possibility of creating a menu that met the healthy eating recommendations outlined in the 2020 Dietary Guidelines for Americans (DGA), even if most of the calories (>80%) came from UPFs as defined by the NOVA classification system. They successfully built a sample menu with a whopping 91% of calories that came from UPFs. Furthermore, this menu still achieved a high score (86 out of a possible 100) using the Healthy Eating Index 2015 (HEI-2015), a measure of overall diet quality. While not perfect, the main limitations of the menu were slightly high sodium content and a lack of whole grains. Despite the high UPF content, this sample menu provided enough of the most essential nutrients, including macronutrients and micronutrients, with the exception of vitamin D, vitamin E, and choline. This study suggested that following healthy dietary patterns is achievable even with a significant portion of calories coming from UPFs, and such a diet can still be considered high quality and meet nutrient requirements, although some specific deficiencies might arise (Hess et al., 2023).

2.1.2.3 Ultra-processed foods and environmental factors

Rauber et al. (2022) in the 2014–2016 UK National Diet and Nutrition Survey conducted on 543 adolescents aged 11–18 years, examined the relationship between the percentage of total daily energy intake derived from UPFs and eating context patterns. The contribution of UPFs to daily energy intake was about 67%. Three patterns were utilized for lunch ('At school with friends', 'TV during family meal', and 'Out-of-home (no school)'), and three for dinner ('Watching TV alone in the bedroom', 'TV during family meal', and 'Out-of-home with friends'). The consumption of UPFs was not significantly correlated with any of the three patterns during lunch. At dinner, the patterns ‘Out-of-home with friends’ (coefficient: 3.13; 95% CI: 0.21, 6.14) and ‘Watching TV alone in the bedroom’ (coefficient: 4.95; 95% CI: 1.87, 8.03) were related with higher UPFs consumption (Rauber et al., 2022). Furthermore, a cross-sectional study conducted on 9,078 Italian participants 5–97 years old investigated the association of UPFs and their sociodemographic, psychosocial and behavioural correlates. The mean energy consumption from UPF was 17.3% (95% CI, 17.1%, 17.6%) for adults and 25.9% (95% CI, 24.8%, 27.0%) for children and adolescents when processed meats (32.5%) and bread substitutes (16.7%) were the main UPF sources. UPF was directly correlated with screen viewing during meals, as well as low sleep quality [$\beta = 2.34$; 95% CI (1.45, 3.23)], unfavorable life events [$\beta = 2.33$; 95% CI (1.48, 3.18)], and poor self-rated health [$\beta = 5.32$; 95% CI (2.66, 7.99)]. A Mediterranean diet was inversely correlated with UPF for all ages, for high vs low adherence in adults [β = −4.86; 95% CI (−5.53, −4.20)] and for children [β = −5.08; 95% CI (−8.38, −1.77)] (Ruggiero et al., 2021). This finding was consistent with a study on 2,499 Brazilian adolescents that found an association between high UPF consumption and poor quality of sleep (Sousa et al., 2020). Concerning the psychosocial dimension and their relationship with UPF intake, Ruggiero et al. (2021) found that higher UPF consumption is linked to worse self-rated health status. This finding was consistent with earlier epidemiological research that had shown an association between UPF consumption and depression risk (Pagliai et al., 2021). Additionally, the authors showed a relationship between negative life circumstances and UPF, which was consistent with research demonstrating poorer diet quality in anxious and neurotic people (Schweren et al., 2021). Lastly, an Italian study showed that UPF consumption was positively correlated with individuals who reported having poor quality of sleep (Ruggiero et al., 2021). Research on factors influencing food consumption in childhood reveals that parents' sociodemographic characteristics have a significant impact on their child's eating standards because the family environment plays a crucial role in the development of a child's eating habits (Patrick & Nicklas, 2005). Pricewise, UPFs made by industry on a large scale were typically less expensive than unprocessed or minimally processed foods like milk, meat, vegetables, and fruits. Consequently, families with higher incomes were more likely than families with lower purchasing power to purchase food that is regarded as healthy (Enes et al., 2019). A cross-sectional study conducted on 10,087 Mexicans showed differences in the relationship between the energy contribution of UPFs and nutrient intake depending on socioeconomic factors, such as in low-income families and households with no formal education (Marrón-Ponce et al., 2019). According to Nardocci et al. (2019) respondents with more formal education had lower consumption of ultra-processed foods (Nardocci et al., 2019). Education and knowledge about nutrition are necessary to make better food choices in a setting where a wide variety of healthy and unhealthy food options are available, even though they do not always translate into healthy eating habits (Mcentee, 2009). A completely different situation was observed in Brazil, where women with greater incomes, educational levels, and urban residents consume more of these products (Louzada et al., 2015). Similarly, a large health cohort study called the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) investigated the eating habits of over 11,800 civil servants working for Brazilian public universities and research institutes. The study participants ranged in age from 35 to 74 years old. Interestingly, the research found that people with higher education levels and income tended to consume higher quantities of UPFs (Canhada et al., 2020). These discrepancies might be explained by the fact that, in some low-income countries like Brazil, UPFs were more expensive than unprocessed and minimally processed foods, when the opposite was true in higher-income countries like the UK (Moubarac et al., 2013).

However, a cross-sectional study conducted on 403 children, aged 4 to 7 years showed that children from lower-income families consumed more minimally processed foods and fewer UPFs. Furthermore, they found that children with less educated parents consumed less fruits and vegetables. Except for fruits and vegetables, adverse sociodemographic characteristics were linked to a better profile of food consumption based on the degree of processing (Viola et al., 2023). Moreover, in Brazil, Pereira et al. (2022) in a cohort study among 4,275 children, found that the consumption of UPFs was higher among children from families of lower socioeconomic status whose mothers present lower education levels (Pereira et al., 2022). Similar results have been found in another Brazilian cohort study with 1,185 children. It was shown that low maternal education was related to high consumption of UPFs (Batalha et al., 2017). According to some authors, a low level of maternal education is related to a lack of purchasing power and access to health information, which may cause children to make unhealthy food choices (Wijtzes et al., 2013).

The parents' low educational level suggests that they do not fully comprehend the importance of health care and dietary recommendations, which leads to a decrease in the availability of foods deemed healthy for children (Valmórbida & Vitolo, 2014). On the other hand, in a cross-sectional study carried out among 204 Brazilian children aged 2-10 years old, it was found that an increase in the intake of UPF in children's diets was correlated with higher maternal educational level (Sparrenberger et al., 2015) as other studies have shown (Wijtzes et al., 2013) and no association between higher consumption of UPF and lower income (Sparrenberger et al., 2015). Another study suggested that school-aged children tended to consume more UPFs compared to preschoolers (ages 2-5 years). This difference might be due to factors like increased marketing, easier access to, and a wider variety of UPFs targeted towards older children. Interestingly, the study found no significant differences in UPF consumption based on parents' education level or family income. This suggests that UPFs were widespread in the diets of US youth across all socioeconomic groups, highlighting the importance of reducing UPF consumption for all children regardless of background (Wang et al., 2021).

A country's economic growth appears to be strongly associated with its UPFs intake. However, high-income countries appear to be saturated with these foods, while low- and middle-income countries are seeing faster growth rates in their consumption (Melo et al., 2017). A study conducted in 2001 on 5,643 households in Canada evaluated the relationship between the nutrient profile of the total food purchases and the purchase of UPFs. Purchases of foods higher in free sugar, sodium and energy density, and lower in protein and fibre were substantially correlated with increases in the purchase share of UPFs (Moubarac et al., 2013). Furthermore, in 1990, 2000, and 2010 a Spanish household study (n = 2,012; 33,730; and 22,116, respectively) evaluated the relationship between the amount of added sugar in total food purchases and the purchase of ultra processed foods. Increased consumption of ultra-processed foods was linked to higher levels of added sugar in total food purchases, exceeding the 10% energy limit in all three surveys (Latasa et al., 2018).

Globally, in 2013, the United States and Canada had the highest per capita sales of ultra-processed foods, averaging 307 and 231 kg/person, respectively. These figures were significantly higher than those of other high-income nations such as France (125 kg/person) and Italy (113 kg/person) (Pan American Health Organization, 2015). In addition, a household study in Brazil, which included three rounds (n=13,611 in 1987–1988, n=16,014 in 1995-1996, and n=13,848 in 2002–2003), showed that households have steadily replaced minimally processed foods and processed culinary ingredients with UPFs and this presented a nutritional profile of much higher energy density, more added sugar, more saturated fat, more sodium and less fibre (Monteiro et al., 2011; Moubarac et al., 2013).

The trends in the volume sales/per capita of ultra processed food and drink (UPFD) and their correlations with adult BMI trajectories were assessed by Vandevijvere and colleagues. The mean adult BMI from the NCD Risk Factor Collaboration (2002-2014) was associated with total food and drink volume sales/capita from Euromonitor for 80 countries (2002-2016). The average BMI for men and women increased by 0.195 kg/m^2 (P <0.001) and 0.072 kg/m^2 (P =0.003), respectively, for every standard deviation increase in ultra processed drink volume sales (51 kg/capita, 2002). The average BMI increased by 0.316 kg/m^2 for men (P <.001) for every standard deviation (40 kg/capita, 2002) increase in ultra processed food volume sales; for women, the association was not statistically significant. Consequently, positive correlations were found between population-level BMI trajectories and increases in UPFD volume sales/capita. Among 80 high- and middle-income countries, the Netherlands (143.8 kg/capita/year), Germany (141.8 kg/capita/year), and the UK (140.7 kg/capita/year) had the highest volume sales of UPF per capita in 2016 according to a recent analysis of the global trend in this area (Vandevijvere et al., 2019).

A recent study examined the impact of considering dietary quality on the established link between UPFs and health problems in cohort studies. Interestingly, the study found that even after accounting for dietary quality or patterns, the connection between UPFs and obesity and other health issues remained strong. These findings suggested that the negative health consequences of UPFs might be independent of overall diet quality. This challenged the idea that simply improving the nutritional content of processed foods (reformulation) would be an effective strategy to combat obesity and related health problems. The researchers acknowledged alternative explanations. Perhaps UPFs crowd out healthier foods in people's diets, or maybe they simply fit more readily into existing unhealthy dietary patterns. However, even after considering factors like adherence to a Mediterranean diet or other dietary patterns, the link between UPF intake and negative health outcomes largely persisted, including an increased risk of weight gain and obesity (Dicken & Batterham, 2021).

2.2 Ultra-processed foods and Health Outcomes

2.2.1 Risk factors in adults

2.2.1.1 Overweight/Obesity

Global food systems have changed, displacing traditional meal-based dietary patterns with ones that are increasingly composed of ultra-processed foods, which appears to be the cause of the rise in obesity rates worldwide. Most of the research relating UPF consumption to obesity and weight control comes from observational studies and cohort studies. The findings have been summarized in several reviews. Overall, findings demonstrate that there is an increased likelihood of weight gain, being overweight, and obesity with higher consumption of UPF.

There are several studies indicating the association of UPFs consumption with obesity in adults. In Australia, a cross-sectional study on 7,411 Australians aged ≥20 years investigated the relationship between UPFs consumption and obesity. Researchers found that an increase in the consumption of UPFs was significantly related to higher BMI and WC as well as increased likelihood of obesity and abdominal obesity. Compared to Australians whose diets did not include UPFs (<22% of energy intake), those who consumed UPFs >62% of total energy intake had a BMI that was 0.97 units higher, a waist circumference that was 1.92cm greater, and a likelihood of obesity and abdominal obesity that was 61 and 38% higher, respectively. Consequently, there was a causal relationship between UPFs intake and weight gain (Machado et al., 2020). Findings from 4 cycles of NHANES (2011-2018) among 9,640 adults highlighted that those in the highest quintile of UPFs consumption had a 1.60 higher total percentage fat (95% CI: 0.94, 2.26), 2.08 higher android percentage fat (95% CI: 1.26, 2.89), and 1.32 higher gynoid percentage fat (95% CI: 0.71, 1.93) than individuals in the lowest (p-trend < 0.001) (Liu et al., 2023). Similarly, a cross-sectional study among

15,977 US adults 20–64 years old showed that consuming ≥74.2% in the highest vs ≤36.5% in the lowest quintile of total energy from UPFs was related with 1.61 units higher BMI (95% CI 1.11, 2.10), 4.07cm greater WC (95% CI 2.94, 5.19) and this supported that higher consumption of UPFs was associated with excess weight (Juul et al., 2018). Another cross-sectional study included 19,363 Canadian adults aged ≥18 years old found an increased consumption of UPFs, which was higher among younger adults and those who were physically inactive and had fewer years of formal education. Additionally, results demonstrated a 32% higher risk of obesity in those whose diets primarily consisted of UPFs compared to those whose diets did not (Nardocci et al., 2019).

The UK Biobank cohort study with 22,659 participants aged 40–69 years indicated that increasing consumption of UPFs was strongly associated with an increasing risk of multiple indicators of obesity in the adult population (Rauber et al., 2021). Furthermore, the UK National Diet and Nutrition Survey (2008–16) among 6,143 participants aged 19-96 years old found that compared to those with the lowest consumption, those with the highest consumption of ultra-processed food had 3.56cm greater WC (95% CI: 1.79–5.33), 1.66 kg/m^2 higher BMI (95% CI: 0.96–2.36), and 90% higher odds of being obese (OR = 1.90, 95% CI 1.39–2.61). Furthermore, a 10% increase in consumption of UPFs was related to an increase of 0.87cm in WC (95% CI: 0.40-1.33), 0.38 kg/m^2 in BMI (95% CI: 0.20-0.55), and an 18% higher likelihood of obesity (OR = 1.18, 95% CI: 1.08-1.28) (Rauber et al., 2020). In Brazil, a longitudinal study conducted on 11,827 adults aged 35–74 years showed that by comparing those in the highest with the lowest quartile of ultra-processed food consumption found about 20–30% higher likelihood of large weight and WC gains and a higher prevalence of overweight/obesity across 3.8 years of follow-up. Furthermore, the authors indicated comparable relationships in a secondary analysis after eliminating sweetened beverages from the NOVA classification of UPFs, indicating that sweetened beverages were not the only source of risk associated with ultra-processed foods (Canhada et al., 2020). In another study of 8,451 middle-aged Spanish, a total of 1,939 overweight and obese were identified during follow-up. Individuals who consumed UPFs at the highest quartile had a higher likelihood of becoming overweight or obese (adjusted HR: 1.26; 95% CI: 1.10, 1.45; P-trend = 0.001) compared to those who consumed them at the lowest quartile (Mendonça et al., 2016). In 2023, a cross-sectional study in Greece among 346 young participants aged 18-22 years showed a positive relationship between UPFs consumption and central adiposity in males but no association between UPF and BMI (Detopoulou et al., 2023).

The authors of a systematic review that analyzed the association between consumption of UPFs with overweight and obesity showed a positive association between

UPFs and excess body weight in adults (Askari et al., 2020). An ecological study across 19 European countries demonstrated a positive correlation between the national prevalence of adult obesity and the availability of UPFs in households nationwide (Monteiro et al., 2018). In 1960–2010, another ecological study in Sweden among adults ≥ 18 years found a decrease of 2% and 34% in unprocessed or minimally processed foods and processed ingredients, respectively, while the consumption of processed foods and UPFs was remarkably increased by 116% and 142%, respectively. These results demonstrated the shift from eating freshly prepared nutritious meals to ready-to-eat and nutritionally unbalanced products. At the same time, with these changes in UPFs, the prevalence of obesity in adults increased from 5% in 1980 to over 11% in 2010 (Juul et al., 2015). Furthermore, Hall et al. (2019) through a randomized controlled trial during 28 days among 10 male and 10 female weight-stable adults aged 31.2 ± 1.6 years found that energy intake was higher during the ultra-processed diet (508±106 kcal/d; p=0.0001), with higher consumption of carbohydrate (280 ± 54 kcal/d, p < 0.0001) and fat (230 ± 53 kcal/d, p = 0.0004) but not protein (−2 ± 12 kcal/d, p = 0.85). Weight changes were strongly associated with energy intake, with participants gaining 0.9 ± 0.3kg (p = 0.009) during the diet rich in UPFs and losing 0.9 ± 0.3kg (p = 0.007) during the unprocessed diet (Hall et al., 2019).

2.2.1.2 Cardiometabolic co-morbidities

According to the evidence, following a healthy eating pattern, like the Mediterranean diet or other similar healthy eating patterns, was linked to a lower risk of developing various morbidities (Schulze et al., 2018). Although research on the relationship between UPF consumption and the multimorbidity of cancer and cardiometabolic diseases was lacking, a prospective cohort study found that a higher UPF consumption was linked to an increased risk of multimorbidity of cardiovascular and respiratory diseases (Li et al., 2023). The relationship between UPFs consumption and health outcomes in adults was summarized in a systematic review. The review included 20 studies, most of them cohort studies, conducted on 334,114 participants and examined ten health outcomes. Authors highlighted that UPFs consumption was associated with a higher risk of all-cause mortality, overall cardiovascular diseases, coronary heart diseases, cerebrovascular diseases, hypertension, metabolic syndrome, overweight and obesity, depression, irritable bowel syndrome, overall cancer, postmenopausal breast cancer, gestational obesity, adolescent asthma and wheezing, and frailty (Chen et al., 2020). A recent cohort study among 266,666 participants from seven European countries investigated the relationship between UPF consumption and type 2 diabetes, cardiovascular disease, and cancer. Findings from this study showed that higher

UPF consumption was associated with an increased risk of multimorbidity of cancer and cardiometabolic diseases (HR: 1.09, 95% CI: 1.05, 1.12) (Cordova et al., 2023).

Considering cardiovascular disease (CVD), a cohort study in France investigated the relationship between UPFs consumption and the risk of cardiovascular disease among 105,159 participants aged ≥ 18 years. Srour et al. (2019) showed that an increase in UPFs intake was associated with higher risks of cardiovascular, coronary heart, and cerebrovascular diseases (Srour et al., 2019). Similarly, Juul et al. (2021) in a cohort study of 3,003 adults free from cardiovascular diseases with a mean age of 53.5 years showed that higher portions of UPFs were associated with increased risk of CVD incidence and mortality. More specifically, each additional serving of UPFs per day was related to an increase of 7% in the risk of CVD, 9% in coronary heart disease (CHD), 5% in overall CVD and 9% in CVD mortality (Juul et al., 2021). According to NHANES 2011–2016, among 11,246 adults aged ≥20 years old, 55.4% of the daily energy intake came from UPFs. There was a 0.14-point reduction in cardiovascular health (CVH) score (CVH metrics were based on the "Life's Simple 7" metrics developed by the American Heart Association and included smoking, physical activity, healthy dietary scores, BMI, total cholesterol, blood pressure, and fasting plasma glucose) (P<0.001) for every 5% increase in calories from UPFs. The authors indicated a graded inverse relationship between CVH and the percentage of kcal from UPFs. The fact that a large number of foods high in cholesterol - such as eggs, cheese, beef, shellfish, etc. - were not considered UPFs might help to explain the inverse relationship between UPFs and cholesterol (Zhang et al., 2021). Regardless of replacement nutrients, higher TFA intakes have generally been linked to a 20–30% higher risk of all-cause mortality (de Souza et al., 2015). TFA has been linked to negative health outcomes and the disruption of circulating lipid biomarkers; in particular, it has been shown to increase levels of LDL-cholesterol, lipoprotein (little) a (Lpα), and triacylglycerol levels, decrease HDL-cholesterol levels and LDL-cholesterol particle size (Wang et al., 2013), and increased the ratio of total to HDL cholesterol (Micha & Mozaffarian, 2009). In several populations, trans fatty acid consumption has been linked to an increased risk of all-cause mortality (Chien et al., 2013). The contentious relationship between the consumption of saturated fatty acids and mortality (de Souza et al., 2015) emphasized the importance of considering the sources of saturated fatty acids in food (Guasch-Ferré et al., 2015). Furthermore, Magriplis and colleagues in a cross-sectional study among 3,537 individuals, found that a high intake of TFA combined with high SFA intakes further increased the likelihood of dyslipidemia (Magriplis et al., 2022). Furthermore, a systematic review aimed to summarise and discuss evidence of the relationship between food consumption according to degree of food processing and cardiometabolic risk. Studies have shown a positive association between UPF consumption with excess body weight, hypertension, dyslipidemia and metabolic syndrome features (Silva Meneguelli et al., 2020).

Hypertension is also related to high CVD risk. A Spanish cohort study with 14,790 participants who were free of hypertension at baseline after a follow-up of a mean of 9.1 years showed that there was a positive association between UPF consumption and hypertension risk (Mendonça et al., 2017). Furthermore, a longitudinal study from Brazil conducted on 8,754 individuals aged 35–74 years in 2008-2010 with a 4-year follow-up assessed the association between UPFs intake and changes in hypertension and showed that after adjustment, adults with high UPF consumption had a 23% higher risk of developing high blood pressure (OR = 1.23, 95% CI: 1.06, 1.44) compared to those with low intake of UPF (Scaranni et al., 2021). Similarly, another longitudinal study among 1,221 participants classified as non-hypertensive at baseline and monitored for 2 years found that 25.8% of the daily energy intake came from UPF, and the incidence of hypertension was high. After adjustment, those in the high quintile of total energy intake of UPF showed an increased risk of hypertension (RR: 1.35; 95% CI: 1.01, 1.81), whereas those in the upper quintile of total energy intake of unprocessed or minimally processed and processed foods showed a decreased risk of this outcome (RR: 0.72; 95% CI: 0.52, 0.98) (Rezende-Alves et al., 2021). To examine the effects of consuming ultra-processed meats on blood pressure, Lajous et al. (2014) tracked 44,616 French women for a period of 15 years. The study findings indicated that there was a higher risk of hypertension associated with higher consumption of ultra-processed meat (hazard ratio=1.17; 95% CI: 1.09, 1.26) compared to lower consumption (Lajous et al., 2014). Finally, a systematic review among 111,594 individuals showed that higher UPFs consumption increased the risk of hypertension significantly (Wang et al., 2022).

In addition, the relationship between Metabolic syndrome (MetS) and UPFs consumption was studied by NHANES 2009-2014 among 6,385 individuals aged 20+ years. Findings showed a significant association between UPFs intake and the prevalence of MetS. A 10% increase in contribution was associated with a 4% increase in the prevalence of MetS. The association was more important in young adults and decreased with age (Martínez Steele et al., 2019). Moreover, from 2008 to 2010, a cross-sectional study conducted on 15,105 participants aged 35–74 years investigated the association between UPFs intake and increased risk of metabolic syndrome. It was found that after adjustment, an increase of 150g/day in UPF consumption increased the risk of incident Mets by 7%. Consequently, higher UPFs intake was related to an increased risk of MetS (Canhada et al., 2023).

In 2019, 463 million adults aged 20-79 years old had diabetes, and 374 million were at higher risk of developing type 2 diabetes, according to the most recent International Diabetes Federation report. Also, most countries were seeing an increase in the percentage of their population with T2D (International Diabetes Federation, 2019). Llavero-Valero et al. (2021) in the SUN project - a cohort study- assessed 20,060 participants for their UPFs intake and the incidence of T2D. Even after accounting for potential confounders, higher consumption of UPF was linked to an increased hazard for new-onset type 2 diabetes in this highly educated study with a low initial absolute risk of T2D. These results indicated that higher consumption of UPF was related to a higher risk of developing T2D (Llavero-Valero et al., 2021). Moreover, a cross-sectional study examined the relationship of UPF consumption with incident type 2 diabetes in 15,105 Brazilian adults 35–74 years old. In a follow-up period of 8.2 years, 1,799 (17.6%) incident cases were found. When comparing the extreme quartiles of UPF consumption and increases in consumption of 150g/day, the relationship was clear and linear over the relevant consumption range (Canhada et al., 2023). Chen et al. (2023) in a systematic review of 3 U.S. cohort studies (5,187,678 people), showed that UPFs consumption was associated with a higher risk of T2D. More specifically, the meta-analysis indicated that each 10% increment in UPFs consumption was associated with a 12% higher risk of T2D (Chen et al., 2023).

In France, a cohort study of 104,707 adults ≥18 years showed that UPFs consumption was related to a higher risk of diabetes type 2 (T2D) even after adjustment for several markers of the nutritional quality of the diet, for other metabolic comorbidities (Srour et al., 2020). This study was in agreement with the findings of the UK Biobank (2007-2019) study conducted on 21,730 adults with a mean age of 55.8 years old and without diabetes which examined the relationship between the consumption of UPF and the risk of type 2 diabetes (T2D). The authors found that during a 5.4-year follow-up period, individuals with the highest levels of UPFs intake had a 44% increased risk of developing type 2 diabetes compared with those with the lowest consumption. Furthermore, for every 10% increase in the consumption of UPFs, there was a 12% increase in the risk of incident type 2 diabetes (Levy et al., 2021). Although both the French and British cohorts consumed a significant amount of UPFs (17.3% and 22.1%, respectively), the types of UPFs consumed by participants varied significantly. Sugary products (28%), ultra-processed fruits and vegetables (18%), and beverages (16%) were the most popular UPFs consumed by the French cohort. In contrast, the British cohort's ultra-processed foods were primarily sourced from beverages (39.1%), bakery products and breakfast cereals (29.9%), and prepared meals (19.3%). This implied that regardless of the food and beverage categories consumed, UPFs might be linked to an increased risk of T2D incidence, but more evidence is needed on this aspect (Levy et al., 2021).

Research indicates that artificial sweeteners may change the microbiota and may be associated with the development of type 2 diabetes and other metabolic disorders, which are leading causes of preventable death (Suez et al., 2014). There is also a possibility that food packaging contains endocrine disrupting ingredients. Food products can absorb chemicals from food contact articles during storage and transportation. Some of these chemicals, like bisphenol A, may have harmful effects on health (Alonso-Magdalena et al., 2010). Endocrine disruptors may raise the risk of metabolic disorders like diabetes and obesity as well as endocrine cancers, according to epidemiologic data (Kabir et al., 2015). Furthermore, high concentrations of this compound are toxic to neurons in animal models that regulate metabolic homeostasis, including insulin secretion and action, leading to an increase in fasting blood glucose levels and severe visceral fat accumulation (Hernández Bautista et al., 2019). Furthermore, there is a positive correlation between the degree of food processing and the likelihood of raising blood glucose levels and lowering the satiety index, two key mechanisms connected to the accumulation of body fat (Pfeiffer & Keyhani-Nejad, 2018). These processes entail the function of the intestinal hormone known as glucose-dependent insulinotropic polypeptide (GIP), which causes the pancreas to release insulin in response to an increase in blood glucose. Given that foods high in glycaemic index cause blood glucose to rise quickly and, in turn, release more GIP, there is an early insulin response that is typified by increased fat deposition and decreased fat oxidation (Costa et al., 2021).

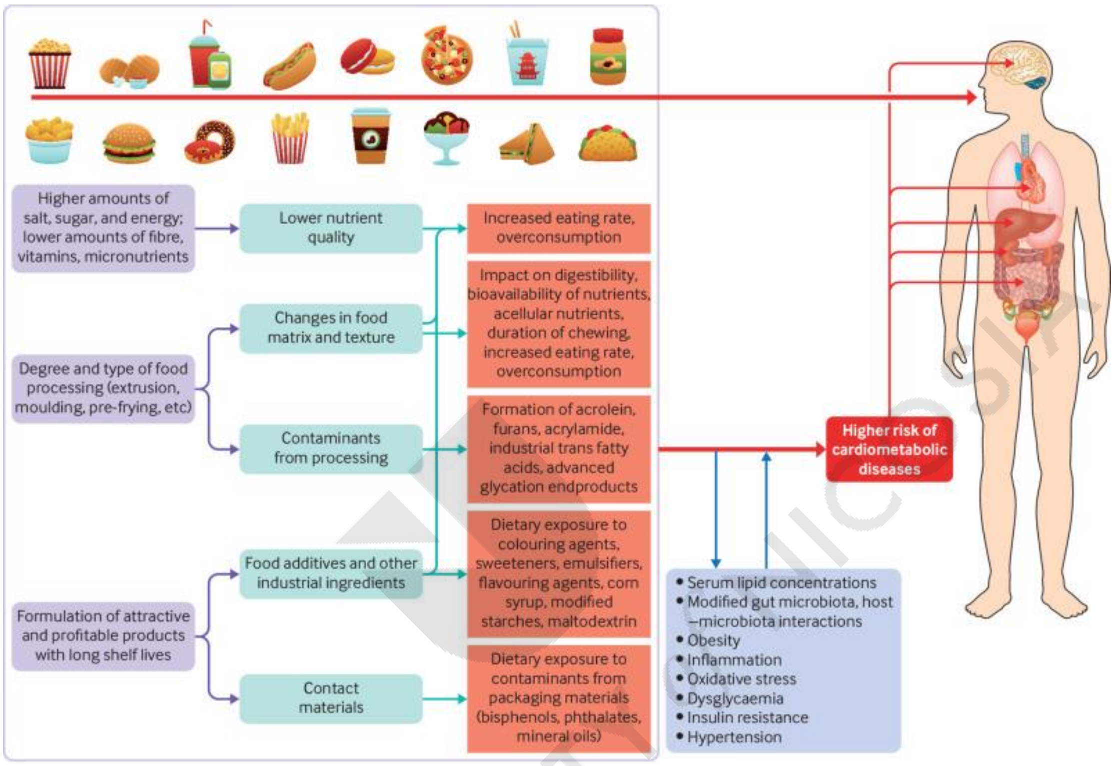
It is very important to highlight that UPFs consumption was related to a higher risk of mortality. The French NutriNet-Sante Study cohort study launched in 2009 until 2017 among 44,551 participants > 45 years old examined the relationship between UPFs intake and all-cause mortality risk. The authors found that 29.1% of total energy intake came from UPFs. During the follow-up period, there were 602 deaths (1.4%). Findings showed that after adjustment for a range of confounding factors, an increase in UPFs consumption was related to a higher risk of all-cause mortality (HR per 10% increment, 1.14, 95% CI: 1.04-1.27, p = 0.008) (Schnabel et al., 2019). These findings agreed with a Spanish cohort study conducted in 1999-2018 among 19,899 participants aged 20-91 years and followed-up every two years between 1999 and 2014, aimed to investigate the relationship between the consumption of UPFs and all causes of mortality. During the follow-up period of 200,432 persons, 335 deaths occurred. Each additional serving of UPFs increased all-cause mortality by 18% (Rico-Campà et al., 2019). Furthermore, Zhong et al. (2021) included 91,891 participants aged 55-74 years in a cohort study and found that increased consumption of

UPFs was associated with a higher risk of overall cardiovascular and heart disease mortality (Zhong et al., 2021). A multinational cohort study from 21 countries in 2023 indicated that a higher intake of UPFs was associated with a higher risk of mortality (5%), CV mortality (5%), and non-CV mortality (4%). This association was stronger among participants in low- and middle-income countries than in high-income countries (Dehghan et al., 2023). On the other hand, findings from the Korean Genome and Epidemiology Study-Health Examinees (KoGES-HEXA) cohort study among 113,576 participants aged 40-69 years found no association between higher intake of ultra-processed foods and mortality (Kityo & Lee, 2023).

Due to their consistent associations with mortality in prospective studies, processed meats and sugary drinks might play a role in the observed correlation between ultra processed foods and mortality (Schwingshackl et al., 2017). In contrast, UPFs typically contained very little fibre. Higher consumption of these foods has been linked to a lower intake of fibre, while fibre has been consistently associated with a significantly lower risk of mortality (Yang et al., 2015). These foods might contribute to the increase in non-communicable diseases, which raise the risk of death even more. According to studies, cutting back on added sugar, salt, and saturated and trans fats in the diet might have significant benefits, like lowering the risk of cardiovascular disease (Moreira et al., 2018).

A review of prospective cohort studies indicated that the adverse consequences of UPFs on obesity and health-related outcomes were independent of nutrient content and dietary patterns (Dicken & Batterham, 2021). Furthermore, an umbrella study of meta-analyses showed that increased UPFs consumption was associated with multiple health outcomes such as obesity, hypertension, diabetes and mortality (Wang et al., 2024). Similar findings were shown by Lane et al. (2024) in an umbrella review of 45 existing meta-analyses that examined the associations between exposure to ultra-processed foods and adverse health outcomes. They indicated that increased intake of UPFs was related to a higher risk of adverse health outcomes, particularly cardiometabolic, common mental disorders and mortality (Lane et al., 2024). Interestingly, another systematic review included 19 cross-sectional and prospective cohort studies that investigated the intake of UPFs and health status. After analyzing ten cross-sectional studies, it was found that adults who had consumed higher levels of UPF than those who had consumed less had an increased risk of overweight/obesity, high waist circumference, reduced HDL cholesterol levels, and metabolic syndrome, but not of other outcomes like hypertension, hyperglycemia, or hypertriacylglycerolaemia. In addition, the evaluation of cohort studies showed a significant increase in overweight/obesity risk, as well as a 29% increase in the likelihood of CVD incidence and/or mortality, a 20% increase in the risk of depression, and a 34% increase in the risk of cerebrovascular disease (Pagliai et al., 2021). Figure 2.1 shows the potential factors and mechanisms of UPFs consumption with health outcomes (Touvier et al., 2023).

Figure 2.1 Potential factors and mechanisms of UPFs consumption with adverse health outcomes (Touvier et al., 2023).



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2.2.2 Risk factors in children and adolescents

2.2.2.1 Overweight/Obesity

The urge to eat when children see, smell, or taste palatable food - such as ultra-processed foods - was positively correlated with higher consumption of UPFs at age 4. In a study involving preschoolers from Australia and Britain, food responsiveness was positively correlated with the desire for UPFs but negatively correlated with liking fruits and vegetables (Fildes et al., 2015). Evidence from the past indicated that even in states of satiety, highly appetizing food cues encourage food-seeking behaviours (Schulte et al., 2015). This is one of the risk factors for obesity.

Regarding the association of UPFs consumption and childhood obesity, a follow-up of a randomized controlled trial conducted on 307 children aged 4 and 8 years found that

UPFs consumption at preschool age was related to an increase in delta WC to schoolage children. These findings implied that early UPFs consumption contributed to the rise in childhood abdominal obesity (Vedovato et al., 2021; Costa et al., 2019). Similarly, the Avon Longitudinal Study of Parents and Children (ALSPAC), a cohort study among 9,025 children who were followed up from 7 to 24 years of age, showed that increasing consumption of UPFs was associated with higher increases in adiposity indices such as BMI, fat mass index, weight and waist circumference from childhood to early adulthood (Chang et al., 2021). A longitudinal study conducted on 1,470 children examined the relationship between five lifestyle behaviors (physical activity, sleep time, television time, plant-based foods, and intake of ultra-processed foods) and obesity at age 4 years and age 7 years. Bawaked et al. (2020) found that at age 4, the lifestyle score had no impact on outcomes. However, at age 7, it was found to be negatively associated with BMI and WC z-scores. The risk of overweight or obesity at age 7 (OR = 0.61; 95% CI: 0.39; 0.96) and abdominal obesity (OR = 0.48; 95% CI: 0.24; 0.96) was lower for children in the highest tertile of the score at age 4. A healthier lifestyle started at age four was associated with a lower risk of overweight, obesity, and abdominal obesity at age seven (Bawaked et al., 2020). In 2004, the Pelotas-Brazil 2004 Birth Cohort in children at 6 and 11 years of age investigated the relationship between consumption of UPFs and body fat. Findings showed that an increase of 100g in contribution from UPFs to daily food intake at ages 6 to 10 was linked to an increase of 0.14 kg/m^2 in the fat mass index in the same period at fully adjusted analysis. When comparing the change in the fat mass index from 6 to 11 years, the calorie content of UPF consumed at 6 years accounted for 58% of the total effect. They also found that UPF contributed to 42% and 33% of the daily energy intake at 6 and 11 years of age, respectively (Costa et al., 2021). Another notable result from a Canadian cross-sectional study among preschoolers was the inverse association between the consumption of unprocessed foods and abdominal obesity (Ashraf et al., 2022). These findings were in accordance with a randomized control study from China with 54 overweight/obese children and adolescents 2-18 years old. The study showed a significant decrease in BMI in the minimally processed diet group and government-recommended diet (a modified diet with restriction of sugar and UPFs but none in energy) group, from 27 to 24.5 kg/m^2 and from 27 to 26 kg/m^2 ($p < 0.001$), respectively. Furthermore, it was shown that a 12-week self-intervention with a minimally processed diet and no energy intake restriction could lead to a more significant decrease in weight and abdominal obesity among participants (Chen et al., 2022).

Findings from NHANES in 3,587 participants highlighted that the highest consumption of UPFs was associated with 45%, 52%, and 63% higher odds of total-, abdominal-, and visceral overweight/obesity, respectively, compared with the lowest consumption (Neri et al., 2022). In addition, findings from the cross-sectional Brazilian Dietary Survey on 30,243 participants aged ≥10 years from 2008–2009 showed that individuals in the highest quintile of UPFs intake had significantly higher BMI (0.94 kg/m^2, 95% CI: 0.42,1.47) and higher odds of being obese (OR=1.98, 95% CI: 1.26,3.12) and excess weight (OR=1.26, 95% CI: 0.95,1.69) compared with those in the lowest quintile of consumption (Louzada et al., 2015). Additionally, there was a cross-sectional study with 1,525 adolescents 18 to 19 years of age which found that UPFs consumption was inversely associated with BMI, muscle mass, and lean mass index. A 1% increase in the percent contribution of UPFs to total dietary energy intake was associated with a decrease in muscle mass and lean body mass (Viola et al., 2020).

In Brazil, during a cross-sectional study of 6,805 adolescents 14-19 years old, authors found that an increase in BMI and body fat was observed when participants had higher consumption of UPFs at breakfast and dinner (Neves et al., 2022). Furthermore, a systematic review evaluated the association between UPFs consumption and body fat among children and adolescents. Most studies found a positive association between the consumption of UPFs foods and soft drinks/sweetened beverages and body fat in children and adolescents (Costa et al., 2018).

On the other hand, findings from the Adolescent Nutritional Assessment Longitudinal Study (ELANA) among 1,035 adolescents aged 15-17 years showed that even if an increasing consumption of UPFs is a marker of an unhealthy diet, no association between UPFs intake and BMI at baseline and follow-up was found (Cunha et al., 2018). Furthermore, a cross-sectional study examined the relationship between UPF consumption and anthropometric indicators of obesity in 164 children aged 7–10 years. The average daily energy consumption was 1762.76 kcal, with unprocessed or minimally processed, culinary ingredients and processed food, and ultra-processed food accounting for 45.42%, 10.88%, and 43.70%, respectively. While anthropometric measures of obesity (BMI, WC, WHtR) and ultra-processed food consumption were not found to be associated, children in the study had high rates of overweight and abdominal obesity in addition to ultra-processed food consumption. It should be highlighted that there several factors contribute to the etiology of obesity, including genetics, physical inactivity, family lifestyle, and psychological factors, all of which were not examined in this study (Oliveira et al., 2020). Another cross-sectional study conducted in 200 Brazilian adolescents aged 10-18 years old investigated the relationship between UPFs consumption and obesity indicators. Enes et al. (2019) found that obesity was prevalent in 47% of the population, with 21.5% having an increased waist circumference and the average daily energy intake was 4176 kcal, of which UPFs accounted for 50.6%. Among UPFs, processed bread (16.2%), pasta (6.0%), sweets and candy (6.2%), and sweetened drinks (5.1%) had the highest caloric contributions. However, no association was found between UPFs intake and obesity (Enes et al., 2019). Melo et al. (2017) also in a cross-sectional study in Brazil, with 249 participants 14–19 years old, found an inverse relationship between the consumption of minimally processed foods and excess weight. Nevertheless, the consumption of ultra-processed foods was not associated with excess weight in adolescents (Melo et al., 2017).

Early-life food-approaching behaviours, or eating behaviours that suggest moving toward food, are the most common types of repetitive behaviours in children and have been shown to act as mediators for subsequent weight gain (Albuquerque et al., 2017). In Portugal, a cohort study of 1,175 children examined the relationship between UPFs intake at 4 and 7 years of age with appetitive traits at 7 years and BMI at 10 years of age. Findings showed that between the ages of 4 and 7 years, ultra-processed consumption showed a fair degree of stability. This corresponded to 27.3% and 29.3% of total energy intake, respectively. At 4 years old, consumption of ultra-processed foods was linked to BMI at 10 years old; however, appetitive behaviors did not significantly moderate this relationship (Vedovato et al., 2021). Unexpectedly, a later food-avoidant eating profile with high levels of fussiness and satiety responsiveness was linked to increased early-life intake of UPFs. Insufficient food intake and lower energy intake are generally associated with food avoidant behaviors (Brown et al., 2016). This did not imply that kids had eaten less foods high in energy. In this sample, preliminary data indicated that the consumption of UPFs was positively correlated with food fussiness and negatively correlated with the intake of fruits and vegetables (Vedovato et al., 2021). The observed correlation might be the consequence of UPFs consumption leading to adaptations in food reward systems (Small & DiFeliceantonio, 2019). The higher sugar and fat content of these products, along with their unusual combinations, appeared to affect the integrity of gut-brain signaling regarding food choices. Essentially, higher dosages of UPFs lead to an increase in food reinforcement (Small & DiFeliceantonio, 2019).

As far as choosing food is concerned, what someone likes, and someone wants are two different things. Research has shown that although one may want to consume more UPFs this doesn’t necessarily mean that he is enjoying them to the same extent while consuming them. When someone is unfed and shown pictures of UPFs, a strong appetitive drive is generated (David et al., 2018). Additionally, bigger motivational reactivity is manifested when compared to minimally processed foods or processed foods (Delgado Rodríguez et al., 2023), as well as approach motivation and consumption intent than minimally processed foods (Lemos et al., 2022). While and after eating UPFs, initial studies show that they are significantly less possible to lead to satiety than minimally processed foods (Fardet et al., 2017). Minimally processed foods and processed foods are less energy-dense than UPFs, as they consist of hyperpalatable combinations of carbohydrates, fats and salt that are rarely found in nature (Dicken et al., 2024). This can lead to passing over the mechanisms that provide feeding homeostasis, changing the relationship between taste and nutrients and making it easier to eat rapidly (Fazzino et al., 2023).

There have been proposed several mechanisms that could address the link between UPF consumption and the likelihood of causing obesity and reaching an excess body weight by modern studies. It is well known that UPFs contain a large amount of refined carbohydrates, which can result in changing the levels of insulin, increasing its impact on nutrients and augmenting storage in adipose tissue (Hall, 2017). Researchers suggested that one may crave more food, which results in severe consumption of UPFs as they contain high fat or refined carbohydrates that may cause changes in the reward circuit of the brain (Schulte et al., 2015).

2.2.2.2 Cardiometabolic co-morbidities

Several cardiometabolic risk factors have been associated with the consumption of UPFs in adults, but only a few studies have been conducted on children. These risk factors for non-communicable diseases could be dyslipidemia, blood pressure, glucose profile and metabolic syndrome.

A cohort study in Brazil conducted with 345 children aged 3-4 years and 7-8 years found that UPFs consumption during preschool was linked to a higher increase in total cholesterol and LDL cholesterol from preschool to school age. Authors indicated that early consumption of UPFs altered lipoprotein profiles in children from a low-income Brazilian community (Rauber et al., 2015). Another longitudinal study of a randomized field trial of 308 children at 3 and 6 years in Brazil investigated UPFs consumption and its effect on blood lipids at 6 years with blood tests that were performed to measure lipid profile. During the follow-up period, the contribution of UPF to total energy intake increased by 10%, from 43.4% at 3 years to 47.7% at 6 years of age. When compared to children in the lowest tertile, children in the highest tertile of UPF consumption at age 3 years had higher levels of total cholesterol (β 0.22 mmol/l; 95% CI: 0.04, 0.39) and TAG at age 6 years (β 0.11 mmol/l, 95% CI: 0.01, 0.20). A 10% increase in UPF resulted in a positive dose-response relationship with TC (β 0.07 mmol/l, 95% CI: 0.00, 0.14) and TAG (β 0.04 mmol/l, 95% CI: 0.01, 0.07). According to these results, the intake of UPF was significantly increased over time and was correlated with higher blood lipid levels in participants from low-income families (Leffa et al., 2020). According to a French cohort study, a 10% increase in UPF consumption was linked to a 12% rise in adult CVD rates (Fiolet et al., 2018). Zhang et al. (2022) in NHANES conducted on 5,565 adolescents, investigated the association between the seven cardiovascular health (CVH) metrics developed by the American Heart Association and the typical percentage of energy from UPF. The authors found that 12.1% of individuals had low CVH, 56.3% moderate, and 31.6% high. The average usual % of energy from UPF was 65.7%. Moreover, there was a 0.13-point reduction in CVH scores ($p < .001$) for every 5% increase in calories from UPF (Zhang et al., 2022). On the other hand, a cohort study of participants aged 11.3 ± 1.3 years and 15.1 ± 1.4 years in 2008–2009 and 2012–2013, respectively, showed that there was no direct relationship between UPFs consumption and dyslipidemia in adolescents (Gadelha et al., 2019).

Blood pressure is another cardiometabolic risk factor. According to Bawaked et al. (2020) a cross-sectional study of 1,480 children investigated the relationship between five lifestyle behaviours (physical activity, sleep time, television time, plant-based foods and intake of ultra-processed foods) on blood pressure at age 7 years. Findings showed that higher consumption of UPFs at 4 years was associated with higher DBP z-scores at 7 years. It was also found that there were no significant associations between the overall lifestyle behaviours and blood pressure at 7 years, but there was a single lifestyle factor that was linked to blood pressure. They found inverse associations between sleep time and SBP z-scores but not DBP (Bawaked et al., 2020). On the other hand, some cross-sectional studies indicated no association between UPFs consumption and blood pressure in children and adolescents. Oliveira et al. (2020) in a cross-sectional study with 164 children aged 7–10 years, examined the relationship between UPF consumption and blood pressure. The findings of the study determined that the caloric contribution of unprocessed or minimally processed was inversely related to diastolic blood pressure, indicating that a 10% increase in energy intake from minimally processed foods resulted in a 0.96 mmHg reduction in diastolic blood pressure (β: -0.10; 95% CI: -0.19 to -0.01; $r^2 = 0.20$). However, there was no association between UPF consumption and systolic blood pressure. The absence of an association in the current study is most likely due to the children's age, as they might not have consumed these types of foods for long enough to cause changes in their metabolism and/or cardiovascular system that may appear later in life. It should be mentioned that the cause of hypertension is multifactorial, including genetics, physical inactivity, family lifestyle and psychological factors (Oliveira et al., 2020). Moreover, a cross-sectional study conducted on 249 Brazilian adolescents aged 16 years old was designed to examine the intake of minimally processed, processed and UPFs and assess whether it was linked with excess weight, large waist circumference, and high blood pressure. It was found that there was an inverse relationship between minimally processed foods and excess weight. Despite the lack of correlation between UPFs intake and high blood pressure, excess weight, or a larger waist circumference, 46.2% of the sample reported they consumed them more than once per week.

A diet high in unprocessed or minimally processed foods promotes cardiometabolic health (Damasceno et al., 2011). The nutritional composition of the final product is one factor in food processing that could contribute to this association. Unprocessed or minimally processed foods have a low energy and sodium density while being high in fiber and protein, in contrast to UPFs. According to a study of adolescents, increasing fiber consumption to daily recommendations was linked with expected reductions in diastolic blood pressure of 5.2 and 3.0 mmHg in boys and girls, respectively (Dong et al., 2019). Few studies have investigated the effects of certain types of UPFs on the health of children and adolescents. One serving of sugar-sweetened beverages per day was found to increase systolic blood pressure by 0.8 mmHg (95% CI: 0.4-1.2) and diastolic blood pressure by 0.3 mmHg (95% CI: 0.0-0.5) (de Boer et al., 2018). Another study among Spanish children aged 5–16 years indicated that diastolic hypertension was related to increased consumption of salty foods, including pizza, chips, and sausages (Oliveira et al., 2020).

Furthermore, high consumption of UPFs was associated with the prevalence of MetS in 210 adolescents aged 12–19 years, according to a cross-sectional study (Tavares et al., 2012). On the other hand, Costa et al. (2019) through a longitudinal study of preschool age 4 years old and schoolage children aged 8 years old found that while there was an association between UPFs and abdominal obesity, there was no significant association between the consumption of these products and glucose profile. This finding could be attributed to the young age of participants. Perhaps they have not been consuming these unhealthy foods for sufficient time to trigger negative effects on their glucose metabolism (Costa et al., 2019).

2.3 Conclusion

There are various methods for categorizing foods based on processing, as documented in several studies. The NOVA classification is the most widely used system, but its effectiveness is not definitively established. Studies have shown that UPF consumption not only varies by country but also tends to decrease with age. On average, children consume the most UPFs. Furthermore, taking into consideration the possible implication of UPF and their nutritional patterns in altering risk factors associated with long-term diseases and mortality, many scientists and public health experts have been highly interested in this area. Research on diet and nutrition in the past has shown that the more food processed, the less healthy outcomes could achieved, notably when it came to UPFs intake. Moreover, a recent study has shown that a diet including UPF can have at least one deleterious effect on somebody's health (Elizabeth et al., 2020). However,, it should pointed out that there had been a great dispute in updating guidelines and public policies when nutrient and processing-based dietary advice was concerned due to the fact that UPFs have several components and lack strong proof (Koios et al., 2022). In addition, one should consider that so far, there has been little research on children and adolescents, as most research has been focused and carried out on adults, to find whether there is an impact on UPF intake and health problems (Lane et al., 2021). Consequently, it is essential that to date, scientific proof in this field is identified, gathered, and summed up in a systematic and understandable way (Wang et al., 2024).

However, the current public dietary guidelines offer a crucial foundation for disease prevention and health improvement. This will not be replaced by the holistic approach to food processing. As frameworks for incorporating NOVA into national dietary guidelines have been published, evidence regarding UPF should instead supplement and broaden the current understanding of diet and obesity. Nowadays, a number of countries include UPF in their dietary guidelines (Ministry of Health of Brazil, 2015; Santé Publique France, 2023), as do WHO (World Health Organization, 2016) and PAHO (Pan American Health Organization, 2019) for health and overweight/obesity. Nonetheless, there is ongoing scientific disagreement regarding the usefulness of incorporating UPF into dietary recommendations (Astrup et al., 2022) such as the UK Scientific Advisory Committee on Nutrition (GOV.UK., 2023) and British Nutrition Foundation (British Nutrition Foundation, 2024). This indicates that the level of food processing that children consume should to be given more attention. The following are the main sources of inspiration for the suggestion of nutritional education initiatives based on the Ten Steps for a Healthy Diet (2014) and the Food Guide for the Brazilian Population (2014), as Fonseca et al. (2023) mentioned:

1. Promote the consumption of natural or minimally processed foods in your diet.
2. Suggest avoiding the consumption of highly processed foods.
3. Give further guidance in the context of healthy eating.

Prevention of chronic diseases should begin at birth, as they are often the result of years of poor diet, particularly with a high intake of UPFs (Fonseca et al., 2023).

2.4 Systematic review in ultra-processed foods

In conclusion, unhealthy dietary habits, as well as their main consequences such as obesity and cardiometabolic co-morbidities, followed in childhood and adolescence, tend to track into adulthood. Furthermore, investigating the impact of the modern industrial food system and food processing on human health is very important, too. The rising rates of childhood obesity and cardiometabolic co-morbidities, the widespread use of UPFs among children and adolescents, and the scarcity of systematic reviews on the subject prompted us to conduct the current systematic literature review, which aims to collect all existing knowledge about the relationship between UPF consumption and obesity and cardiometabolic risk factors among children and adolescents. The entire article is presented below and the published manuscript (Petridi et al., 2023) is in Appendix 1.

Title page

Title: The impact of ultra-processed foods on obesity and cardiometabolic co-morbidities in children and adolescents: A systematic review

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Abstract

Context: Over the past few decades, traditional foods have been displaced by ultra-processed foods (UPFs), with the latter being associated with health problems.

Objective: This scoping systematic review aimed to identify the relationship between UPFs intake and overweight/obesity as well as other cardiometabolic risk factors during childhood and adolescence.

Data Sources: The guidance for this protocol is the Preferred Reporting Items for Systematic Review (PRISMA-P). A systematic search was undertaken on PubMed, Scopus and Cochrane Library electronic databases based on prespecified inclusion and exclusion criteria up to 6 February 2022.

Data Extraction: A total of seventeen observational studies; 9 cross-sectional, 7 cohort-longitudinal and one study reporting both cross-sectional and longitudinal outcomes, among children and adolescents aged ≤18 years were eligible for inclusion in this review. Fourteen studies evaluated the consumption of UPFs in association with overweight/obesity and nine studies examined the association of UPFs consumption and cardiometabolic related risk factors.

Data Analysis: Most studies (14/17) showed that an increase in UPFs was associated with a higher prevalence of overweight/obesity and cardiometabolic co-morbidities among children and adolescents, while 4/17 (3 cross-sectional and 1 cohort) studies found none. Most cohort & cross-sectional studies had a good quality according to NIH and to NewCastle-Ottawa quality assessment, respectively.

Conclusions: The positive association between UPFs and overweight/obesity and cardiometabolic co-morbidities among children and adolescents found, raise concerns for future health. Further investigation is recommended to explore the role of specific types of UPFs on cardiometabolic conditions and to identify the amount of daily intake that increase risk, in order to shape appropriate public health policies.

Keywords: ultra-processed foods, childhood obesity, cardiometabolic risk, adolescence

Introduction

The prevalence of childhood and adolescent obesity has increased over the last three decades (NCD Risk Factor Collaboration, 2017) and dietary patterns, one of the most important modifiable lifestyle factors have transitioned from traditional to Western (Branca et al., 2019). This transition has been linked with childhood obesity and its related cardiometabolic disorders, including dyslipidemia, diabetes and hypertension. The causes of this transition are multifactorial with sociocultural changes, industrialization, and globalization of food production being among the most dominant factors (Popkin et al., 2012).

The quality of the dietary pattern individuals follow is determined not only by its content in specific nutrients or food items but also by other important factors such as its content in processed foods (Monteiro et al., 2018; Hall et al., 2019). Evidence suggests that modern diets are characterized by a high consumption of many foods which have undergone some degree of processing. The NOVA system, a food classification based on the nature, extent and purpose of industrial food processing (Monteiro et al., 2018), is a system designed to divide foods into four groups: unprocessed or minimally processed foods; processed culinary ingredients; processed foods; and ultra-processed foods (UPFs). UPFs are manufactured using several ingredients, they contain little or no whole food, follow a series of processes and they are combined with a sophisticated use of additives, to increase their shelf-life and their palatability. They are ready-to-consume or ready-to-heat and thus require little or no culinary preparation, which makes them easily accessible and convenient (Moubarac et al., 2017; Rauber et al., 2018). Therefore, investigation of the impact of modern industrial food systems and consequently food processing on human health is very important.

Over the last few decades, in several countries, traditional foods and freshly prepared dishes and meals have been displaced by UPFs, and therefore modern diets are characterized by high energy-density, sugar, sodium, saturated fats and trans-fats and low fiber and micronutrient content which is evidenced in children, adolescents and adults (Moubarac et al., 2017; Cediel et al., 2021). Many studies have found a direct association between consumption of UPFs and health problems. A systematic review conducted in adults showed that in most studies, there was a positive association between UPFs' consumption and cardiometabolic risk factors such as excess body weight, hypertension, increased total cholesterol and low-density lipoprotein-cholesterol (LDL-C), and metabolic syndrome (Silva Meneguelli et al., 2020); associations that lead to higher mortality in the general population (Blanco-Rojo et al., 2019). With regards to children there are currently only a few studies investigating the role of UPFs on body weight and cardiometabolic risk factors. A cross-sectional study conducted in 386 children aged 4-6 years highlighted the association of UPFs consumption with poor diet quality, since high energy intake from UPFs was inversely associated with adherence to the Mediterranean diet among preschoolers (da Rocha et al., 2021). In a systematic review regarding solely the role of UPFs on body fat accumulation in children and adolescents, the authors concluded that the majority of studies showed a positive association, however children's body weight was not accounted for (Costa et al., 2018). Furthermore, results remain controversial with respect to UPF intake and cardiometabolic conditions, with the majority showing unfavorable associations (Leffa et al., 2020; Tavares et al., 2012) and others showing null effects adolescents

It is crucial to also understand the association between UPF consumption with obesity and cardiometabolic co-morbidities in children and adolescents, since many studies indicate in adults have shown a positive effect. The existing knowledge about UPFs and childhood obesity has been summed up in a systematic review by Costa et al. (2018) studying children's body fat, where a positive association was found (Costa et al., 2018), while another systematic review reported conflicted data between UPFs consumption and obesity and adiposity parameters among children and adolescents (De Amicis et al., 2022). To the best of our knowledge no review has been published on the association of UPFs and cardiometabolic co-morbidities in children and adolescents.

The increasing rates of childhood obesity and cardiometabolic co-morbidities, the high consumption of UPFs worldwide among children and adolescents and the lack of systematic reviews on this issue, led us to conduct the present scoping systematic review aiming to gather all existing knowledge regarding the association between the consumption of UPFs with obesity and cardiometabolic risk factors among children and adolescents.

Methods

This systematic review of observational studies, as defined in the Cochrane Handbook and based on Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) is 'an overview that attempts to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question' (Higgins et al., 2021). The research question is "what is the relationship between UPFs consumption and childhood obesity and its cardiometabolic co-morbidities". To summarize and communicate results, providing reliable findings to draw new conclusions accurate systematic methods were used (Higgins et al., 2021) and the PRISMA checklist supported the effort to design this systematic review (Page et al., 2021). This review has been registered with PROSPERO (Reg. number: CRD42022316432) and the protocol is shown in Supporting information.

Eligibility criteria

Inclusion criteria were: (1) population consisting of children and adolescents aged 2-18 years, (2) cross-sectional and longitudinal study design, (3) consideration of UPFs as classified with NOVA classification system (Food and Agriculture Organization of the United Nations, 2015; Monteiro et al., 2019; Pan American Health Organization, 2015), (4) English language and (5) anthropometric indices for overweight/obesity or one or more cardiometabolic co-morbidities included in the outcome i.e. blood pressure, dyslipidemia, diabetes, and metabolic syndrome. See PICOS criteria for inclusion and exclusion of studies (Table 2.4.1).

Exclusion criteria were: (1) groups with health problems like cancer, hepatic disease, renal disease etc. and (2) ecological, case-control and intervention studies, as well as animal studies. Interviews, commentaries, case-series, letters to the editor, editorials, reviews and meta-analyses were also excluded (Table 2.4.1).

Information sources and search strategy

For the literature search three scientific databases were used: PubMed, Scopus and Cochrane Library. The results from each database were then exported to the RefWorks program to be further evaluated. The keywords used in BOOLEAN operators were: ("ultra-processed foods" OR "ultraprocessed foods" AND child* OR adolescen*). Also, keywords like BMI, obesity, overweight, cardiometabolic risk factors like blood pressure, dyslipidemia, diabetes, and metabolic syndrome, were used to the aforementioned search strategy, to confirm that no articles were left out. Furthermore, the reference list of the retrieved publications and the “similar or related articles” for each article in every database were checked for additional related studies, systematic reviews and meta-analysis. All studies which have been published until 6 February 2022 were utilized for the systematic review.

Selection of studies and data extraction

The eligibility for this systematic review was identified by two independent reviewers, “Evgenia Petridi” MSc (“EP”) and “KK”, who screened the studies by title and abstract. The full articles were selected for retrieval after excluding studies considered as ineligible. Disagreement between the two reviewers was discussed and resolved by consensus. Where there was disagreement which was not solved by consensus a third reviewer “EM” was consulted. The process of included and excluded articles was performed according to the PRISMA flow diagram (Figure 2.4.1) (Page et al., 2021). The extracted data included information for author’s name, year of publication, title, country of origin, study design, sample size, participants, period of study, dietary assessment, outcome assessed, results regarding obesity and results regarding other co-morbidities.

Risk of bias

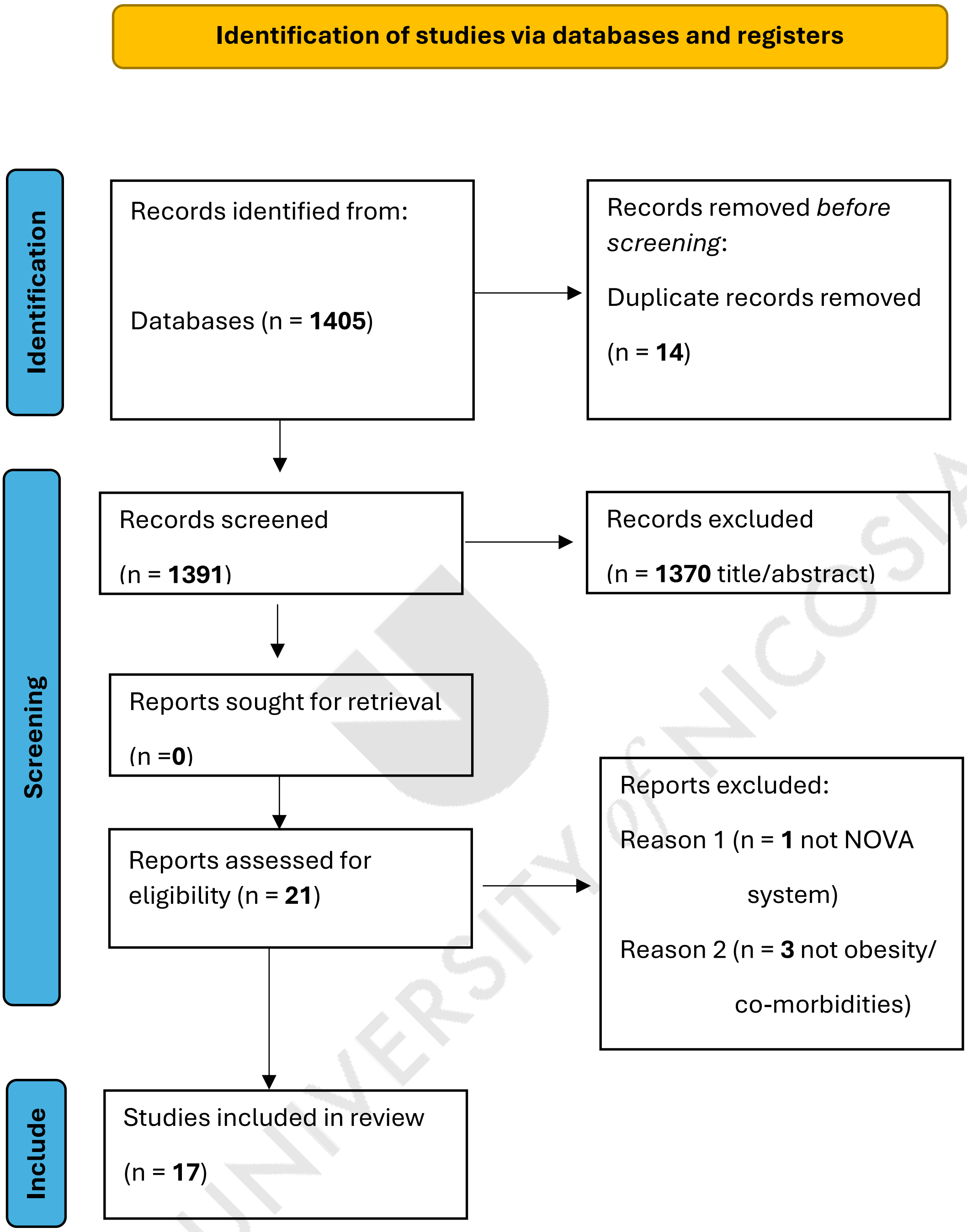
Risk of bias for the full text of studies included was assessed independently using the NIH Quality Assessment Tool for cohort studies (NHI National Heart, Lung, and Blood Institute, 2020) and the NewCastle-Ottawa (Wells et al., 2011) adapted for cross-sectional studies (Modesti et al., 2016). The NIH Quality Assessment Tool includes 14 parameters; one about the aim of the study; 4 parameters about the population; 4 parameters are referring to the exposure measures; 2 parameters refer to the outcome measures; 2 parameters are about blinding of outcomes and follow-ups and finally one more refers to statistical analysis. The options for the answers are “yes’’, “no”, “cannot determine”, “not applicable” and “not reported”. This quality assessment tool has a poor, fair and good quality level (NHI National Heart, Lung, and Blood Institute, 2020). The NewCastle-Ottawa (adapted for cross-sectional studies) includes 3 parameters; one about selection with 4 sub-parameters; one refers to comparability and finally one parameter refer to outcome with 2 sub-parameters. This quality assessment has 3 domains and a scale from 1 to10 stars; the first domain has a maximum of 5 stars, the second of 2 stars and the last one maximum of 3 stars studies (Modesti et al., 2016). Any disagreement was discussed and resolved by consensus.

Table 2.4.1 Definition of PICOS and inclusion of studies.

Parameter	**Inclusion Criteria**
Participants	Individuals 2-18 years
Interventions	None
Comparisons based on exposure level	Level/amount of UPF intake
Outcomes	Overweight/Obesity • BMI • Waist circumference • Body fat percentage Cardiometabolic factors • Blood pressure • Dyslipidemia • Diabetes • Metabolic syndrome
Study Design	Prospective cohort studies, cross-sectional studies
Exclusion Criteria: Individuals with health problems like cancer, hepatic disease, renal disease, Individuals >18 years, UPF intake not evaluated not clearly defined/measured, ecological studies, case-control studies, intervention studies, animal studies, interviews, commentaries, case-series, letters to the editor, editorials, reviews and meta-analysis	

BMI, body mass index, UPF, ultra processed food

Figure 2.4.1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 flow diagram.



Results

Study selection

As shown in Figure 2.4.1, overall, 1405 studies were identified through database searching of which 14 were excluded as duplicates. Following that, 1391 studies were screened for eligibility according to title and abstract, and reference lists and related articles were also thoroughly screened and retrieved no additional studies. Of these, 21 articles were scanned based on full-text, one (n=1) was excluded based on food classification not conducted according to the NOVA system and three (n=3) articles because they did not provide outcomes regarding overweight/obesity or cardiometabolic co-morbidities. A total of 17 articles were included in the present systematic review.

Study characteristics

The study characteristics are shown in Table 2.4.2. All studies included children of both genders. Twelve of the studies were conducted in Brazil (Leffa et al., 2020; Tavares et al., 2012; Melo et al., 2017; Neves et al., 2022; Costa et al., 2021; Costa et al., 2019; Oliveira et al., 2020; Louzada et al., 2015; Rauber et al., 2015; Viola et al., 2020; Cunha et al., 2018; Enes et al., 2019), 2 studies were conducted in USA (Zhang et al., 2022; Neri et al., 2022), 1 study in Spain (Bawaked et al., 2020), 1 in England (Chang et al., 2021) and 1 in Portugal (Vedovato et al., 2021). Furthermore, the design of nine studies was cross-sectional (Tavares et al., 2012; Melo et al., 2017; Neves et al., 2022; Oliveira et al., 2020; Louzada et al., 2015; Viola et al., 2020; Enes et al., 2019; Zhang et al., 2022; Neri et al., 2022), seven were longitudinal (Leffa et al., 2020; Costa et al., 2021; Costa et al., 2019; Rauber et al., 2015; Cunha et al., 2018; Chang et al., 2021; Vedovato et al., 2021) and one study was reported on both cross-sectional and longitudinal outcomes (Bawaked et al., 2020). Regarding the range of participants' age, seven studies examined children younger than 12 years old (Leffa et al., 2020; Costa et al., 2021; Costa et al., 2019; Oliveira et al., 2020; Rauber et al., 2015; Bawaked et al., 2020; Vedovato et al., 2021), from which 4 examined preschoolers (Leffa et al., 2020; Costaet al., 2019; Rauberet al., 2015; Bawaked et al., 2020), seven studies included participants 12 to 18 years (Tavares et al., 2012; Melo et al., 2017; Neves et al., 2022; Viola et al., 2020; Cunha et al., 2018; Zhang et al., 2022; Neri et al., 2022), and in three studies individuals were 7 to 24 years old (Louzada et al., 2015; Enes et al., 2019; Chang et al., 2021). Regarding the study sample, half the studies (n=8) included <1000 participants (Leffa et al., 2020; Tavares et al., 2012; Melo et al., 2017; Neves et al., 2022; Costa et al., 2019;

Oliveira et al., 2020; Rauber et al., 2015; Enes et al., 2019), while the other nine studies had >1000 children and/or adolescents (Costa et al., 2021; Louzada et al., 2015; Viola et al., 2020; Cunha et al., 2018; Zhang et al., 2022; Neri et al., 2022; Bawaked et al., 2020; Chang et al., 2021; Vedovato et al., 2021).

Main exposures and outcomes

Across the seventeen included studies, children's overweight/obesity and other risk factors for cardiometabolic co-morbidities were examined. Nutritional assessment was conducted with food frequency questionnaires, 24h recalls (with 1, 2 or 3 days) or food diaries. Evaluation of UPFs consumption was done by considering their contribution as percentage of total energy intake (%TEI), grams per day (g/day), number of weekly servings and grams of macronutrients of UPFs (g/day). Risk of overweight/obesity was assessed through anthropometric indices such as weight, height, body mass index (BMI), waist circumference (WC), Waist-to-Height Ratio (WHtR), Waist-to-Hip Ratio (WHR), sagittal abdominal diameter (SAD) and tricipital and subscapular skinfold thickness, and, through body composition indices such as fat mass, lean mass, fat mass index (FMI), lean mass index (LMI), percentage of body fat (%BF), fat free mass. The indices that were used for the assessment of cardiometabolic co-morbidities were: total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), non-high-density lipoprotein (nHDL), triglycerides (TG), blood pressure (BP), systolic blood pressure (SBP), diastolic blood pressure (DBP), serum glucose (Glu), insulin (Ins) and homeostatic model assessment for insulin resistance (HOMA-IR).

Overweight/Obesity

Thirteen of the identified studies examined the association of UPFs consumption with the risk of overweight/obesity (Melo et al., 2017; Neves et al., 2022; Costa et al., 2021; Costa et al., 2019; Oliveira et al., 2020; Louzada et al., 2015; Viola et al., 2020; Cunha et al., 2018; Enes et al., 2019; Neri et al., 2022; Bawaked et al., 2020; Chang et al., 2021; Vedovato et al., 2021).

Seven of these studies indicated that higher consumption of UPFs consumption is associated with an increase in risk of overweight/obesity using BMI as a predictor (Neves et al., 2022; Louzada et al., 2015; Viola et al., 2020; Neri et al., 2022; Bawaked et al., 2020; Chang et al., 2021; Vedovato et al., 2021). More specifically, one study showed that higher consumption of UPFs at breakfast or dinner was associated with a higher BMI-for-age z-score β = 0.23 (95% CI: 0.01, 0.46) and β = 0.27 (95% CI: 0.02, 0.54), respectively (Neves et al., 2022). Similarly, Louzada et al. (2015) showed that participants of the highest vs lowest quantile of consumption of UPFs had a significantly higher BMI 0.94kg/m^2 (95% CI: 0.42,1.47), odds of being obese (OR=1.98; 95% CI: 1.26, 3.12) and odds of excess weight (OR=1.26; 95% CI: 0.95, 1.69) (Louzada, M. L. et al., 2015). Also, a cohort study showed that increasing consumption of UPFs was associated with higher BMI by an additional 0.06 kg/m^2 (95% CI, 0.04, -0.08) per year (Chang et al., 2021). Vedovato et al. (2021) indicated that a higher consumption of UPFs at 4 years was associated with a higher BMI z-score at 10 years (β= 0.028; 95% CI: 0.006, 0.051) (Vedovato et al., 2021).

Three studies examined the relationship of UPFs and indicators of central adiposity (WC, SAD) (Costa et al., 2019; Neri et al., 2022; Chang et al., 2021). Costa et al. (2019) showed that higher UPFs consumption by preschoolers were associated with increasing WC from preschool to school age (β = 0.07; 95% CI 0.01, -0.14) (Costa et al., 2019). Another longitudinal study also indicated that UPFs consumption was positively associated with WC and with an increased risk of high WC by an additional 0.17cm (95% CI: 0.11, -0.22) per year (Chang et al., 2021). Finally, Neri et al. (2022) in a cross-sectional analysis of the NHANES 2011–2016, concluded that higher consumption of UPFs was associated with 52%, and 63% higher odds of abdominal, and visceral overweight/obesity respectively, compared to lower consumption (Neri et al., 2022). It was also indicated that a 10% increase in UPFs consumption, increases the risk of both abdominal overweight/obesity (OR = 1.07; 95% CI: 1.01, 1.13) and visceral overweight/obesity (OR = 1.07; 95% CI: 1.02, 1.13).

The association of UPFs consumption and the risk of overweight/obesity using indicators of body composition was also studied. Among four relevant studies (Neves et al., 2022; Costa et al., 2021; Viola et al., 2020; Chang et al., 2021), one showed an increase in %BF by 1.21% (95% CI: 0.23, 2.64), in adolescents who consumed more UPFs at breakfast (Neves et al., 2022). Viola et al. (2020) indicated that an increase of 1% of total dietary energy intake of UPFs was associated with a 0.04kg decrease in muscle mass (β= -0.04; 95% CI: -0.06, -0.02) and a 0.01kg decrease in lean body mass (β= -0.01; 95% CI: -0.02, -0.01) (Viola et al., 2020). Furthermore, FMI was found to increase by an additional 0.03 kg/m^2 (95% CI: 0.01, 0.05) per year in the highest quintiles of UPFs consumption compared to the lowest (Chang et al., 2021). Similarly, Costa et al. (2021) indicated that an increase in daily UPFs consumption by 100g was associated with a gain of 0.14 kg/m^2 in FMI from 6 to 11 years (Costa et al., 2021).

On the other hand, even if the majority of studies showed a positive association between UPFs and overweight/obesity, three studies had opposite results. In these studies which examined BMI and WC as predictors of overweight/obesity and abdominal obesity, no association between UPFs consumption and prevalence of overweight/obesity or abdominal obesity was seen (Melo et al., 2017; Oliveira et al., 2020; Enes et al., 2019). Contrary to all previous studies, Cunha et al. (2018) in a longitudinal analysis reported that consumption of UPFs was inversely associated with BMI and percentage of body fat, in 1037 adolescents 15-17 years old (Cunha et al., 2018).

Cardiometabolic co-morbidities

Most of the studies included in the present systematic review apart from overweight/obesity, also looked at other cardiometabolic co-morbidities associated with UPFs consumption, such as dyslipidemia, blood pressure (BP), glucose (Glu) and metabolic syndrome (MetS). Three studies examined the relationship between UPFs consumption and dyslipidemia and indicated that an increase in UPFs is associated with an increase in total cholesterol (TC), LDL-cholesterol and triglycerides (TG) dyslipidemia (Leffa et al., 2020; Rauber et al., 2015; Zhang et al., 2022). Three studies examined the possible association of UPFs consumption with blood pressure in children and adolescents (Melo et al., 2017; Oliveira et al., 2020; Bawaked et al., 2020). In two of these studies, it was reported that higher consumption of UPFs had greater impact in blood pressure levels (Bawaked et al., 2020; Oliveira et al., 2020), while Melo et al. (2017) showed no such association. Costa et al. (2019) showed that UPFs had no impact on the glucose profile of children aged 4-8 years old (Costa et al., 2019). However, Tavares et al. (2012) investigated the relationship between UPFs and metabolic syndrome and indicated that an increase in UPFs is associated with a higher prevalence of MetS in adolescents (Tavares et al., 2012).

Risk of bias

The evaluation of the risk of bias by NIH Quality Assessment Tool for cohort studies (NHI National Heart, Lung, and Blood Institute, 2020) as shown in Table 2.4.3, showed that no study was of poor quality, three studies were categorized as being of fair quality (Cunha et al., 2018; Bawaked et al., 2020; Chang et al., 2021) and five as good quality (Leffa et al., 2020; Costa et al., 2021; Costa et al., 2019; Rauber et al., 2015; Vedovato et al., 2021). Considering the cross-sectional studies, the evaluation of the risk of bias using the NewCastle-Ottawa quality assessment scale (Wells et al., 2011) adapted for cross-sectional studies (Modesti et al., 2016) showed that one study had 5/10 stars (Melo et al., 2017), three studies had 6/10 stars (Tavares et al., 2012; Viola et al., 2020; Enes et al., 2019), one study had 7/10 stars (Louzada et al., 2015); four studies had 8/10 stars (Neves et al., 2022; Oliveira et al., 2020; Neri, D. et al., 2022; Bawaked et al., 2020) and one study had 9/10 stars quality (Zhang et al., 2022) (Table 2.4.4). Since the study of Bawaked et al. (2020) included both a cohort and a cross-sectional design, the total number of assessments were eighteen rather than seventeen (Bawaked et al., 2020).

Table 2.4.2 Characteristics and findings of the included studies investigating the association between consumption of UPFs and overweight/obesity and cardiometabolic co-morbidities in children and adolescents.

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
Bawaked et al. 2020	Spain	Cross-sectional, Longitudinal	1480	1st phase: 4y 2nd phase: 7y	1st phase 2003 2nd phase 2008	Semi-quantitative FFQ	BMI, BP, Lipid profile	↑ UPFs at 4 years were associated with higher BMI z-score at 7 years (β = -0.07; 95% CI: -0.18,0.03).	↑ UPFs at 4 years were associated with higher DBP z-scores at 7 years (β = -0.17; 95% CI: -0.31,0.03).
Chang et al. 2021	England	Longitudinal	9025	7-24 y	1998-2017	Food diaries 3 days	BMI, Anthropometric indices, BF%, FMI, LMI	Highest vs lowest quintile of UPFs consumption was associated with: ↑ BMI by an additional 0.06 (95% CI: 0.04,0.08) per year ↑ FMI by an additional 0.03 (95% CI: 0.01,0.05) per year	-

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
								↑ WT by an additional 0.20 (95% CI: 0.11,0.28) per year ↑ WC by an additional 0.17 (95% CI: 0.1,0.22) per year.	
Costa et al. 2019	Brazil	Longitudinal	1st phase 354 2nd phase 315	1st phase: 4y 2nd phase: 8y	2001- 2002	24h-recall 2 days	BMI, Anthropometric indices, Glu	↑ UPFs consumption at preschool age was associated with ↑ delta WC from preschool to school age (β = 0.07; 95% CI: 0.01,0.14).	No significant association between UPFs consumption and glucose profile was observed at age 8 years.
Costa et al. 2021	Brazil	Longitudinal	1st phase 3128 2nd phase 3454	1st phase: 6 y 2nd phase: 11 y	1st phase 2010-2011 2nd phase 2015	Semi-quantitative FFQ	FMI	↑ 100g UPFs daily was associated with a gain of 0.14 kg/m^2 in FMI from 6 to 11 years.	-

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
Cunha et al. 2018	Brazil	Longitudinal	1035	15-17 y	1st phase 2010 2nd phase 2011 3rd phase 2012	Semi-quantitative FFQ	BMI, %BF	↑ UPFs consumption was associated with ↓ BMI (23.1 in 1st quartile vs 21.3 in 4th quartile at baseline) and (24 in 1st quartile vs 22.4 in 4th quartile after 2 years follow-up) ↓ %BF (25.1% in 1st quartile vs 21.9% in 4th quartile at baseline) and (25.9% in 1st quartile vs 22.1% in 4th quartile after 2 years follow-up) both at baseline and at follow-up	-

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
Enes et al. 2019	Brazil	Cross-sectional	200	10-18 y	2016	Semi-quantitative FFQ for adolescents	BMI, Anthropometric indices	No association between UPFs consumption and anthropometric indices.	-
Leffa et al. 2020	Brazil	Longitudinal	308	1st phase: 3y 2nd phase: 6y	1st phase 2011-2012 2nd phase 2014-2015	24h-recall 2 days	BMI, Lipid profile	-	↑ 10% in TDEI of UPFs was associated with: ↑ TC (β 2.76 mg/dL; 95% CI: 0.04,5.44) ↑ TG (β 3.44 mg/dL; 95% CI: 0.46,6.42).
Louzada et al. 2015	Brazil	Cross-sectional	7534	10-19y	2008- 2009	24h-recall 2 days	BMI	Adolescents in the highest quintile of consumption of UPFs had: ↑ higher mean BMI 0.84kg/m^2 (95% CI: -0.16,1.85) ↑odds of being obese	-

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
								(OR=2.74; 95% CI: 0.78,9.60) ↑odds of excess WT (OR=1.52; 95% CI: 0.75,3.07).	
Melo et al. 2017	Brazil	Cross-sectional	249	14-19 y	-	Semi-quantitative FFQ	BMI, Anthropometric indices, BP	No association between UPFs and excess WT or high WC.	No association between UPFs and high blood pressure.
Neri et al. 2022	USA	Cross-sectional	3587	12-19 y	2011-2016	24h-recall 2 days	BMI, Anthropometric indices	Highest vs lowest consumption of UPFs was associated with 45%, 52%, and 63% higher odds of total-, abdominal-, and visceral overweight/ obesity, respectively (OR 1.45, 95% CI: 1.03,2.06; OR 1.52, 95%	-

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
								CI: 1.06,2.18; OR 1.63, 95% CI: 1.19,2.24) respectively. ↑10% of TDEI of UPFs was associated with ↑ risk of both abdominal overweight/obesity (OR 1.07; 95% CI: 1.01,1.13) and visceral overweight/obesity (OR 1.07; 95% CI: 1.02,1.13).	
Neves et al. 2022	Brazil	Cross-sectional	790	14-19 y	2018-2019	24h-recall 2 days	BMI, Body fat	↑ UPFs at breakfast were associated with: ↑ BMI-for-age (z-score) β = 0.23 (95% CI: 0.01,0.46) and	-

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
								↑ Body fat 1.21% (95% CI: 0.23,2.64) ↑ UPFs at dinner were associated with: ↑ BMI-for-age (z-score) β = 0.27 (95% CI: 0.02,0.54).	
Oliveira et al. 2020	Brazil	Cross-sectional	164	7-10 y	2018-2019	24h-recall 3 days	BMI, Anthropometric indices, BP	No association between the caloric contribution of food groups and BMI, WC, WHtR.	No significant association between UPFs consumption and BP.
Rauber et al. 2015	Brazil	Longitudinal	1st phase 345 2nd phase 307	1st phase: 3-4y 2nd phase: 7-8y	2001-2002	24h-recall 2 days	Lipid profile	-	UPFs consumption was a predictor of a higher increase in TC (β = 0.430; 0.008-0.853) and LDL cholesterol (β =0.369; 0.005-0.733) from

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
									preschool to school age.
Tavares et al. 2012	Brazil	Cross-sectional	210	12-19y	2006- 2007	Semi-quantitative FFQ	Metabolic syndrome	-	↑ UPFs were associated with higher prevalence of MetS (prevalence ratio = 2.5; P = 0.012).
Vedovato et al. 2021	Portugal	Longitudinal	1175	1st phase: 4 y 2nd phase: 7 y 3rd phase: 10y	1st phase 2009-2011 2nd phase 2012-2014 3rd phase 2015-2017	Food diaries 3 days	BMI	UPFs consumption at 4 years old was associated with ↑ BMI z-score at 10 years old (β= 0.028; 95% CI: 0.006,0.051).	-
Viola et al. 2020	Brazil	Cross-sectional	1525	18-19 y	2016	Semi-quantitative FFQ	BMI, LMI, Muscle mass	BMI, muscle mass, and LMI were inversely associated with UPFs consumption. ↑ 1% of TDEI of UPFs was associated with a 0.04 kg	-

Authors	Country	Study Design	Sample Size (n)	Participants' Age (y)	Period of Study	Dietary Assessment	Outcome Assessed	Results for Obesity	Results for cardiometabolic co-morbidities
								decrease in muscle mass (β = -0.04; 95% CI, -0.06 to -0.02) and a 0.01 kg/m^2 decrease in lean body mass (β = -0.01; 95% CI, -0.02 to -0.01).	
Zhang et al. 2022	USA	Cross-sectional	5565	12-19 y	2007-2018	24h-recall 2 days	CVH metrics	-	↑ 5% in UPFs calories was associated with 0.13 points lower CVH scores (p<0.001).

FFQ, food frequency questionnaire; BMI, body mass index; BP, blood pressure; UPFs, ultra-processed foods; DBP, diastolic blood pressure; %BF, body fat percentage; FMI, fat mass index; LMI, lean mass index; WT, weight; WC, waist circumference; Glu, glucose; TDEI, total dietary energy intake; TC, total cholesterol; TG, triglycerides; WHtR, waist to height ratio; MetS, metabolic syndrome; CVH, cardiovascular health; ↑ increase, y, years

* Quality assessment according to NIH Quality Assessment Tool for cohort studies (Poor, Fair, Good)

** Quality assessment according to NewCastle-Ottawa adapted for cross-sectional studies (1 to10 stars)

All reported outcomes used diagnosed or measured values.

Table 2.4.3 Quality assessment for cohort studies (NIH Quality Assessment Tool).

Criteria / Studies	Leffa et al., 2020	Bawaked et al., 2020	Costa et al., 2019	Rauber et al., 2015	Chang et al., 2021	Cunha et al., 2018	Vedovato et al., 2021	Costa et al., 2021
1. Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y	Y	Y	Y	Y
2. Was the study population clearly specified and defined?	Y	Y	Y	Y	Y	Y	Y	Y
3. Was the participation rate of eligible persons at least 50%?	Y	Y	Y	Y	Y	Y	Y	Y
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Y	Y	Y	Y	Y	Y	Y	Y
5. Was a sample size justification, power description, or variance and effect estimates provided?	Y	CD	Y	N	N	N	N	N
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	N	N	N	N	N	N	N	N

Criteria / Studies	Leffa et al., 2020	Bawaked et al., 2020	Costa et al., 2019	Rauber et al., 2015	Chang et al., 2021	Cunha et al., 2018	Vedovato et al., 2021	Costa et al., 2021
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	Y	Y	Y	Y	Y	Y	Y	Y
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	Y	Y	Y	Y	Y	Y	Y	Y
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	N	Y	Y	N	N	N	N
10. Was the exposure(s) assessed more than once over time?	Y	Y	Y	Y	Y	N	Y	Y
11. Were the outcome Measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all	Y	Y	Y	Y	Y	Y	Y	Y

Criteria / Studies	Leffa et al., 2020	Bawaked et al., 2020	Costa et al., 2019	Rauber et al., 2015	Chang et al., 2021	Cunha et al., 2018	Vedovato et al., 2021	Costa et al., 2021
study participants?								
12. Were the outcome Assessors blinded to the exposure status of participants?	Y	N	Y	Y	NA	NA	NA	NA
13. Was loss to follow-up after baseline 20% or less?	NA	N	N	N	N	N	Y	Y
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Y	Y	Y	Y	Y	Y	Y	Y
Score	Good	Fair	Good	Good	Fair	Fair	Good	Good

Y, yes; N, no; CD, cannot determine; NA, not applicable.

Table 2.4.4 Quality assessment for cross-sectional studies (NewCastle-Ottawa).

Criteria / Studies	Neves et al., 2022	Bawaked et al., 2020	Oliveira et al., 2020	Louzada et al., 2015	Melo et al., 2017	Tavares et al., 2012	Viola et al., 2020	Enes et al., 2019	Zhang et al., 2021	Neri et al., 2022
Selection										
1.Representativeness of the sample: a) Truly representative of the average in the target population. * (all subjects or random sampling) b) Somewhat representative of the average in the target population. * (non random sampling) c) Selected group of users. d) No description of the sampling strategy.	*	*	*	*	-	-	-	-	*	*
2. Sample size: a) Justified and satisfactory. * b) Not justified.	*	*	*	-	-	-	-	-	*	*
3. Non-respondents: a) Comparability between respondents and non-respondents characteristics is established, and the response rate is satisfactory. *	*								*	

Criteria / Studies	Neves et al., 2022	Bawaked et al., 2020	Oliveira et al., 2020	Louzada et al., 2015	Melo et al., 2017	Tavares et al., 2012	Viola et al., 2020	Enes et al., 2019	Zhang et al., 2021	Neri et al., 2022
b) The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory. c) No description of the response rate or the characteristics of the responders and the non-responders.		-	-	-	-	-	-	-		-
4. Ascertainment of the expo sure (risk factor): a) Validated measurement tool.** b) Non-validated measurement tool, but the tool is available or described. * c) No description of the measurement tool.	*	*	*	*	*	*	*	*	*	*
Comparability										
1. The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled. a) The study controls for the most important factor (select one). *	*	*	*	*	*	*	*	*	*	*

Criteria / Studies	Neves et al., 2022	Bawaked et al., 2020	Oliveira et al., 2020	Louzada et al., 2015	Melo et al., 2017	Tavares et al., 2012	Viola et al., 2020	Enes et al., 2019	Zhang et al., 2021	Neri et al., 2022
b) The study control for any additional factor. *		*	*	*	*	*	*	*	*	*
Outcome										
1. Assessment of the Outcome: a) Independent blind assessment. ** b) Record linkage.** c) Self report. * d) No description.	**	**	**	**	**	**	**	**	**	**
2. Statistical test: a) The statistical test used to analyze the data is clearly described and appropriate, and the measurement of the association is presented, including confidence intervals and the probability level (p value). * b) The statistical test is not appropriate, not described or incomplete.	*	*	*	*	-	*	*	*	*	*
Score	8/10	8/10	8/10	7/10	5/10	6/10	6/10	6/10	9/10	8/10

Discussion

The consumption of UPFs has increased during the last decade across all age groups. Although there are many studies examining the association of UPFs consumption and obesity or cardiometabolic risk factors among adults, only a few have investigated this association in children and adolescents, a group characterized by an alarming continuous increase in the prevalence of overweight/obesity and several cardiometabolic risk factors. Taking this into account, the present systematic review highlighted the role of UPFs' consumption on childhood overweight/obesity and to the best of our knowledge is the first that investigated the impact of UPFs' consumption on cardiometabolic risk factors in these ages. It was shown that in the majority of the included studies, there was a positive association of UPFs consumption with childhood overweight/obesity. Also, UPFs were associated with cardiometabolic co-morbidities such as dyslipidemia, blood pressure, diabetes and MetS among children and adolescents.

Findings from cross-sectional and longitudinal studies included in this review reported that consumption of UPFs were associated with overweight/obesity among children and adolescents (Neves et al., 2022; Costa et al., 2021; Costa et al., 2019; Louzada, et al., 2015; Viola et al., 2020; Neri. et al., 2022; Bawaked et al., 2020; Chang et al., 2021; Vedovato et al., 2021). Costa et al. (2018) in a previous systematic review in children and adolescents also revealed a positive association between consumption of UPFs and body fat (Costa et al., 2018). However, de Amicis et. al. (2022) in a most recent systematic review reported that findings are conflicting regarding UPFs consumption and adiposity parameters among children and adolescents (De Amicis et al., 2022). It is of note that relevant studies in adults, revealed more robust results showing a positive association between UPFs consumption and obesity (Zhang et al., 2021; Juul et al., 2018; Nardocci et al., 2019; Machado et al., 2020, Rauber et al., 2021).

There are several mechanisms which describe the association between UPFs consumption and the risk of overweight/obesity. To begin with, UPFs are considered to account for a large part of total daily energy intake. In Chile, UPFs consumption was 49% of the total energy intake among preschoolers (Araya et al., 2021). Rauber et al. (2018) in a cross-sectional study in children aged ≥1.5 year, found that 56.8% of total energy intake came from UPFs (Rauber et al., 2018). This high consumption of UPFs results in a diet with high energy-density, saturated and trans fats, carbohydrates, and total sugars consumption and lower content of fiber, zinc, vitamin A, and folate (Araya et al., 2021). Also, this unbalanced nutritional composition from excessive consumption of UPFs is association with a lower protein intake which contributes to lower muscle mass as Viola et al. (2020) reported in a study conducted in 1,525 adolescents. Furthermore, increased UPFs consumption results in high intake of refined carbohydrates, which can be easily and rapidly absorbed by the body and may lead to increased insulin secretion (Viola et al., 2020). This leads to elevated storage of adipose tissue which is associated with high risk of obesity (Asfaw, 2011; Ludwig & Ebbeling, 2018). Another mechanism, yet investigated only in mice, supports that the alteration of the original food matrix and the added cosmetic additives of these products, are associated with changes in the composition and metabolic behavior of the gut microbiota that promote inflammatory diseases (Payne et al., 2012; Suez et al., 2014). Finally, UPFs are typically packaged in plastic packages, and several plasticizers, such as bisphenol A, which have been found to be associated with obesity in both animals and adults, thus it is very likely that this could also apply in children and adolescents (Thayer et al., 2012; Heindel et al., 2015). It is of note that a large number of prospective studies have performed adjustments in the association of UPFs consumption with unfavorable health consequences using diet quality, fat, sugar, or salt intake as covariates, which showed that healthy or unhealthy dietary patterns have minimal impact on this association. This implies that the negative role of UPFs on human health cannot be solely attributed to the displacement of healthy foods and to diet quality impairment. Perhaps the nature and extend of processing should also be considered as a significant factor of UPFs' health consequences (Dicken & Batterham, 2021).

Cardiometabolic co-morbidities is another field of interest for children and adolescents. Trans and saturated fats are commonly used to improve the palatability and texture of the product by the food industry. In the present review three studies found a positive association between UPFs and dyslipidemia (Leffa et al., 2020; Rauber et al., 2015; Zhang et al., 2022). The same findings were reported in US adults when an inverse association was observed between %kcal from UPFs and cardiovascular health (Juul et al., 2018). There was also a study however which indicated no association of UPFs with dyslipidemia in children, when socioeconomic class and maternal education were also examined (Zhang et al., 2021). Another main problem related to industrial food processing is the high content of salt in UPFs which is associated with elevated BP. In the present systematic review, two studies reported that higher consumption of UPFs were associated with higher BP levels (Bawaked et al., 2020; Oliveira et al., 2020), while one study of Melo et al. (2017) showed no such association among adolescents (Melo et al., 2017). Also, Scaranni et al. (2021) in a longitudinal analysis of 8754 adults, found that higher consumption of UPFs is associated with a higher risk of hypertension (Scaranni et al., 2021). Furthermore, high amounts of added sugars in UPFs can lead to energy imbalance and an unhealthy blood glucose profile. There is only one study among children which found a negative relationship between UPFs and glucose profile (Costa et al., 2019). This is in accordance with studies in adults worldwide, which reported a higher prevalence of type 2 diabetes with higher consumption of UPFs (Levy et al., 2021; Nardocci et al, 2021; Srour et al., 2020). MEtS includes all the above risk factors and Tavares et al. (2012) indicated that an increase in UPFs lead to MEtS among adolescents (Tavares et al., 2012). In a cross-sectional study in USA, it was also shown that higher dietary contribution of UPFs is associated with higher prevalence of MetS among 6385 young adults (Martínez Steele et al., 2019).

Unhealthy dietary habits as well as their main consequences such as obesity and cardiometabolic co-morbidities followed in childhood and adolescence tend to track into adulthood. Therefore, it is of great importance to investigate overconsumption of UPFs and its consequences in children. Additionally, the main causes related to this kind of diet such as the family and social environment should be highlighted, so that future public health initiatives will most effectively tackle this unhealthy dietary behavior. This review highlighted this necessity considering the overall good quality of most of studies included and also the fact that the majority of them used the %TEI to evaluate the consumption of UPFs.

The strength of the present review is that it is the first that demonstrated the impact of UPFs' consumption in overweight/obesity risk and its cardiometabolic comorbidities considering several anthropometric and cardiometabolic indices among children and adolescents. Also, the NOVA food classification system was used for identification of UPFs, which has been recognized as a valid tool for nutrition and public health research and policy (Food and Agriculture Organization of the United Nations, 2015; Monteiro et al., 2019; Pan American Health Organization, 2015). Moreover, the majority of studies had a moderate quality regarding their risk of bias which enables the outcomes to be considered as valid.

Potential limitation of this research is that many studies considered participants >12 years as children and participants <12 years as adolescents and also, there were 3 studies (Louzada et al., 2015; Enes et al., 2019; Chang et al., 2021) which included children and adolescents at the same time and thus reported united results for all ages (7-24 years). Finally, the studies used different methods to estimate the consumption of UPFs. FFQ is less detailed in terms of specific food items compared to 24-h recalls or food diaries, due to food grouping, which might have led to grouping together UPFs and less processed food items in one food group (Cade et al., 2002).

Conclusion

The findings of this review provide information about the association between consumption of UPFs and overweight/obesity or cardiometabolic risk-related outcomes among children and adolescents. The majority of the studies showed a positive association either in the risk of obesity or in cardiometabolic co-morbidities, although type and quantity of processed food consumed have not been evaluated. As consumption of UPFs may directly increase weight and cardiometabolic risk factors during childhood and since childhood dietary habits may also track to adulthood, more longitudinal studies are essential to further investigate these findings, identify facilitating factors and potential barriers for this dietary behaviour in children and adolescents and thus use this information to promote effective policies for reducing intake.

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Declaration of interest

The authors declare no conflict of interest.

2.5 Thesis Hypothesis

The increasing rates of childhood obesity and cardiometabolic co-morbidities, the high consumption of UPFs worldwide among children and adolescents and the lack of evidence among children and adolescents in Greece led us to set the hypothesis of this PhD thesis. Drawing on the literature and theoretical frameworks as well as the systematic review, it was hypothesized that UPF consumption may have a significant impact on children's and adolescents' weight status and diet quality. Subsequently, the aim was to investigate the intake of ultra-processed foods and its associations with body weight among Greek children and adolescents from a national sample of the Hellenic National Nutrition and Health Survey (HNNHS).

The objectives of the current thesis are:

1) to assess the proportion of UPFs in the total daily energy intake and the main food groups contributing to UPF consumption
2) to assess the association of total UPF intake and by UPF food type with weight status
3) to estimate the nutrient content contributed by UPFs
4) to examine associations between consumption of UPFs and nutrient intake recommended in international guidelines for the prevention of NCDs (World Health Organization, 2002).

CHAPTER 3 METHODOLOGY AND METHODS

3.1 Study design

The Hellenic National Nutrition and Health Survey (HNNHS) is a population-based, cross-sectional study designed to assess the health and nutritional status of Greek children over 6 months and adults. It was launched between September 2013 and May 2015. A nationally representative sample was selected with a random stratified design based on the 2011 census data. A multi-stage stratified design was performed according to age (0- 19 years, 20–65 years and 65+), sex (males, females) and geographical region with the aim of having a more representative sample. Finally, from approximately 6000 invitations, 4574 (42.5% males) individuals took part in HNNHS. The sample was distributed throughout Greece, with 47.2% residing in the Athens Metropolitan area, 18.5% in the Central Macedonia region, and the remainder almost evenly distributed throughout the country. Pregnant and lactating women, members of the armed forces, individuals who resided in institutions (e.g., nursing homes, psychiatric institutions, prisons, monasteries) or with progressed mental disabilities, and those who did not speak Greek were excluded. The study allowed for the random selection of more than one individual per household, but no more than one individual from the same age group could be enrolled. If a household had children under the age of six, one (if more were present) was chosen at random to participate in the study upon consent. The study's details have been published elsewhere (Magriplis et al., 2019). Trained interviewers using the Computer Assisted Personal Interview (CAPI) method collected data on anthropometric, sociodemographic and lifestyle parameters with an in-person interview at the participant's residence. Parents or guardians provided written informed consent for participants under the age of 18, and adolescents provided additional written consent.

3.2 Study population

All children and adolescents aged 2-18 years who had provided at least one 24-hour dietary recall were primarily included (n=733). Exclusion criteria included implausible intakes set at ≥ 6000 & ≤ 600 kcal (n=15) and mis-reporters assessed using Goldberg's equations, as modified by Black (Black, 2000). This methodology is based on the ratio of reported Energy Intake and the estimated Basal Metabolic Rate (BMR) as per Schofield's age- and sex-specific equations (Koletzko et al., 2005), multiplied by a specific standard of Physical Activity Level. A total of 172 children were classified as over-reporters while 62 were classified as under-reporters and thus removed from the dataset leading to a sample size of 484 children. Details regarding calculations of over-reporters and under-reporters have been published elsewhere (Mitsopoulou et al., 2020). Furthermore, although missing anthropometric data were imputed to children that had missing information for both weight and height no imputations were performed to minimise bias, and children were excluded (n=41). More specifically, missing data on weight and height were imputed by modeling the variable distribution by age (for each child with missing information on weight or height), under the assumption of Missing at Random (MAR) upon first screening. The derived datasets (12 in total) that had missing values were combined to produce the final analysis. Imputed data were checked to assure they were reasonable compared to the observed non-missing data distribution. The final sample included in this study was 443 children (91.5% of children with plausible intakes).

3.3. Data collection

3.3.1. Dietary Assessment

Assessment of dietary intake was done through a 24 hours recall by trained interviewers using the Automated Multi-pass Method (AMPM) (Blanton et al., 2006). Two 24hR were conducted in non-consecutive days, the first in-person and the second over the telephone 8-20 days later. Dietary data were collected from parents who were used as proxies for children <12 years. Adolescents ≥12 years old completed the dietary recall by themselves. Portion sizes were estimated using age-specific food atlases and household measures (e.g., cups, glasses, spoon sizes). Energy and nutrients for each food were derived from the Nutrition Data System for Research (NDSR) (developed by the University of Minnesota) and the Greek food composition tables for traditional Greek recipes (e.g., baklavas) (Trichopoulou & Georga, 2004).

3.3.1.1. Food Grouping

Food and beverage items were classified according to the NOVA 4 food classification system. NOVA is a system that categorizes food into 4 groups based on the degree and purpose of processing each food has undergone. Specifically, NOVA 1 includes unprocessed or minimally processed foods, NOVA 2 includes processed culinary ingredients, NOVA 3 contains processed foods and, NOVA 4 foods that have encountered a high degree of processing not regularly performed at home, such as refining, hydrolyzation, and pre-frying (Food and Agriculture Organization of the United Nations, 2015; Monteiro et al., 2019; Open Food Facts; Khandpur et al., 2021). For this study, foods in NOVA 4, usually defined as ultra-processed, were evaluated as shown in Table 2.1 in Chapter 2.

A four-step process was performed to identify UPFs. In the first step, a list of all food consumed by each child was compiled from the 24hR. In Step 2, UPF foods were identified and categorized as NOVA 4 the procedure of gathering information (brands where possible) from 24-h recalls, the eating location (bakeries compared to home) and other food specific facets. At this step, foods that were of unclear classification were flagged and categorized following team consultation. For the decision to be made reported food details from the child's 24hR were evaluated (where it was consumed, if a recipe was homemade or ready to eat, etc). In Step 3, all foods were categorised into specific food groups based on their main food ingredient, as per nutritional guidelines belonging to a greater category. For example, the food group 'breakfast cereals' contains all reported cereals that are refined or whole grain but contain added sugar, hence categorised in another food group compared to the main food group 'grains and cereals'. Details of the created food groups can be seen in Table 3.1. In Step 4, the energy of all food per food group was summed, for each recall (in kcal, as per each food nutrient profile) and was then averaged for children with two 24hRs.

Table 3.1 NOVA 4 Food Group derivation with types of food and beverages included in each group.

NOVA 4 Subgroups	**Foods and Beverages included in each subgroup**
Ready to eat/heat dishes	
Ready-to-eat/heat sandwiches	Hotdogs, wheat Arabic pita, crepes, baguettes, sandwiches, tortillas, toast
Ready-to-eat/heat pizza	Pizza
Savoury pies/tarts	Pies (cheese, ham, sausage, vegetables)
Other ready-to-eat/heat-mixed dishes	Stuffed pasta, Greek meat or poultry (souvlaki), meat products (schnitzel, gyros)
Flavoured dairies products	
Milk	Condensed sweetened milk
Yoghurt	Flavoured yoghurt
Flavoured dairy drinks	Milkshake, hot chocolate
Sugar-sweetened beverages	
Sugar-sweetened and diet soft drinks	Sugar-sweetened and diet soda, iced tea
Fruit drinks	Fruit juices with added sugars or concentrated fruit remixed with water
Branded breads	
Grain products	Branded slices of bread
Pita breads	Arabic pita, pita bread with additives, tortillas, sesame bread rings
Savoury snacks	
Savoury snacks	Salted crackers, breadsticks, rice cakes, sesame bread rings with cheese, Cheetos, chips (potato, tortillas), popcorn, bread with cheese
Baked goods	Butter croissant, short & puff pastry savoury pies (e.g. cheese pie, spinach pie, meat pie, etc)
Sweet grain products	

NOVA 4 Subgroups	Foods and Beverages included in each subgroup
Bakery sweet products	Chocolate croissants, short & puff pastry sweet pies, ‘tsoureki’, ‘melomakarono’
Cereal bars and biscuits	Branded bars, biscuits
Waffles and crepes	Branded waffles, crepes
Breakfast cereals	Branded cereals (wheat, whole grain, oat) with added sugar
Sweets	
Desserts	Gelatin desserts, traditional sweets with sirup, sweets with chocolate, puddings (chocolate, vanilla), mille-feuille, loukoumi, cakes, cheesecake, profiterole, ice-creams, halva (sesame), Honey sesame bars, chocolate-pie
Sweet pies and tarts	Pies (lemon pie), sweet tarts
Candies & chocolate bars	Candies, jellies, chewing gums, chocolate, chocolate waffle bars, syrups, jams
Other sweet UPFs	Sweet spreads (praline, sesame, peanut butter)
Other	
Fast-food or reconstituted meat, poultry, and fish products	Ham from reconstituted meat or poultry, bacon, meat (pate), sausages, nuggets (chicken, cheese)
Fast food or pre-prepared potato products	Fast food, pre-prepared, frozen French fries
Fats, spreads and sauces	Margarine (with or without butter), cheese spread, sauces, dips, cream cheese
Other UPFs	Distilled alcoholic drinks, sparking water, chocolate powder, baby formulas (milk, creams, chamomile formula)

3.3.1.2 Energy assessment

The total daily energy intake (TEI) of foods was calculated by summing the energy content of each food item. Then the average intake per child per day was estimated. The energy derived from all food groups of NOVA 4 was summed up and the value was divided by the total mean daily energy intake of each child to calculate the total proportion of the diet consisting of UPFs. Food group contribution was derived as percent total energy per food group (kcal) divided by the total energy (kcal) from all NOVA 4 food groups consumed by each child and then multiplied by 100 (Block et al., 1985). Proportions were calculated for the total sample and by children's weight status groups.

3.3.1.3 Nutrients intake estimation

The nutrient composition of the overall diet for the whole population and across tertiles of UPFs consumption was estimated. The nutritional indicators were energy, carbohydrates, added sugars, proteins, total, saturated and polyunsaturated fats, cholesterol, fibre, and 21 vitamins and minerals. The intake was expressed (median, IQR) in percentages or absolute terms (milligrams and micrograms) per day and relative to the total daily intake of the specific participant.

For macronutrients, acceptable distribution ranges (daily values) were used according to the dietary guidelines of the American Heart Association (AHA) (Krauss et al., 2000). The prevalence of carbohydrates (<60% of total energy), proteins (<20% of total energy), fats (<35% of total energy), cholesterol (<300mg/d), saturated fats (<10% of total energy), polyunsaturated fats (≥6% of total energy), and dietary fibre (≥20g/d) were assessed using American Heart Association's (AHA) (Krauss et al., 2000) and added sugars (<10% of total energy) using WHO's (World Health Organization, 2002; World Health Organization, 2013; World Health Organization, 2015) recommended dietary nutrient goals for preventing chronic diseases respectively.

The Institute of Medicine's (IOM) estimated average requirement (EAR) cut-off point method used to assess the adequacy of children's and adolescents' vitamins and minerals intakes (National Academies of Sciences, Engineering, and Medicine, 2019). The EAR is the average daily nutrient value estimated to meet the requirement of 50% of all healthy individuals in a particular life group. An estimate of the frequency of inadequate intakes in a group can be obtained by calculating the percentage of individuals who typically consume less than the EAR (National Academies of Sciences, Engineering, and Medicine, 2019). As there are no established EAR values for vitamin K, pantothenic acid, sodium, and potassium, the proportion below the adequate intake (AI) was used to assess the nutrient adequacy of groups. The AI is a recommended average daily nutrient intake level, based on experimentally derived intake levels or approximations of observed mean nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate.

3.3.2 Anthropometric variables

Body Mass Index (BMI) was used to evaluate the children’s weight status. Body weight and height were measured by the parent or guardian for children <12 years and for adolescents ≥12 years by themselves. A total of 107 data were imputed for children when at least one of the two was available, using the Missing at Random (MAR) process (information stated previously). BMI was calculated by dividing weight in kg by height in meters squared (kg/m^2). To categorise children and adolescents according to their BMI, the extended International Obesity Task Force (IOTF) tables were used (Cole & Lobstein, 2012). These tables are a set of growth reference charts and cutoffs, that consider age and sex differences in growth patterns, specifically designed to monitor and address childhood obesity on a global scale. Children who were overweight and children living with obesity were grouped for further analysis to have adequate power of analysis.

3.3.3 Other Variables

Information on socio-economic data such as sex, age, screen time for children, parental educational level and employment status were collected. Screen time was defined as the average time spent in front of any type of screen per week, not including active gaming and a mean daily average was estimated. Parental education level was categorised by school years (elementary school, middle school and higher level of education) and their employment status was categorised as employed, unemployed (including homemakers) or retired.

3.3.3.1 Demographic / Socioeconomic Questionnaire

The demographic and socioeconomic characteristics of the sample were collected using a questionnaire specifically designed for this study. The information requested from participants is below (Magriplis et al., 2019).

«Δημογραφικά/ Κοινωνικο-Οικονομικά Χαρακτηριστικά»

ΚΩΔΙΚΟΣ ΕΘΕΛΟΝΤΗ

3

Ημερομηνία: _ _/_ _/ _ _ _ _
Ηλικία ΕΣ: _ _ Φύλο ΕΣ: ____

≥6 μηνών

ΤΜΗΜΑ 1. ΟΙΚΟΓΕΝΕΙΑΚΗ ΚΑΤΑΣΤΑΣΗ

ΔΚΧ 1. Ποια είναι η οικογενειακή σας κατάσταση; {Στην περίπτωση που ο συμμετέχοντας είναι κάτω των 18 ετών ηερώτηση αφορά στην οικογενειακή κατάσταση του γονέα ή του κηδεμόνα.}

1. Άγαμος/η 2. Έγγαμος/η 3. Με σύμφωνο συμβίωσης 4. Χήρος/α 5. Διαζευγμένος/η
6. Σε διάσταση 777. ΔΞ 999. ΔΑ

Μου είπατε ότι στο σπίτι σας κατοικούν, μαζί με εσάς, Χ άτομα. {Επιβεβαίωση απάντησης από την ερώτηση ΕΕ1 του ερωτηματολογίου επιλεξιμότητας.}

ΔΚΧ 2. Πόσα άτομα συνολικά, μαζί με εσάς, συντηρούνται από τον προϋπολογισμό του νοικοκυριού, είτεσυνεισφέρουν σε αυτόν είτε όχι, και ανεξάρτητα από το αν διαμένουν ή όχι στο σπίτι σας;

1.☐☐ (αριθμός ατόμων 0-20) 777. ΔΞ 999. ΔΑ

ΤΜΗΜΑ 2. ΕΚΠΑΙΔΕΥΣΗ

≥18 ετών

ΔΚΧ 3. Ποιο είναι το ανώτερο επίπεδο σπουδών που έχετε ολοκληρώσει; {Καταγράφεται η εκπαιδευτική βαθμίδα που ο συμμετέχοντας έχει ολοκληρώσει κατά την ημέρα διενέργειας της συνέντευξης. Για όσους παρακολουθούν κάποια βαθμίδα εκπαίδευσης, θα καταχωρηθεί το επίπεδο εκπαίδευσης το οποίο έχει ήδη ολοκληρωθεί π.χ. αν ο συμμετέχοντας παρακολουθεί μαθήματα σε κάποιο ανώτατο εκπαιδευτικό ίδρυμα, θα απαντήσει ότι έχει ολοκληρώσει το Λύκειο.} **ΔΕΙΞΤΕ ΚΑΡΤΑ 1**

Ανώτατο επίπεδο σπουδών
1. Δεν παρακολούθησα ποτέ καμία βαθμίδα εκπαίδευσης/ Μερικές τάξεις του Δημοτικού
2. Απολυτήριο Δημοτικού Σχολείου
3. Απολυτήριο Γυμνασίου
4. Απολυτήριο Λυκείου ή Εξατάξιου Γυμνασίου
5. Απολυτήριο Τεχνικού Λυκείου, Σχολής Μαθητείας ΟΑΕΔ
6. Πτυχίο ΙΕΚ, Ιδιωτικού Κολλεγίου, Κέντρου ελευθέρων Σπουδών
7. Πτυχίο ΑΕΙ
8. Πτυχίο ΤΕΙ, ΑΤΕΙ
9. Κάτοχος Μεταπτυχιακού Τίτλου Σπουδών
10. Κάτοχος Διδακτορικού
11. Άλλο, προσδιορίστε:
777. ΔΞ
999. ΔΑ

ΤΜΗΜΑ 3. ΑΣΦΑΛΕΙΑ ΥΓΕΙΑΣ ΚΑΙ ΧΡΗΣΗ ΥΠΗΡΕΣΙΩΝ ΥΓΕΙΑΣ

≥ 6 μηνών

ΔΚΧ 4. Διαθέτετε ασφάλεια υγείας;

1. Ναι
   - → 1. Ιδιωτική
   - → 2. Δημόσια
   - → 3. Ιδιωτική και Δημόσια
   - → 777. ΔΞ
   - → 999. ΔΑ

0. Όχι 777. ΔΞ 999. ΔΑ

ΔΚΧ 5. Συνολικά τον τελευταίο χρόνο αντιμετωπίσατε κάποιο θέμα υγείας ώστε να χρειάστηκε να απευθυνθείτε σε κάποια από τις υπηρεσίες υγείας; {Ναι ή Όχι} {Αν ναι:} ΔΕΙΞΤΕ ΚΑΡΤΑ 2 Για ποιο λόγο; Επιλέξτε έναν ή περισσότερους λόγους.

1.Ναι
   - → 1. Προληπτικές εξετάσεις
   - → 2. Συμπτώματα ή προσωρινή ασθένεια όπως κρύωμα ή τραυματισμός
   - → 3. Αντιμετώπιση χρόνιας ασθένειας ή χρόνιου προβλήματος υγείας
   - → 4. Συνταγογράφηση
   - → 5. Οδοντίατρος
   - → 6.Άλλη αιτία, προσδιορίστε ______________________
   - → 777. ΔΞ
   - → 999. ΔΑ

0. Όχι 777. ΔΞ 999. ΔΑ

ΤΜΗΜΑ 4. ΑΠΑΣΧΟΛΗΣΗ

≥ 2 μηνών

{Για συμμετέχοντες ≥12 ετών} ΔΚΧ 6α. Με τι ασχολείσθε σήμερα; Επιλέξτε μία ή περισσότερες απαντήσεις. Για παράδειγμα, αν είστε φοιτητής και εργάζεστε επιλέξτε 1 και 7.

{Για συμμετέχοντες ≥2- <5 ετών} ΔΚΧ 6β. Πηγαίνει το παιδί σας παιδικό σταθμό ή νηπιαγωγείο;

{Για συμμετέχοντες ≥5- <12 ετών} ΔΚΧ 6γ. Πηγαίνει το παιδί σας σχολείο; {Αν ναι: Σε ποια τάξη;}ΔΕΙΞΤΕ ΚΑΡΤΑ 3

Απασχόληση	**Αν 4 ή 5**
1. Εργαζόμενος/η (Περιλαμβάνονται και άμισθοι βοηθοί στην οικογενειακή επιχείρηση, οι μαθητευόμενοι με αμοιβή, καθώς και όσοι προσωρινά απουσιάζουν από την εργασία τους λόγω άδειας μητρότητας, γονικής άδειας, ασθένειας ή είναι σε διακοπές)	1. Παιδικός σταθμός 2. Νηπιαγωγείο 3. Δημοτικό. Σε ποια τάξη 1. Α' Δημοτικού 2. Β' Δημοτικού 3. Γ' Δημοτικού 4. Δ' Δημοτικού 5. Ε' Δημοτικού 6. Στ' Δημοτικού 4. Γυμνάσιο. Σε ποια τάξη; 1. Α' Γυμνασίου 2. Β' Γυμνασίου 3. Γ' Γυμνασίου 5. Λύκειο. Σε ποια τάξη; Α' Λυκείου Β' Λυκείου Γ' Λυκείου
2. Σε καθεστώς διαθεσιμότητας	
3. Άνεργος/η	
4. Μαθητής	
5. Παρακολουθεί κατ' οίκον διδασκαλία	
6. Δεν πηγαίνει σχολείο	
7. Φοιτητής, μετεκπαιδευόμενος, μαθητευόμενος χωρίς αμοιβή για απόκτηση εμπειρίας	
8. Συνταξιούχος, σε κανονική ή πρόωρη συνταξιοδότηση ή έχετε διακόψει τις εργασίες της επιχείρησής σας	
9. Μόνιμη αναπηρία (Περιλαμβάνονται και όσοι έχουν μακροχρόνια προβλήματα υγείας ή ασθένεια) Συνταξιούχοι λόγω αναπηρίας	
10. Στρατιώτης {όχι στρατιωτικός που είναι το 1.}	

11. Οικιακά	
12. Άλλο, προσδιορίστε:	
777. ΔΞ	
999. ΔΑ	

! {Αν η απάντηση στην ερώτηση ΔΚΧ 6 είναι:
1. Εργαζόμενος συνεχίστε στην 7
2. Σε καθεστώς διαθεσιμότητας συνεχίστε στην 8α
3. Άνεργος συνεχίστε στην 8β
8. Συνταξιούχος συνεχίστε στην 8γ
Σε κάθε άλλη περίπτωση προχωρήστε στην 14}

! Αν στην ερώτηση 6 έχουν επιλεγεί περισσότερες από μία απαντήσεις, τότε ισχύουν οι συνθήκες για όλες τις επιλογές.

≥ 16 ετών

ΔΚΧ 7. Ως τυπική εβδομάδα θεωρείται μία συνηθισμένη εβδομάδα κατά τη διάρκεια της χρονιάς και όχι απαραίτητα η τελευταία εβδομάδα. Σε μία τυπική εβδομάδα, συμπεριλαμβανομένου του σαββατοκύριακου, πόσες ημέρες και πόσες ώρες εργάζεστε, συνολικά για όλες τις δουλειές σε περίπτωση που εργάζεστε σε περισσότερες από μία;

1. ☐ (αριθμός ημερών) ή Εύρος ☐ - ☐
Και ☐☐☐ (αριθμός ωρών) ή Εύρος ☐☐☐ - ☐☐☐ 777. ΔΞ 999. ΔΑ

Πόσες από τις ώρες αυτές είναι από υπερωριακή απασχόληση;
☐☐☐ (αριθμός ωρών) 777. ΔΞ 999. ΔΑ
{Προχωρήστε στην ερώτηση ΔΚΧ 9α.}

{ΜΟΝΟ ΣΕ ΚΑΘΕΣΤΩΣ ΔΙΑΘΕΣΙΜΟΤΗΤΑΣ} ΔΚΧ 8α. Πόσο καιρό είστε σε διαθεσιμότητα;

1. Εισάγετε χρονικό διάστημα ☐☐ και κυκλώστε μονάδα χρόνου: Ημέρες, Εβδομάδες, Μήνες Χρόνια777. ΔΞ 999. ΔΑ
{Προχωρήστε στην ερώτηση ΔΚΧ 9β.}

{ΜΟΝΟ ΣΕ ΑΝΕΡΓΟΥΣ} ΔΚΧ 8β. Πόσο καιρό είστε άνεργος;

1. Εισάγετε χρονικό διάστημα ☐☐ και κυκλώστε μονάδα χρόνου: Ημέρες, Εβδομάδες, Μήνες Χρόνια777. ΔΞ 999. ΔΑ
{Προχωρήστε στην ερώτηση ΔΚΧ 9β.}

{ΜΟΝΟ ΣΕ ΣΥΝΤΑΞΙΟΥΧΟΥΣ ή ΔΙΑΚΟΠΗ ΕΡΓΑΣΙΑΣ} ΔΚΧ 8γ. Πόσο καιρό είστε συνταξιούχος ή έχετε διακόψει τηνεργασία σας;

1. Εισάγετε χρονικό διάστημα ☐☐ και κυκλώστε μονάδα χρόνου: Ημέρες, Εβδομάδες, Μήνες Χρόνια ή Έτος συνταξιοδότησης ☐☐☐☐777. ΔΞ 999. ΔΑ
{Προχωρήστε στην ερώτηση ΔΚΧ 9β.}

ΔΚΧ 9α. Ποια είναι η <u>κύρια</u> απασχόλησή σας; {π.χ. υπάλληλος ΔΕΗ- γραμματέας, υπάλληλος ΔΕΗ- διευθυντής, υπάλληλος ΔΕΗ- τεχνικός} {Στην περίπτωση που ο συμμετέχοντας έχει παραπάνω από μία εργασίες, ως κύρια εργασία θεωρείται αυτή που ο συμμετέχοντας θα υποδείξει ή σε περίπτωση που ο συμμετέχοντας αδυνατεί, αυτή στην οποία εργάζεται τις περισσότερες ώρες.}

1. ________________________________(περιγραφή/ τίτλος εργασίας)
777. ΔΞ 999. ΔΑ

{Αν απαντήθηκε η 9α προχωρήστε στη 10.}

ΔΚΧ 9β. Ποια ήταν η <u>κύρια</u> απασχόλησή σας {πριν μείνετε άνεργος, πριν τεθείτε σε διαθεσιμότητα, πριν από τη συνταξιοδότησή σας ή πριν από τη διακοπή της εργασίας σας;} {π.χ. υπάλληλος ΔΕΗ- γραμματέας, υπάλληλος ΔΕΗ- διευθυντής, υπάλληλος ΔΕΗ- τεχνικός}. {Στην περίπτωση που ο συμμετέχοντας έχει παραπάνω από μία εργασίες, ως κύρια εργασία θεωρείται αυτή που ο συμμετέχοντας θα υποδείξει ή σε περίπτωση που ο συμμετέχοντας αδυνατεί, αυτή στην οποία εργάζεται τις περισσότερες ώρες.}

1. ______________________________(περιγραφή/ τίτλος εργασίας)

2. Δεν έχω εργαστεί ποτέ 777. ΔΞ 999. ΔΑ

<u>{Αν στην ΔΚΧ 9β δόθηκε η απάντηση 2 "Δεν έχω εργαστεί ποτέ", προχωρήστε στην ΔΚΧ 11.}</u>

ΔΚΧ 10. Για πόσο διάστημα {κάνετε/ κάνατε} τη συγκεκριμένη εργασία;

1. Εισάγετε χρονικό διάστημα και κυκλώστε μονάδα χρόνου: Ημέρες, Εβδομάδες, Μήνες Χρόνια777. ΔΞ 999. ΔΑ

<u>! Αν στην ερώτηση 8γ η απάντηση είναι έτος πριν από το 2008 ή διάστημα ≥6 ετών προχωρήστε στην ερώτησηΔΚΧ 13.</u>

ΔΚΧ 11. Έχει αλλάξει η επαγγελματική σας κατάσταση εξαιτίας της οικονομικής κρίσης; {Αν ναι: **Με ποιον τρόπο;**}**<u>ΔΕΙΞΤΕ ΚΑΡΤΑ 4</u>**

1. Ναι --- > Με ποιόν τρόπο;
   - → 1. Απόλυση από την εργασία
   - → 2. Πρόωρη συνταξιοδότηση λόγω οικονομικής κρίσης
   - → 3. Μετάβαση σε καθεστώς διαθεσιμότητας
   - → 4. Μετάβαση σε καθεστώς μερικής απασχόλησης
   - → 5. Αλλαγή επαγγέλματος
   - → 6. Απασχόληση σε επιπρόσθετη θέση εργασίας
   - → 7. Άλλο, προσδιορίστε ______________
   - → 777. ΔΞ
   - → 999. ΔΑ

0. Όχι 777. ΔΞ 999. ΔΑ

{Αν η απάντηση στην ερώτηση ΔΚΧ 11 είναι «Όχι», «ΔΞ», «ΔΑ» προχωρήστε στην ερώτηση ΔΚΧ 13.}

ΔΚΧ 12. Ποια χρονιά συνέβη αυτή η αλλαγή στην επαγγελματική σας κατάσταση εξαιτίας της οικονομικήςκρίσης;

1. □□□□ (ΕΕΕΕ) 777. ΔΞ 999.ΔΑ

ΔΚΧ 13. Ως καθαρές αποδοχές θεωρούνται οι αποδοχές που λαμβάνετε αφού αφαιρεθούν από αυτές ο φόρος που παρακρατήθηκε και οι εισφορές για την κοινωνική ασφάλιση. Έχουν αλλάξει οι καθαρές μηνιαίες αποδοχές από όλες τις πηγές, εξαιτίας της οικονομικής κρίσης;

1. Ναι --- > Με ποιόν τρόπο;
   - → 1. Μειώθηκαν
     - → 1. Λίγο
     - → 2. Αρκετά
     - → 3. Πολύ
   - → 2. Αυξήθηκαν
     - → 1. Λίγο
     - → 2. Αρκετά
     - → 3. Πολύ
     - → 777. ΔΞ
     - → 999. ΔΑ
   - → 777. ΔΞ
   - → 999. ΔΑ

0. Όχι, παρέμειναν ίδιες 777. ΔΞ 999. ΔΑ

≥6 μηνών

ΔΚΧ 14. Ποια χρονιά αντιληφθήκατε σημαντική αλλαγή στον προϋπολογισμό του νοικοκυριού σας, έσοδα από όλες τις πηγές και έξοδα, εξαιτίας της οικονομικής κρίσης;

1. □□□□(ΕΕΕΕ)   2. Δεν έχει αλλάξει   777. ΔΞ   999. ΔΑ

ΤΜΗΜΑ 5. ΕΙΣΟΔΗΜΑ

≥6 μηνών

(Θα ήθελα εδώ να σας υπενθυμίσω ότι όλα τα δεδομένα που συλλέγονται είναι εμπιστευτικά. Κανείς άλλος δεν θα λάβει γνώση των στοιχείων αυτών. Τα στοιχεία αυτά θα χρησιμοποιηθούν ανώνυμα για την ανάλυση δεικτών και τη εξαγωγή συμπερασμάτων σημαντικών για την υγεία του ελληνικού πληθυσμού.)

ΔΚΧ 15. Ποιο είναι το συνολικό καθαρό μηνιαίο εισόδημα του νοικοκυριού σας από {όλα τα μέλη} <u>και όλες τις</u> <u>πηγές</u>; Στην κάρτα αυτή, <u>ΔΕΙΞΤΕ ΚΑΡΤΑ 5</u>, υπάρχουν κάποια παραδείγματα πηγών εισοδήματος. Στην κάρτα αυτή, <u>ΔΕΙΞΤΕ ΚΑΡΤΑ 6</u> βλέπετε μία σειρά από εισοδήματα που συνοδεύονται από έναν αριθμό. Θα ήθελα να επιλέξετε την απάντηση που ταιριάζει καλύτερα στο καθαρό μηνιαίο εισόδημα του νοικοκυριού σας και να μου πείτε τον αριθμό που της αντιστοιχεί.

ΕΙΣΟΔΗΜΑ ΝΟΙΚΟΚΥΡΙΟΥ {Αριθμός απάντησης ή 777. ΔΞ, 999. ΔΑ}

- Πόσο χρόνο σας πήρε η συμπλήρωση του ερωτηματολογίου; □□
- Ποιος απάντησε το ερωτηματολόγιο;

□ Ο ίδιος/ Η ίδια   □ Η μητέρα   □ Ο πατέρας   Άλλος, προσδιορίστε

- Βοηθός συνέντευξης:

- Λόγος διακοπής συνέντευξης:

Σχόλια
Για συγκεκριμένες ερωτήσεις του ερωτηματολογίου:
Για το σύνολο του ερωτηματολογίου:

3.4. Bioethics

The study was approved by the Ethics Committee of the Department of Food Science and Human Nutrition of the Agricultural University of Athens in 2024, with protocol number 13/21.02.2024. The study was also approved by the Hellenic Data Protection Authority. It was conducted in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

3.5. Statistical Analyses

The proportion of total daily energy intake from UPFs was estimated according to NOVA 4 food groups and their specific food subgroups. P-P plots were used to assess the normality of the distribution. Numerical variables following normal distribution were presented with a mean (standard deviation) and those skewed with medians and ranges (P25 and P75). Categorical variables were described as relative frequencies. Between-group differences were estimated using parametric (student t-test) or non-parametric methods (Mann Whitney U-test) for numerical data and chi-square test for categorical data. Cuzick test for trend was used to evaluate differences in percentages of the contribution of NOVA 4 group and NOVA 4 food subgroups (for each individual) to total energy intake across tertiles.

A general linear model (GLM) for maximum logistic likelihood analysis was used of the binomial family to assess the likelihood of being overweight/obese compared to normal weight according to the dietary contribution of % total energy intake (%TEI) of NOVA 4 food group, categorized in tertiles. The model was adjusted for age (continuous by 4-year increase), sex (binary), the area of residence (main metropolitan areas, islands & Crete, mainland), total screen time (continuous) and %TEI. The predicted probability of overweight and obesity was also examined only for the main NOVA 4 food group contributors using a continuous approach, to examine the level of intake to which they may influence children's weight status.

Linear regression models were used to test trends in energy and nutrients in the dietary energy share provided by UPFs. To allow for comparisons across variables with different units, standardized regression coefficients (β) were calculated. Prevalence ratios for the association between the dietary share of UPFs (tertiles) and the frequency of dietary nutrient inadequacies were estimated with Poisson regression models. The models were adjusted for age (years), sex, parents' educational level (≤6 years, >6-12 years, ≥12 years), screen time (hours) and the area of residence (Main metropolitan areas, islands & Crete, Mainland).

Outcomes are presented according to corresponding 95% confidence intervals. Significance was set at alpha 5% ($p < 0.05$), being considered statistically significant. The statistical software package STATA 17.0 was used for analysis (Stata Corp LLC., College Station, TX, USA).

CHAPTER 4 RESULTS

4.1. UPFs consumption and weight status

The aim of the present study was to assess the proportion of UPFs in the total daily energy intake and the main food groups contributing to UPF consumption in children and adolescents using data from the Hellenic Nutrition and Health Survey (HNNHS). The association of total UPF intake and UPF food type with weight status was also assessed (Petridi et al.) (Appendix 2).

The children's anthropometric, lifestyle and sociodemographic characteristics are shown in Table 4.1.1. Among 443 children for which both weight and height were available, 75% (n=332) were categorized as normal weight and 25% (n=111) as overweight/obese. Between groups, significant differences were found only for screen time with overweight/obese children (27%) having a 2.5-hour median screen time (27%) compared to normal-weight children (73%) who had a 2.2-hour median screen time, although in both cases it was above the daily 2-hour level recommended by the American Pediatric Association (Daniels et al., 2015). Most primary guardians were employed, and their average level of education was more than 12 years, with no distribution differences by weight status observed. A subsample of all children was weighed and measured by the researchers and a high correlation (>0.95) was found. More specifically a random sample of 83 children were weighed and the mean weight measured was 41.8±19.3 while the mean weight reported by the same children/guardians was 40.6±18.6. The correlation for height was comparative to that of weight.

Table 4.1.1 Anthropometric and lifestyle characteristics of children and adolescents, and guardians' sociodemographic information.

	Total	Normal weight	Overweight/Obesity	p-Value
Total sample, n (%)	443	332 (74.9)	111 (25.1)	
Age (years), [median, (range)]	9 (6, 14)	9 (5, 14)	9 (6, 12)	0.000
Weight (kg), [median (range)]	36 (21, 55)	32.7 (19, 52)	42 (28.5, 65)	0.000
Height (m), mean (SD)	1.4 (0.3)	1.4 (0.3)	1.4 (0.2)	0.451
BMI (kg/m^2), mean (SD)	18.7 (4.0)	17.4 (3.0)	22.6 (4.2)	0.000
Group Age, n (%)				0.456
Children	258 (58.2)	190 (57.2)	68 (17.8)	
Adolescents	185 (41.8)	142 (42.8)	32 (7.2)	
Sex, n (%)				0.763
Male	221 (49.9)	167 (37.7)	54 (12.2)	
Female	222 (50.1)	165 (37.2)	57 (12.9)	
Total screen time (hours), [median, (range)]	2.2 (1.2, 3.5)	2.2 (1.12, 3.5)	2.5 (1.5, 3.5)	0.024
Primary Guardian Education level, n (%)				0.303
≤6 years	12 (3.8)	10 (3.2)	2 (0.6)	
6-12 years	124 (39.6)	86 (27.5)	38 (12.1)	
≥12 years	177 (56.5)	135 (43.1)	42 (13.4)	
Primary Guardian Professional Status, n (%)				0.849
Employed	216 (70.4)	159 (51.8)	57 (18.6)	
Unemployed/Homeworkers	76 (24.8)	57 (18.6)	19 (6.2)	
Pension	15 (4.9)	12 (3.9)	3 (1.0)	

$p < 0.05$; Student t-test for normally distributed values and Mann-Whitney test for skewed numerical variables (two group comparison); chi-square test for categorical variables IQR: Interquartile range.

Table 4.1.2 shows the percentages of total energy intake from NOVA 4 food group that were consumed in total and by normal weight and overweight/obese children. No significant differences were observed between the groups; for the total population the proportion was 39.8%, and for normal weight and overweight/obese children the percentages of total energy intake from the NOVA 4 food group were 39.5% and 40.2%, respectively. Moreover, differences in the percentage of total energy intake contribution from NOVA 4 food subgroups between normal weight and overweight children/children living with obesity were not statistically significant, except from the subgroup of "other" 2.1% (which includes the food subgroups reconstituted meats, pre-prepared potatoes, spreads and sauces, distilled alcoholic drinks, sparkling water and chocolate powder). Consequently, normal weight children eat more reconstituted meats, pre-prepared potatoes, fats, spreads, and sauces than overweight children/those living with obesity.

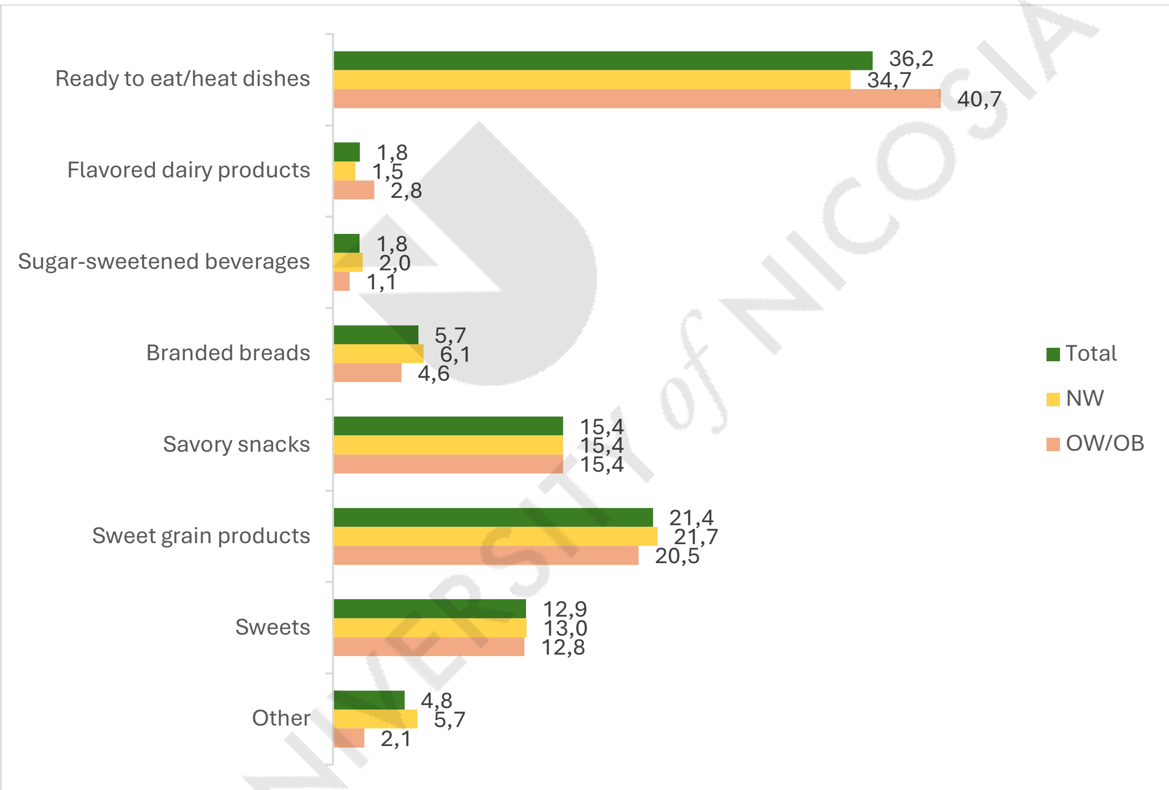
Table 4.1.2 Percent of NOVA 4 foods consumed (as total and by subgroup) with mean energy intake; results presented for all children and by children's weight status.

%E NOVA Foods, median, (range)	Total	Normal weight	Overweight/Obesity	p-value
NOVA 4	39.8 (25.4, 55.0)	39.5 (24.5, 54.3)	40.2 (27.0, 57.3)	0.535
[a]Ready to eat/heat dishes	22.9 (14.2, 35.5)	22.1 (13.7, 35.5)	26.2 (16.7, 36.9)	0.197
[b]Flavoured dairy products	4.3 (2.0, 8.3)	3.02 (1.6, 7.2)	6.6 (3.5, 10.7)	0.183
[c]Sugar-sweetened beverages	3.0 (1.8, 5.0)	3.5 (1.9, 5.1)	2.6 (1.3, 3.4)	0.20
[d]Branded breads	6.3 (3.6, 10.1)	6.62 (4.0, 10.2)	4.6 (3.3, 9.9)	0.409
[e]Savoury snacks	13.0 (5.7, 24.0)	12.6 (5.7, 23.2)	13.4 (8.4, 26.8)	0.504
[f]Sweet grain products	10.8 (5.8, 19.5)	10.8 (5.8, 19.4)	10.8 (5.6, 19.7)	0.98
[g]Sweets	8.5 (4.2, 13.9)	8.3 (4.1, 13.7)	9.93 (4.5, 14.2)	0.959
[h]Other	2.1 (0.7, 7.0)	2.5 (0.8, 7.4)	0.9 (0.5, 4.0)	0.02

$p < 0.05$; Mann-Whitney test for skewed numerical variables (two group comparison); %E: total daily energy intake; Range: 25th – 75th percentiles of the distribution, [a] Sandwiches, pizza, pies, tarts, mixed dishes, [b] Milk, yoghurt, drinks, [c] Sugar-sweetened drinks, fruit drinks, [d] Grain products, pita bread, [e] Savoury snacks, bakery pies, [f] Bakery sweets, cereal bars and biscuits, waffles and crepes, cereals, [g] Desserts, sweet pies and tarts, candies, jams, other sweet UPFs, [h] Reconstituted meats, pre-prepared potatoes, fats, spreads and sauces, other UPFs (distilled alcoholic drinks, sparkling water, chocolate powder, baby formulas)

To increase understanding of specific food group intake, the percent of each (sub)-food group of UPF to total energy provided by all NOVA 4 food groups was calculated. These are presented in total and by weight status in a bar graph (Figure 4.1.1). Four food groups contributed >10% to total NOVA 4 adding up to 86% of total UPF intake. Ready-to-eat/heat dishes are the most prominent with 36.2% of the total population (34.7% among normal weight children and 40.7% among overweight children/children living with obesity followed by sweet grain products (21.4%), savory snacks and baked goods such as savory pies with cheese, spinach or meat sweets in contrast to sweet grain products such as short & puff pastry sweet pies or tsoureki (15.4%) and sweets (12.9%).

Figure 4.1.1 Main food groups contributors to NOVA 4 category* in children and adolescents; results depicted by weight status.



*derived as percent total energy per food group (kcal) divided by the total energy (kcal) from all NOVA 4 food groups consumed by each individual, and then multiplied by 100.
[a] Sandwiches, pizza, pies, tarts, mixed dishes, [b] Milk, yoghurt, drinks, [c] Sugar-sweetened drinks, fruit drinks, [d] Grain products, pita bread, [e] Savoury snacks & baked goods, [f] Bakery sweets, cereal bars and biscuits, waffles and crepes, cereals, [g] Desserts, sweet pies and tarts, candies, jams, other sweet UPFs, [h] Reconstituted meats, pre-prepared potatoes, fats, spreads and sauces, other UPFs (distilled alcoholic drinks, sparkling water, chocolate powder, baby formulas)

The adjusted Odd Ratio (AOR) between weight status and tertile of NOVA 4 consumption (as % of total caloric intake) is depicted in Table 4.1.3. No significant differences were found by tertile of NOVA 4 intake as a proportion of calories. The model was adjusted for sex, age category, total energy intake and total screen time.

Table 4.1.3 Multiple logistic regression between weight status and ultra-processed foods consumption (%kcal/day) in children of HNNHS.

Weight status[a]	Odds ratio	[95% Confidence Interval]	
NOVA 4[b], (%kcal/day) [median, range of first tertile: 19.6 (13.4-25.5)]	-	-	-
2nd Tertile [38.6 (33.9, 44.4]	1.5	0.85	2.51
3rd Tertile [60.8 (54.8, 72.6)]	1.1	0.71	1.68

Results following logistic regression by tertile of NOVA 4 (based on % energy contribution) and adjusted for sex, energy intake, age category (children and adolescents) and screen time.

NOVA 4 tertile distributions between children and adolescents did not differ (p for all tertiles > 0.2).

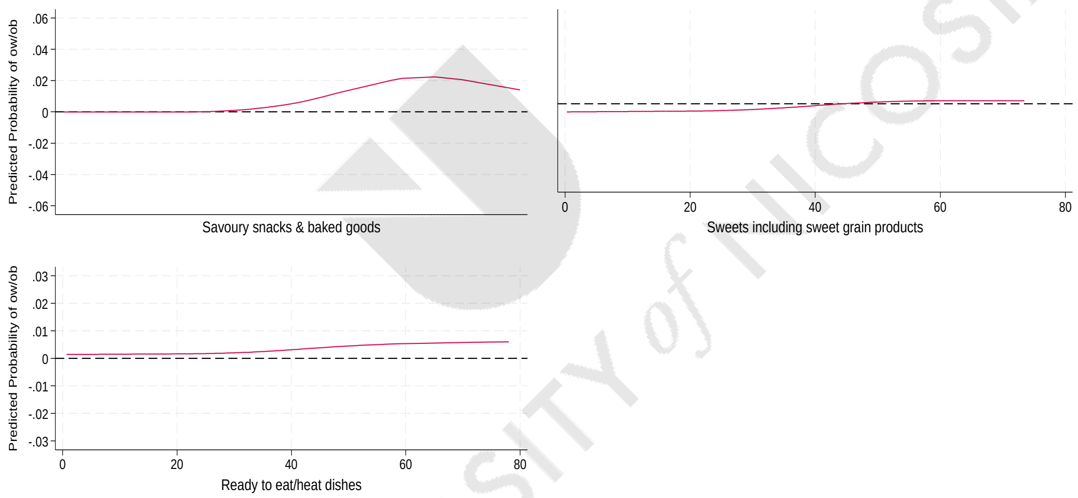
[a]Weight status was normal weight and overweight/obese participants.

[b]Reference tertile for % energy NOVA 4 was the 1st tertile.

*Significant at a=5%

Lastly, specific food groups highly contributing to NOVA 4 as a percentage of total energy intake were modelled in relation to the probability of overweight and obesity (Figure 4.1.2). The results showed that the only food group associated with an increased probability of being overweight/obese were savoury snacks and baked goods for children and adolescents who consumed these >62% of their total daily energy intake. Although the percentage of children found to exceed this level was small (0.4%, n=2), a significant effect was found potentially indicating the magnitude their effect on weight status over and above this level of consumption. The total proportion of all NOVA 4 subgroups was not significantly associated with weight in accordance with logistic regression results (see Table 4.1.3).

Figure 4.1.2. Predictive probability (margins) of overweight or obesity among children by specific NOVA 4 food group intake (% of total energy).



Cubic spline graphs based on generalized linear models (GLM) of the binomial family and logit link; adjusted for sex, age, mean daily energy intake and area of residence.

The three main NOVA 4 contributors are depicted (NOVA4 group seen on the x-axis for each graph displayed). The vertical dotted line represents no effect. The red line represents the measure of effect (Predicted odds of overweight/obesity by an increased level of energy-adjusted consumption).

Savoury snacks & baked goods: salted crackers, breadsticks, all crisps & Cheetos, short crust and puff pastry type savory pies

Ready-to-eat/heat dishes: Sandwiches, pizza, pies, tarts, mixed dishes,

Sweets include sweet grain products: Desserts, sweet pies and tarts, candies, jams, bakery sweets, cereal bars and biscuits, waffles and crepes and breakfast cereals.

4.2. UPFs consumption and diet quality

UPF consumption in relation to diet quality has yet to be studied in Greek children. Therefore, the objective of this study is firstly to estimate the dietary content of nutrients from UPFs and secondly to examine associations between the consumption of UPFs and nutrient intake recommended in international guidelines for the prevention of NCDs (World Health Organization, 2002) among school-aged children and adolescents.

Participants were classified into three groups based on the energy contribution of UPFs. The distribution of anthropometric and sociodemographic characteristics for the whole population and across the tertiles of UPF consumption are shown in Table 4.2.1. Among the 469 participants, the age of children and the energy contribution of UPFs across the tertiles differed significantly. Furthermore, they spent more time than recommended (> 2 h per day) in front of a screen, with a significant difference between the tertiles (p=0.006). A significant difference in children's UPFs consumption was also observed between parents' educational levels. This may arise because the educational level of parents influences the occupation, which, in turn, influences the income level. Furthermore, the time required to prepare meals at home increases with increasing socioeconomic status. Therefore, all these factors may have an impact on the prevalence of overweight/obesity in children and adolescents.

Table 4.2.1 Distribution of anthropometric and sociodemographic characteristics for the whole population and across tertiles of energy contribution of ultra-processed foods.

		Median Relative Intake of UPFs (% of Total Energy Intake) Tertiles of the Contribution of UPFs to Total Energy Intake†			
	Total	**Q1 19.6% (13.4, 25.6)**	**Q2 38.6% (33.9, 44.4)**	**Q3 60.9% (54.8, 72.6)**	**p-Value**
n, (%)	469	157 (33.5)	156 (33.3)	156 (33.3)	
Age years, median (IQR)	9 (6-13)	7 (3, 14)	9 (6, 13)	9.5 (6.5, 14)	0.003
Weight, kg, median (IQR)	35 (21-54)	28 (17, 53)	38 (22, 52)	37 (25-55)	0.005
Height, m, mean, (SD)	1.39 (0.3)	1.34 (0.3)	1.39 (0.3)	1.44 (0.2)	0.013
BMI, kg/m^2, mean, (SD)	18.78 (4)	18.24 (3.8)	19.1 (4.1)	19 (4.1)	0.493
Group Age, n, (%)					0.681
Children	309 (65.9)	107 (22.9)	103 (22)	99 (21.1)	
Adolescents	160 (34.1)	50 (10.7)	53 (11.3)	57 (12.2)	
Sex n, (%)					0.754
Male	237 (50.5)	83 (17.7)	78 (16.6)	76 (16.2)	
Female	232 (49.5)	74 (15.8)	78 (16.6)	80 (17.1)	
Weight Status n, (%)					0.4
Normal weight	323 (74.4)	110 (25.6)	103 (23.7)	110 (25.4)	
Overweight / Obese	111 (25.6)	31 (7.1)	42 (9.7)	38 (8.8)	
Total screen time (hours), median (IQR)	2.2 (1.25, 3.5)	2 (1, 3)	2.2 (1, 3.5)	2.5 (1.8, 3.7)	0.006

		Median Relative Intake of UPFs (% of Total Energy Intake) Tertiles of the Contribution of UPFs to Total Energy Intake†			
	Total	**Q1 19.6% (13.4, 25.6)**	**Q2 38.6% (33.9, 44.4)**	**Q3 60.9% (54.8, 72.6)**	**p-Value**
Primary Guardian Education level, n (%)					0.05
≤6 years	12 (3.8)	3 (1)	8 (2.6)	1 (0.3)	
>6-12 years	123 (39.3)	42 (13.4)	35 (11.2)	46 (14.7)	
≥12 years	178 (56.9)	47 (15)	67 (21.4)	64 (20.5)	
Primary Guardian Professional Status, n (%)					0.441
Employed	215 (70)	59 (19.2)	81 (26.4)	75 (24.4)	
Unemployed / Homeworkers	77 (25.1)	28 (9.1)	21 (6.8)	28 (9.1)	
Pension	15 (4.9)	5 (1.6)	6 (2)	4 (1.3)	
Residual area, n (%)					0.231
Athens - Thessaloniki	269 (57.9)	87 (18.7)	84 (18)	98 (21.1)	
Islands - Crete	57 (12.3)	16 (3.4)	24 (5.2)	17 (3.7)	
Mainland	139 (29.9)	54 (11.6)	46 (10)	39 (8.4)	

$p < 0.05$; one-way ANOVA test for normally distributed values and Kruskall – Wallis test for skewed numerical variables (three group comparison); chi square test for categorical variables IQR: Interquartile range.

Table 4.2.2 shows the mean energy share of the NOVA 4 food group and its subgroups across tertiles of UPFs consumption. The results regarding the overall population were 40.6%, ranging from 19% of total calories in the 1st tertile to 64% in the 3rd tertile. The dietary share of half of UPFs subgroups increased significantly from the lowest to the highest tertile except for flavored dairy products, sugar-sweetened beverages, bakery products, and “other” UPFs, which include reconstituted meats, pre-prepared potatoes, fats, spreads, sauces, and other UPFs such as distilled alcoholic drinks, sparkling water, chocolate powder, baby formulas.

Table 4.2.2 Distribution (%) of total energy intake according to NOVA 4 food group across tertiles of ultra-processed food consumption in children and adolescents.

Mean Relative Intake (% of Total Energy Intake)					
	Tertiles of the Contribution of Ultra-Processed Foods to Total Energy Intake†				
Food Groups	**Pooled**	**Q1**	**Q2**	**Q3**	**P trend**
NOVA 4	40.6	19	40	64*	0.0
[a]Ready to eat/heat dishes	20.8	12.8	20	31.8*	0.0
[b]Flavoured dairy products	5.6	7.2	5	9.2	0.7
[c]Sugar-sweetened beverages	3.2	4.3	3.7	4.4	0.5
[d]Branded breads	6.1	5.7	9.5	8.5	0.1
[e]Savory Snacks	13	9.1	13.7	22.7*	0.0
[f]Sweet grain products	10.1	9.6	13.1	15.6*	0.0
[g]Sweets	7.6	6.7	10.1	12.8*	0.0
[h]Other	2.2	4.1	4.0	8.5	0.9

*P ≤ 0.05 for linear trend across quintiles of ultra-processed food consumption; %E: total daily energy intake; †Mean dietary share of ultra-processed foods per tertiles: 1^{st} n=157, [19% (7.2)]; 2^{sd} n= 156, [40.0% (5.6)]; 3^{rd} n=156, [64% (11.8)]; [a] Sandwiches, pizza, pies, tarts, mixed dishes, [b] Milk, yoghurt, drinks, [c] Sugar-sweetened drinks, fruit drinks, [d] Grain products, pita bread, [e] Savoury snacks, bakery pies, [f] Bakery sweets, cereal bars and biscuits, waffles and crepes, cereals, [g] Desserts, sweet pies and tarts, candies, jams, other sweet UPFs, [h] Reconstituted meats, pre-prepared potatoes, fats, spreads and sauces, other UPFs (distilled alcoholic drinks, sparkling water, chocolate powder, baby formulas)

The usual dietary intakes of macro-nutrients and their percentage from UPFs consumption according to AHA's recommendations are summarised in Table 4.2.3. In both sexes and all age groups, the percentage of the participants with a usual intake of fat, dietary cholesterol and saturated fats above daily values exceeded 63%. For added sugar, this value reached 29.3%. Additionally, more than 71% of children and adolescents did not meet the recommendations for PUFA and dietary fibre.

Table 4.2.3 Usual intakes of macronutrients stratified by sex and age group and percentage of the population having usual nutrient intakes above the estimated average requirement in Greek children and adolescents.

	Boys			Girls		
	Median (IQR)	**DV threshold[a]**	**>%DV threshold**	**Median (IQR)**	**DV threshold**	**>%DV threshold**
CHO (in relation to % average daily energy intake)						
1-3 years	43.2 (34.2, 49.4)	60% as energy	2.6	43.9 (38.3, 46.5)	60% as energy	0
4-8 years	44.8 (39, 51.6)	60% as energy	6.4	43.9 (40.6, 51.5)	60% as energy	2.7
9-13 years	42.6 (38.6, 48.8)	60% as energy	2.9	42.5 (34.6, 47.5)	60% as energy	3.3
14-18 years	42 (36.6, 48.5)	60% as energy	5.6	45 (39.4, 51.3)	60% as energy	3.1
Total (Boys and Girls)	43.5 (38.3, 49.5)	60% as energy	3.6			
Added sugars (in relation to % average daily energy intake)						
1-3 years	4.9 (1.7, 12.5)	10% as energy	21.1	15.8 (14.3, 18.7)	10% as energy	30
4-8 years	7.2 (4.1, 10.8)	10% as energy	35.9	14.4 (13.4, 18.7)	10% as energy	30.1
9-13 years	6.6 (3.7, 9.3)	10% as energy	37.1	15.5 (12.8, 18.1)	10% as energy	24.6

	Boys			Girls		
	Median (IQR)	**DV threshold[a]**	**>%DV threshold**	**Median (IQR)**	**DV threshold**	**>%DV threshold**
14-18 years	5.9 (3.2, 10.7)	10% as energy	20.4	13,1 (11.1, 17.4)	10% as energy	29.7
Total (Boys and Girls)	6.8 (3.8, 10.8)	10% as energy	29.5			
Protein (in relation to % average daily energy intake)						
1-3 years	15.6 (13.4, 20,5)	20% as energy	0	15.4 (12.1, 19)	20% as energy	0
4-8 years	14.4 (13.3, 16.2)	20% as energy	3.9	14.8 (11.7, 16.5)	20% as energy	12.3
9-13 years	15.1 (14.2, 18.6)	20% as energy	7.1	15.9 (12.9, 17.9)	20% as energy	8.2
14-18 years	17 (14.2, 18.6)	20% as energy	1.9	15.9 (13.4, 18)	20% as energy	6.2
Total (Boys and Girls)	15.2 (13, 17.7)	20% as energy	8.7			
Fat (in relation to % average daily energy intake)						
1-3 years	39.6 (35.5, 46.9)	35% as energy	76.3	43 (38.5, 47)	35% as energy	85
4-8 years	40.3 (34.5, 48)	35% as energy	74.4	41.7 (37, 46.2)	35% as energy	83.6
9-13 years	41.1 (36.2, 48.1)	35% as energy	80	42.9 (38.6, 48.8)	35% as energy	85.2

	Boys			Girls		
	Median (IQR)	**DV threshold[a]**	**>%DV threshold**	**Median (IQR)**	**DV threshold**	**>%DV threshold**
14-18 years	17 (14.2, 18.6)	35% as energy	75.9	39.8 (34.8, 46.3)	35% as energy	71.9
Total (Boys and Girls)	41.3 (36.2, 47.5)	35% as energy	78.9			
Cholesterol (mg/day)			> 300 mg/day			> 300 mg/day
1-3 years	407.9 (297.8,613.7)	300	73.7	315.1 (213.8, 456.3)	300	55
4-8 years	425.1 (295.6, 540.3)	300	74.4	311.6 (200.9, 486.8)	300	54.8
9-13 years	389.1 (211.8, 600.5)	300	61.4	357.8 (212.9, 570.4)	300	60.1
14-18 years	525 (323.8, 820.8)	300	75.9	306 (210.6, 497.8)	300	51.6
Total (Boys and Girls)	378.2 (228.8, 562)	300	63.2			
SFA (in relation to % average daily energy intake)						
1-3 years	15.8 (14.3, 18.7)	10% as energy	97.4	17.6 (13.1, 20.3)	10% as energy	90
4-8 years	15.4 (13.4, 18.7)	10% as energy	89.7	15.8 (12.7, 19.1)	10% as energy	93.1
9-13 years	15.5 (12.8, 18.1)	10% as energy	97.1	16.4 (14.2, 19.4)	10% as energy	88.5
14-18 years	13.1 (11.1, 17.4)	10% as energy	88.9	13.7 (10.8, 16.5)	10% as energy	81.2
Total	15.4 (12.7, 18.4)	10% as energy	90.6			

	Boys			Girls		
	Median (IQR)	DV threshold[a]	>%DV threshold	Median (IQR)	DV threshold	>%DV threshold
(Boys and Girls)						
	Median (IQR)	**DV threshold**	**<%DV threshold**	**Median (IQR)**	**DV threshold**	**<%DV threshold**
PUFA (in relation to % average daily energy intake)						
1-3 years	4.5 (3.8, 5.8)	6% as energy	78.9	4.8 (3.9, 6.2)	6% as energy	70
4-8 years	4.6 (3.9, 5.9)	6% as energy	75.6	4.9 (4, 6.7)	6% as energy	68.5
9-13 years	4.9 (4.2, 6.3)	6% as energy	71.4	4.8 (3.9, 5.7)	6% as energy	80.3
14-18 years	5.3 (4.4, 6.5)	6% as energy	66.7	5.6 (4.1, 8.1)	6% as energy	57.8
Total (Boys and Girls)	4.9 (4.1, 6.5)	6% as energy	70.9			
Dietary fibre (g/day)						
1-3 years	9.9 (7,2, 13.8)	20	92.1	8.9 (6.5, 14.2)	20	97.5
4-8 years	12.6 (8.7, 16.6)	20	85.9	12.2 (8.3, 16)	20	89
9-13 years	12.5 (10, 17.9)	20	81.4	12.1 (8.9, 17.5)	20	83.6
14-18 years	15.3 (9.5, 24)	20	61.1	12.5 (8.8, 16.5)	20	81.2
Total (Boys and Girls)	12.3 (8.6, 17.1)		83.4			

All values refer to medians; IQR: Interquartile range.

[a]% DV, % daily values, acceptable macronutrient distribution ranges according to American Heart Association (AHA): carbohydrates (<60% of total energy), proteins (<20% of total energy), fats (<35% of total energy), cholesterol (<300mg/d), saturated fats (<10% of total energy), polyunsaturated fats (≥6% of total energy), and dietary fiber (≥20g/d); Values recommended by World Health Organization (WHO): free sugars (<10% of total energy).

The usual dietary intakes of micro-nutrients and their percentage from UPFs consumption according to the Institute of Medicine's (IOM) recommendations are summarised in Table 4.2.4. The prevalence of inadequacy in vitamins D, E, K and pantothenic acid among the population was high enough, ranging from 55 to 90%. Regarding minerals, more than 86% of participants exceeded the adequate intake for sodium, while the prevalence of inadequacy for potassium was extremely high (70%) too.

Table 4.2.4 Usual intakes of micronutrients stratified by sex and age group and percentage of the population having usual nutrient intakes below the estimated average requirement in Greek children and adolescents.

	Boys			Girls		
	Median (IQR)	**EAR**	**<EAR%**	**Median (IQR)**	**EAR**	**<EAR%**
Vitamin A (mcg/day)						
1-3 years	996.4 (638.9, 1583)	210	0	830.5 (546, 1142.2)	210	2.5
4-8 years	1135.8 (781, 1662.8)	275	3.8	1040.6 (730.1, 1419.4)	275	0
9-13 years	1163.5 (767.1, 1505.6)	445	10	1051.5 (707.9, 1680.7)	420	9.8
14-18 years	1493.3 (729.7, 2263.1)	630	22.2	1024.4 (672.2, 1484.1)	485	12.5
Total (Boys and Girls)	1090.6 (718.5, 1604.6)		7.7			
Vitamin D (mcg/day)						
1-3 years	6.7 (5.4, 8.6)	10	78.9	5.6 (4, 7.9)	10	90
4-8 years	6 (3.6, 8.5)	10	82.1	5.4 (3.5, 7.1)	10	95.9
9-13 years	5.2 (2.7, 6.6)	10	94.3	4.1 (2, 6.7)	10	90.2
14-18 years	5.3 (3, 8.2)	10	85.2	3.7 (1.9, 4.4)	10	98.4
Total (Boys and Girls)	5.2 (3, 7.3)		90			
Vitamin E (mg/day)						
1-3 years	4.1 (2.9, 5.5)	5	68.4	4 (2.3, 6.2)	5	62.5
4-8 years	6.2 (4.2, 9.6)	6	47.4	5.2 (3.2, 8.1)	6	63
9-13 years	6.2 (4.4, 10)	9	68.6	6.9 (3.8, 9.8)	9	62.3
14-18 years	8.8 (5.1, 13.9)	12	66.7	6 (4.2, 9)	12	87.5
Total	5.8		65.3			

	Boys			Girls		
	Median (IQR)	**EAR**	**<EAR%**	**Median (IQR)**	**EAR**	**<EAR%**
(Boys and Girls)	(3.9, 9.5)					
Vitamin K (mcg/day)						
1-3 years	15 (10.5, 33)	30	73.7†	14.6 (9.4, 24.2)	30	80†
4-8 years	16.7 (12, 24.2)	55	93.6†	17.7 (9.5, 29.1)	55	91.8†
9-13 years	20.2 (10.2, 34.9)	60	88.6†	19.7 (10.4, 29.5)	60	91.8†
14-18 years	28.4 (13.1, 52.5)	75	83.3†	20.7 (12.9, 40.9)	75	89.1†
Total (Boys and Girls)	18.9 (11.3, 33.6)		87.9†			
Vitamin C (mg/day)						
1-3 years	56.3 (21.1, 107.8)	13	10.5	49.8 (21.7, 100.2)	13	15
4-8 years	55.7 (29.8, 98.1)	22	17.8	58.3 (28.6, 91.6)	22	20.5
9-13 years	56.6 (33.3, 97.3)	39	32.9	56.6 (25.7, 106.6)	39	37.7
14-18 years	62.7 (38, 103.4)	63	51.9	47.5 (25.7, 98.1)	56	54.7
Total (Boys and Girls)	56.6 (28, 99.4)		31			
Vitamin B1 (mg/day)						
1-3 years	1.1 (0.8, 1.6)	0.4	2.6	0.9 (0.7, 1.3)	0.4	2.5
4-8 years	1.5 (1.1, 1.9)	0.5	3.8	1.3 (1, 1.6)	0.5	0
9-13 years	1.5 (1.2, 2.2)	0.7	4.3	1.6 (1.2, 2.1)	0.7	1.2
14-18 years	1.9 (1.4, 2.5)	1.0	5.6	1.4 (1.1, 1.7)	0.9	14.1
Total (Boys and Girls)	1.4 (1.1, 1.9)		48.1			
Vitamin B2 (mg/day)						

	Boys			Girls		
	Median (IQR)	EAR	<EAR%	Median (IQR)	EAR	<EAR%
1-3 years	1.7 (1.3, 2.2)	0.4	0	1.4 (1.2, 1.7)	0.4	0
4-8 years	1.8 (1.4, 2.6)	0.5	0	1.7 (1.3, 2)	0.5	1.4
9-13 years	1.8 (1.4, 2.3)	0.7	2.9	1.8 (1.4, 2.2)	0.7	3.8
14-18 years	2 (1.6, 2.7)	1.0	5.6	1.6 (1.2, 2)	0.9	14.1
Total (Boys and Girls)	1.7 (1.3, 2.2)		35.6			
Niacin (mg/day)						
1-3 years	8.7 (6.7, 20)	5	23.7	8.3 (4.2, 12.1)	5	30
4-8 years	12.1 (8.6, 19.1)	6	10.3	10.8 (7.2, 16.4)	6	20.5
9-13 years	13 (9.9, 22.9)	9	18.6	13 (9.8, 19.6)	9	23
14-18 years	21 (14.4, 30.1)	12	14.8	15.2 (9.3, 24.8)	11	34.4
Total (Boys and Girls)	12.9 (8.5, 20.3)		21.1			
Pantothenic acid (mg/day)						
1-3 years	3.4 (2.5, 4.9)	2	5.3†	3 (2.7, 3.8)	2	15†
4-8 years	3.4 (2.5, 4.7)	3	34.6†	3 (2.5, 4)	3	52.1†
9-13 years	3.3 (2.4, 4.2)	4	71.4†	3.2 (2.6, 4)	4	73.8†
14-18 years	4,1 (2.8, 5.6)	5	66.7†	2.9 (2, 3.9)	5	92.2†
Total (Boys and Girls)	3.3 (2.4, 4.3)		55†			
Vitamin B6 (mg/day)						
1-3 years	1.2	0.4	5.3	1	0.4	7.5

	Boys			Girls		
	Median (IQR)	**EAR**	**<EAR%**	**Median (IQR)**	**EAR**	**<EAR%**
	(0.8, 1.9)			(0.8, 1.3)		
4-8 years	1.4 (1, 2.2)	0.5	2.6	1.2 (0.9, 1.7)	0.5	4.1
9-13 years	1.7 (1, 2.3)	0.8	14.3	1.5 (1.1, 2.2)	0.8	14.8
14-18 years	2 (1.5, 2.6)	1.1	5.6	1.3 (1, 1.9)	1.0	26.6
Total (Boys and Girls)	1.4 (1, 2.2)		10.3			
Folate (mcg/day)						
1-3 years	183 (108.2, 279.1)	120	26.3	152.6 (96.4, 210)	120	35
4-8 years	231.3 (166, 359.8)	160	24.4	225.6 (138.6, 292.1)	160	32.9
9-13 years	256.8 (191.1, 390.9)	250	45.8	237.6 (157.4, 335.5)	250	55.7
14-18 years	302.3 (205.4, 434.9)	330	61.1	247.8 (150.8, 343.1)	330	71.2
Total (Boys and Girls)	232.9 (154, 335.1)		44.4			
Vitamin B12 (mcg/day)						
1-3 years	3 (2.3, 4.7)	0.7	0	2.7 (1.8, 3.3)	0.7	2.5
4-8 years	3 (2, 6)	1.0	2.6	2.9 (1.9, 4)	1.0	6.9
9-13 years	3.5 (2.4, 5.5)	1.5	4.3	2.9 (2, 4.4)	1.5	16.4
14-18 years	3.8 (2.5, 5.6)	2.0	16.7	2.4 (1.6, 4.1)	2.0	39.1
Total (Boys and Girls)	3.1 (2, 4.6)		11.5			
Calcium (mg/day)						
1-3 years	985.8	500	5.3	860.5	500	7.5

	Boys			Girls		
	Median (IQR)	**EAR**	**<EAR%**	**Median (IQR)**	**EAR**	**<EAR%**
	(696.9, 1223.9)			(661.2, 1029.5)		
4-8 years	1053.5 (737.1, 1392.9)	800	26.9	953.5 (736.7, 1178)	800	32.9
9-13 years	993.9 (692.7, 1475. 7)	1100	58.6	1047.8 (727.9, 1352)	1100	55.7
14-18 years	1017.8 (687.4, 1642.9)	1100	53.7	860 (591.8, 1061.8)	1100	81.3
Total (Boys and Girls)	966.8 (691.6, 1270.7)		43.1			
Phosphorus (mg/day)						
1-3 years	1011.8 (805.1, 1348.1)	380	0	880.9 (718, 1061.2)	380	2.5
4-8 years	1116.5 (837.3, 1358.3)	405	1.3	986.1 (755.4, 1275.6)	405	1.4
9-13 years	1066 (846.7, 1513.5)	1055	50	1114.6 (854.9, 1307.4)	1055	44.3
14-18 years	1306.6 (1051.8, 1787.4)	1055	25.9	978.3 (744.8, 1174.5)	1055	64.1
Total (Boys and Girls)	1032.8 (807.8, 1342.1)		25.1			
Magnesium (mg/day)						
1-3 years	182.4 (146.3, 247.5)	65	0	162.7 (144.6, 192.9)	5	2.5
4-8 years	207.2 (162.9, 252.6)	110	5.1	191.9 (151.4, 222.1)	110	8.2
9-13 years	192.3 (162.7, 283.1)	200	54.3	204 (154.6, 258)	200	45.9
14-18 years	268.8 (210.5, 350.9)	340	68.5	210.6 (165.9, 257.4)	300	85.9
Total (Boys and Girls)	203 (161.2, 261.2)		35.4			
Iron (mg/day)						
1-3 years	8.4 (5.9, 12.1)	3.0	7.9	6.1 (4.4, 10.3)	3.0	12.5
4-8 years	10	4.1	2.6	9.5	4.1	12.3

	Boys			Girls		
	Median (IQR)	**EAR**	**<EAR%**	**Median (IQR)**	**EAR**	**<EAR%**
	(6.7, 16.4)			(6.9, 13.4)		
9-13 years	12.1 (8.5, 17.2)	5.9	10	11.9 (8.3, 14.9)	5.7	11.5
14-18 years	15.2 (11, 21.3)	7.7	9.3	10.9 (7.9, 16.2)	7.9	25
Total (Boys and Girls)	10.9 (7.5, 15.7)		11.3			
Zinc (mg/day)						
1-3 years	7 (5.6, 9.9)	2.5	0	6.2 (4.9, 8.2)	2.5	7.5
4-8 years	8 (6.1, 11.4)	4.0	3.9	7 (5.3, 9.2)	4.0	11
9-13 years	9.2 (6.5, 12.5)	7.0	28.6	8.6 (6.7, 10.7)	7.0	27.9
14-18 years	10.8 (8.2, 15.2)	8.5	29.6	6.7 (5.3, 9.2)	7.3	59.4
Total (Boys and Girls)	8.1 (6, 10.9)		22			
Copper (mcg/day)						
1-3 years	636.7 (477.9, 787)	260	0	593.1 (490.8, 735.8)	260	10
4-8 years	710.6 (595.6, 933.9)	340	3.9	600.4 (457.4, 865.2)	340	12.3
9-13 years	727.9 (535.9, 989.9)	540	25.7	729.7 (543.8, 944.8)	540	24.6
14-18 years	891.2 (560.6, 1.450.7)	685	29.6	681.7 (495, 926.3)	685	51.6
Total (Boys and Girls)	707.7 (525.1, 960.8)		20.5			
Selenium (mcg/day)						
1-3 years	56.3 (41, 79.6)	17	0	49.5 (36.7, 78.9)	17	0

	Boys			Girls		
	Median (IQR)	**EAR**	**<EAR%**	**Median (IQR)**	**EAR**	**<EAR%**
4-8 years	70 (52.2, 91.2)	23	1.3	61 (43.1, 86.5)	23	8.2
9-13 years	78.1 (55.2, 105.4)	35	10	76.3 (53.6, 100.9)	35	9.8
14-18 years	100.3 (64.3, 133.6)	45	9.3	66.4 (50.9, 94)	45	20.3
Total (Boys and Girls)	69.2 (50.1, 97.6)		7.9			
Potassium (mg/day)						
1-3 years	1992.1 (1467.9, 2330.2)	2000	50†	1741.6 (1443.2, 2121.9)	2000	70†
4-8 years	1858.2 (1524.8, 2439.5)	2300	65.4†	1911.4 (1510.5, 2184.5)	2300	79.5†
9-13 years	1906.2 (1519.2, 2467.5)	2500	77.1†	1981.5 (1542.9, 2577.4)	2300	70.5†
14-18 years	2520.9 (1905.4, 3333.6)	3000	63†	1859.8 (1329.4, 2271.1)	2300	76.6†
Total (Boys and Girls)	1935.8 (1526.8, 2456.2)		70.3†			
	Median (IQR)	**EAR**	**≥EAR%**	**Median (IQR)**	**EAR**	**≥EAR%**
Sodium (mg/day)						
1-3 years	1631.5 (943.4, 2316.6)	800	92.1†	1168.7 (832.6, 1651)	800	75†
4-8 years	1928.8 (1491.8, 2702.8)	1000	94.9†	1705.8 (1141.5, 2460.7)	1000	83.6†
9-13 years	2181.5 (1635.4, 3037.4)	1200	87.1†	2404.3 (1769.2, 3049.8)	1200	86.9†
14-18 years	2874 (1968.4, 3522.8)	1500	87†	2045.2 (1651.3, 2855.2)	1500	81.3†
Total (Boys and Girls)	2028.4 (1421.2, 2897.8)		86.4†			

All values refer to medians; IQR: Interquartile range.

EAR, estimated average requirement; AI, adequate intake;

†AI and therefore the percentages of subjects below AI have been calculated.

The median contents of all macronutrients of the overall diet and across tertiles of ultra-processed foods are shown in Table 4.2.5. From the first to the third tertile, there were increases in total carbohydrates (from 42.6 to 43.7% kcal), added sugars (from 4.5 to 8.1% kcal), saturated fats (from 14.9 to 16% kcal), PUFA (from 4.9 to 5.2% kcal), energy density (from 1416 to 1920 kcal/day) while there were reductions in proteins (from 15.9 to 14.6% kcal). Even after controlling for potential sociodemographic confounders, both trends - an increase in NCD-promoting nutrients and a decrease in NCD-protective nutrients - were statistically significant across tertiles of UPFs consumption (P<0.05), except for saturated fats and fibre.

Table 4.2.5 Median content of macronutrients in the overall diet across tertiles of ultra-processed food consumption in accordance with AHA's recommendations in children and adolescents.

Indicator[a]	Overall Diet	Intakes by tertiles of Ultra-Processed Foods as per mean Energy Intake			Standardized Regression Coefficient			
	Total	**Q1**	**Q2**	**Q3**	**Crude**	**P trend**	**Adjusted [c]**	**P trend**
Energy (kcal/day)	1655.4 (1299.1, 2185.1)	1415.8 (1127.5, 1776.2)	1692.7 (1365.6, 2147.6)	1920 (1477, 2425.9)	0.2*	0.0	0.2*	0.0
CHO (%)	43.5 (38.3, 49.5)	42.6 (36, 48.3)	45 (38.9, 50.2)	43.7 (38.6, 43.9)	0.1*	0.01	0.2*	0.01
Added sugar (%)	6.8 (3.8, 10.8)	4.5 (2.3, 8.8)	7.7 (5.1, 10.8)	8.1 (4.9, 13)	0.3*	0.0	0.3*	0.0
Protein (%)	15.2 (13, 17.7)	15.9 (14, 19.4)	15.1 (12.9, 17.5)	14.6 (11.7, 16.2)	-0.3*	0.0	-0.3*	0.0
Fat (%)	41.3 (36.2, 47.5)	41.8 (36.1, 47.1)	40.1 (35.9, 45.9)	42.4 (36.9, 48.4)	0.0	0.97	-0.03	0.7
Cholesterol (mg/d)	378.2 (228.8, 562)	385.1 (232.4, 609.3)	352.9 (222.4, 521.3)	385.8 (225.2, 543)	-18.1	0.3	-0.9	0.1
SFA (%)	15.4 (12.7, 18.4)	14.9 (11.9, 18.1)	15.3 (12.6, 18)	16 (13.4, 18.9)	0.1*	0.03	0.1	0.3
PUFA (%)	4.9 (4.1, 6.5)	4.9 (4.2, 6.2)	4.9 (4.2, 6.1)	5.2 (3.9, 7.6)	0.1*	0.0	0.2*	0.0
Dietary fibre (g/d)	12.3 (8.6, 17.1)	11.3 (7.6, 16.3)	13.1 (9.9, 17.9)	12.3 (9, 17.2)	0.01	0.9	-0.2*	0.0

[a]All values refer to medians; IQR: Interquartile range;

[b]Adjusted for age (years), sex, residual areas (main Metropolitan areas), screen time (hrs), and parents' educational level (≤6 years, >6-12 years, ≥12 years) and NOVA 4 tertiles;

*P ≤ 0.05 for linear trend across quintiles of ultra-processed food consumption.

The median contents of all micronutrients of the overall diet and across tertiles of ultra-processed foods are presented in Table 4.2.6. From the first to the third tertile, there were increases for sodium (from 1641 to 2485 mg/day), vitamins E and B1, folate, calcium and iron, while there were decreases for potassium (1953 to 1799mg/d). Even after controlling for potential sociodemographic confounders, both trends - an increase in NCD-promoting nutrients and a decrease in NCD-protective nutrients - were statistically significant across tertiles of UPFs consumption ($P<0.05$), except for vitamins A, K, B2, niacin, B12 and phosphorus.

Table 4.2.6 Median content of micronutrients in the overall diet across tertiles of ultra-processed food consumption in accordance with IOM's recommendations in children and adolescents.

Indicator[a]	Overall Diet	Intakes by tertiles of Ultra-Processed Foods as per mean Energy Intake			Standardized Regression Coefficient			
	Total	Q1	Q2	Q3	Crude	P trend	Adjusted [b]	P trend
Vitamin A (mcg/d)	1090.6 (718.5, 1604.6)	899.9 (637.1, 1545.4)	1106.7 (756.7, 1556)	1195.4 (785, 1780.8)	0.1*	0.03	0.08	0.2
Vitamin D (mcg/d)	5.2 (3, 7.3)	5.5 (3.8, 7.9)	4.9 (3, 6.8)	4.8 (2.5, 7.2)	-0.01	0.9	0.1	0.1
Vitamin E (mg/d)	5.8 (3.9, 9.5)	5.1 (3.4, 8)	6.1 (4.3, 9.3)	6.6 (4.1, 12.2)	0.2*	0.0	0.2*	0.0
Vitamin K (mcg/d)	18.9 (11.3, 33.6)	15.6 (9.7, 29.5)	20.1 (12.5, 33)	20.8 (12.5, 40.4)	0.04	0.3	0.1*	0.02
Vitamin C (mg/d)	56.6 (28, 99.4)	61.5 (30.6, 102.6)	60.5 (28.5, 99.3)	46.8 (27, 94.5)	-0.04	0.4	-0.04	0.5
Vitamin B1 (mg/d)	1.4 (1.1, 1.9)	1.2 (0.9, 1.7)	1.5 (1.1, 1.9)	1.6 (1.2, 2.3)	0.2*	0.0	0.2*	0.0
Vitamin B2 (mg/d)	1.7 (1.3, 2.2)	1.7 (1.2, 2.1)	1.7 (1.3, 2.2)	1.8 (1.4, 2.5)	-0.1*	0.01	0.1*	0.03
Niacin (mg/d)	12.9 (8.5, 20.3)	10.8 (6.7, 18.4)	13.2 (9.4, 20.2)	14.3 (9.7, 22.9)	0.1*	0.04	0.1	0.1
Pantothenic acid (mg/d)	3.3 (2.4, 4.3)	3.3 (2.5, 4.3)	3.5 (2.5, 4.1)	3.3 (2.4, 4.4)	0.2	0.99	0.1	0.3
Vitamin B6 (mg/d)	1.4 (1, 2.2)	1.5 (1, 2)	1.4 (1.1, 2.2)	1.4 (0.9, 2.2)	0.0	0.97	0.0	0.98
Folate (mcg/d)	232.9 (154, 335.1)	200.9 (124, 312.3)	248 (165, 326.9)	249.6 (176.8, 407)	0.1*	0.01	0.2*	0.02
Vitamin B12 (mcg/d)	3.1 (2, 4.6)	3.1 (2, 4.4)	3 (2, 4.4)	3.1 (1.9, 4.9)	0.1	0.1	0.2*	0.01
Calcium (mg/d)	966.8 (691.6, 1270.7)	879.4 (648, 1088.2)	935.4 (693.2, 1237.8)	1096.9 (805.6, 1476.9)	0.2*	0.0	0.2*	0.0

Indicator[a]	Overall Diet	Intakes by tertiles of Ultra-Processed Foods as per mean Energy Intake			Standardized Regression Coefficient			
	Total	Q1	Q2	Q3	Crude	P trend	Adjusted[b]	P trend
Phosphorus (mg/d)	1032.8 (807.8, 1342.1)	967.7 (779.4, 1279.5)	1016.6 (805.1, 1311.1)	1132.9 (850.6, 1450.6)	0.1*	0.01	0.1	0.1
Magnesium (mg/d)	203 (161.2, 261.2)	186.2 (147.4, 241.6)	170.7 (208.2, 269.7)	203.1 (163.4, 277.2)	0.04	0.4	-0.0	0.9
Iron (mg/d)	10.9 (7.5, 15.7)	10 (5.6, 15.3)	11.1 (8.1, 15.2)	11.6 (8.4, 18.4)	0.2*	0.0	0.2*	0.01
Zinc (mg/d)	8.1 (6, 10.9)	8 (5.4, 10.4)	8.1 (6.1, 10.8)	8.2 (6.1, 11.2)	0.1	0.1	0.8	0.2
Copper (mcg/d)	707.7 (525.1, 960.8)	609.3 (456.4, 881.3)	733.4 (586, 971.2)	741.6 (541, 1010.9)	0.1	0.1	0.1	0.3
Selenium (mcg/d)	69.2 (50.1, 97.6)	59.1 (40.9, 93.2)	71 (52.9, 100.1)	77.2 (53.2, 99.6)	0.1	0.1	0.1	0.3
Potassium (mg/d)	1935. 8 (1526.8, 2456.2)	1952.8 (1535.2, 2575.8)	2014.2 (1646.8, 2503.3)	1799.4 (1397.5, 2307)	-0.1*	0.0	-0.2*	0.01
Sodium (mg/d)	2028.4 (1421.2, 2897.8)	1640.5 (1059, 2264.9)	2121 (1451.4, 2826.4	2484.8 (1818.3, 3240.8)	0.3*	0.0	0.3*	0.0

[a]All values refer to medians; IQR: Interquartile range;

[b]Adjusted for age (years), sex, residual areas (main Metropolitan areas), screen time (hrs), and parents' educational level (≤6 years, >6-12 years, ≥12 years) and NOVA 4 tertiles;

*P ≤ 0.05 for linear trend across quintiles of ultra-processed food consumption.

Regarding dietary recommendations for preventing NCD, Table 4.2.7 presents the prevalence of nutrient intake inadequacies in the overall diet and across tertiles of ultra processed foods. As the dietary share of UPFs to total energy intake increased, the prevalence of people exceeding the upper limits recommended for added sugars increased significantly. A large majority of the population did not meet the adequate intake for potassium, and the prevalence increased as the consumption of ultra-processed foods rose. Most notable were the trends of added sugars, which increased from 17.2% to 39.7% (2 times), and sodium, which increased from 79.6% to 91% from the lowest to the highest UPFs tertile. The highest prevalence of excessive nutrient intake was found for saturated fats (90.6%), followed by sodium (86.4%) and added sugars (29.8%). However, the highest prevalence of inadequate nutrient intake was indicated in dietary fibre (83.5%), PUFA (70.9%) and potassium (70.3%).

Table 4.2.7 Prevalence of inadequate nutrient intake across tertiles of ultra-processed food consumption among children and adolescents aged 2-18 years, (HNNHS 2015).

		Intakes by tertiles of Ultra-Processed Foods as per mean Energy Intake			PR			
Indicator	**Overall Diet**	**Q1**	**Q2**	**Q3**	**Crude**	**P trend**	**Adjusted[a]**	**P trend**
	Individuals who did not meet the recommendation (%)							
Added sugars (≥10% of total energy)	29.5	17.2	32.7	39.7	1.5*	0.0	1.5*	0.0
Saturated fats (≥10% of total energy)	90.6	90.4	89.7	91.2	1.0	0.9	1.0	0.7
Polyunsaturated fats (<6% of total energy)	70.9	72.6	74.4	64.7	1.0	0.4	0.9	0.4
Dietary fibre (<20g/d)	83.5	84.1	81.4	84	1.0	0.99	1.0	0.8
Sodium (≥AI%)	86.4	79.6	91	91	0.6*	0.05	0.7	0.1
Potassium (<AI%)	70.3	63.7	67.3	78.8	1.1	0.1	1.1	0.2

AI, adequate intake;

PR = Prevalence ratios estimated using Poisson regression;

[a]Adjusted for age (years), sex, residual areas (main Metropolitan areas), screen time (hrs), and parents' educational level (≤6 years, >6-12 years, ≥12 years) and NOVA 4 tertiles;

*P ≤ 0.05 for linear trend across quintiles of ultra-processed food consumption.

CHAPTER 5 DISCUSSION

Over the last four decades, the number of children and adolescents aged 5-19 years with overweight/obesity has increased more than tenfold worldwide. The prevalence of obesity has nearly tripled from 4% in 1975 to over 18% in 2016 (World Health Organization, 2021). Childhood obesity is classified as one of the major public health issues of the 21st century (Spinelli et al., 2019) as it is associated with adverse health consequences such as cardiometabolic disorders, including dyslipidemia, hypertension, insulin resistance, and glucose intolerance (Reilly, 2006) as well as an increased risk of obesity later in life (Freedman et al., 2009). Increasing evidence suggests that the key risk factors for the development of overweight and obesity are unhealthy diets (Sirkka et al., 2021).

There is evidence that the population of southern Europe is moving away from traditional eating habits like the Mediterranean diet in favor of more "Westernized" eating habits (Grosso et al., 2014). The quality of the dietary pattern that individuals follow is determined not only by its content of specific nutrients or food items but also by other important factors such as the content of processed foods (Monteiro et al., 2018; Hall et al., 2019). Diet surveys have been showing the negative eating habits of adolescents, that they replaced healthy foods with ultra-processed (Sirkka et al., 2021; Parnham et al., 2022).

The rising prevalence of childhood obesity and cardiometabolic co-morbidities, the widespread use of UPFs among children and adolescents, and the scarcity of systematic reviews on this topic prompted us to conduct a scoping systematic review with the goal of gathering all existing knowledge about the relation between UPF consumption and obesity and cardiometabolic risk factors during childhood and adolescence.

Consumption of UPFs was related to overweight and obesity in children and adolescents, according to findings from cross-sectional and longitudinal studies included in the systematic review (Neves et al., 2022; Bawaked et al., 2020; Vedovato et al., 2021; Costa et al., 2019; Costa et al., 2021; Chang et al., 2021; Neri et al., 2022; Louzada et al., 2015; Viola et al., 2020). In a previous systematic review of children and adolescents, Costa et al. (2018) found a positive relationship between UPF consumption and body fat (Costa et al., 2018). On the other hand, de Amicis et al. (2022), in a recent systematic review, found inconsistent results concerning UPF consumption and adiposity measures in children and adolescents (De Amicis et al., 2022). Noteworthy, pertinent research on adults revealed more robust findings indicating a positive relationship between UPF intake and obesity (Rauber et al., 2021; Juul et al., 2018; Nardocci et al., 2019; Machado et al., 2020).

Cardiometabolic co-morbidities are another area of interest among children and adolescents. The food industry commonly uses trans and saturated fats to improve product palatability and texture. According to three studies included in our systematic review, there was a positive association between UPFs and dyslipidemia (Leffa et al., 2020; Rauber et al., 2015; Zhang et al., 2022). Similar findings were observed in US adults, with an inverse association between % kcal from UPFs and cardiovascular health (Zhang et al., 2022). However, a studyindicated no association of UPFs with dyslipidemia in children when socioeconomic class and maternal education were also examined (Gadelha et al., 2019). Another major issue with industrial food processing is the high salt content of UPFs, which is related to high blood pressure. Findings from our systematic review indicated that two studies found that higher consumption of UPFs was associated with higher BP levels (Bawaked et al., 2020; Oliveira et al., 2020), while Melo et al. (2017) showed no such association among adolescents (Melo et al., 2017). In addition, a higher consumption of UPFs was associated with an increased risk of hypertension, according to a longitudinal analysis of 8754 adults (Scaranni et al., 2021). Moreover, high levels of added sugars in UPFs can cause energy imbalances and an unhealthy blood glucose profile. Only one study of children found a positive association between UPFs and glucose profile (Costa et al., 2019), and this was consistent with studies in adults globally that indicated a higher prevalence of type 2 diabetes with higher consumption of UPFs (Srour et al., 2020; Levy et al., 2021; Nardocci et al., 2021). All the aforementioned risk factors included in MEtS, and Tavares et al. (2012) found that an increase in UPFs caused MEtS among adolescents (Tavares et al., 2012). A cross-sectional study among 6,385 US young adults found that a higher dietary contribution of UPFs was related to a higher prevalence of MetS (Martínez Steele et al., 2019).

In the current PhD thesis, under the context of the Hellenic National Nutrition and Health Survey (HNNHS), in a sample of Greek children and adolescents aged ≥ 2-18 years old, it was studied the consumption of UPFs and their major contributors. Furthermore, it was examined the association of high consumption of UPFs with the likelihood of obesity and nutrient intake recommended in international guidelines for the prevention of NCDs (Krauss et al., 2000).

The main finding of this study was that most children and adolescents in Greece have a high UPF diet (41%), with the proportion ranging from 19% to 64% of their total daily energy intake. The main contributors of total energy intake from the NOVA 4 food group that were consumed by weight status and across tertile were ready-to-eat/heated dishes, savory snacks, sweet grain products and sweets. Regarding the dietary share of UPFs subgroups, the consumption of the main contributors increased significantly from the lowest to the highest tertile. Results indicated that there were no significant differences in the percentage of total energy intake contribution from NOVA 4 food subgroups between weight status groups except from the subgroup of “other”. It was shown that normal weight children consume more reconstituted meats, pre-prepared potatoes, fats, spreads and sauces than overweight/obese. Furthermore, the percent of each (sub)-food group of UPF to total energy provided by all NOVA 4 food groups was calculated, and the same four food groups contributed up to 86% of total UPF intake, with ready-to-eat/heat dishes were being the most prominent with 36.2% of the total population. Results from our study are in accordance with other studies that have also reported high UPF consumption among children (Juul et al., 2022; Moubarac et al., 2017; Rauber et al., 2018; Araya et al., 2021; Detopoulou et al., 2023). In particular, the reported range from studies conducted in North America was from 47.7% of total energy (Moubarac et al., 2017) to 57% (Juul et al., 2022), with the latter study also reporting a 3.5% increase in UPF intake in 16 years [from 53.5% in 2001–2002 to 57% in 2017–2018] (Juul, et al., 2022). The highest consumption of UPF in children 4 to 10 years of age was reported in the UK, with an estimated average of 65% of daily calories derived from their National Diet and Nutrition Survey (NDNS) (Onita et al., 2021). In the UK, a previous study conducted in children over 1.5 years found that UPF contributed to 56.8% of daily energy intake (Rauber et al., 2018). Another study conducted on Greece found that 40.7% of the daily caloric intake was derived from UPFs (Detopoulou et al., 2023), even though a convenience sample of young adults was used. To our knowledge, no other studies in Greece have evaluated UPF intake in children.

A recent study demonstrated the high consumption of UPFs. Fonseca et al. (2023) in a cross-sectional study conducted on 326 children aged 7-9 years old in Brazil assessed the rate of UPF consumption and related variables in children attending public schools. Daily consumption of ultra-processed foods was 69.6% of the population. Adjusted analyses revealed that eating ultra-processed food was linked to skipping breakfast, midafternoon snacks, and dinner, being sedentary, and consuming risky foods. Conversely, eating a diet high in natural or minimally processed foods was linked to being older as well as eating lunch, dinner, a mid-afternoon snack, and protective foods (Fonseca et al., 2023). An assessment of energy intake by the level of food processing by age group was conducted through a cross-study among 15,444 individuals older than two years. Authors showed that ultra-processed foods constituted 26% of daily energy intake; this percentage was higher in children and adolescents than adults ($p < 0.01$). Among ultra-processed foods, cookies, pastries, sweetened beverages, and confectionery comprised two-thirds of the energy (Zapata et al., 2023).

Another objective of this study was to assess the association of UPF consumption with weight status in children and adolescents. In a multiple logistic regression between weight status and UPFs consumption, the adjusted odd ratio for sex, age category, total energy intake, and total screen time showed no significant differences by tertile of NOVA 4 increase. Furthermore, the main contributors of NOVA 4, as a percent increase per total energy intake, were examined in relation to the probability of overweight and obesity. Our results showed that savoury snacks & baked goods were found to statistically increase the likelihood of overweight and obesity when consumption exceeded 62% of total caloric intake. The same tendency was observed with ready-to-eat/heat dishes, but it did not reach statistical significance. The lack of an association between UPF consumption and obesity in children observed in the present study is in accordance with other studies that also examined the same relationship (Enes et al., 2019; Oliveira et al., 2020). Inversely, other studies indicated that higher consumption of UPFs was associated with an increase in the risk of overweight/obesity. More specifically, a Brazilian cross-sectional study among 790 adolescents observed that UPF consumption increased for adolescents who skipped breakfast, leading to an increased likelihood of obesity (Neves et al., 2022). The authors did not assess the actual amount but only the frequency of consumption. Furthermore, in Portugal, a longitudinal study with 1,175 children showed that higher consumption of UPFs at 4 years of age was associated with a higher BMI z-score at 10 years (Vedovato et al., 2021), in agreement with another prospective study conducted in 3year-olds (Sirkka et al., 2021), even though the latter examined a UPF type diet based on principal component analysis and NOVA system categorization. A combination of the NOVA system with dietary pattern derivation from a food frequency questionnaire was used by Neri et al. (2022) in adolescents and found that higher consumption of UPFs was associated with 52% and 63% higher odds of abdominal and visceral overweight/obesity, respectively, compared to lower consumption (Neri et al., 2022). Results were based on the proportion of the population following a UPF-like dietary pattern and not on the proportion of UPF in the total daily energy intake.

A longitudinal study with baseline data from 2013–2014 (n = 2,611) included children aged 0–3 years old. A follow-up study comprising 2,383 kids was conducted in 2015–2016. This study investigated how sugar-sweetened beverages (SSB), and sugar-containing ultra-processed (SUP) foods affected body mass index changes during early childhood. In multivariable-adjusted models, the change in BMIz over a 2-year period was positively correlated with the intake of SUP and SSB foods (in combination, but not separately) in both waves (β coefficient: 0.13, 95% confidence interval [CI]: 0.02, 0.23). Among non-consumers, BMI declined. Significant associations were found with SUP foods but not with SSB foods alone. The BMI of children who consumed more than two SSB and

SUP foods at baseline was higher (p for trend = 0.02) (Pereyra-González & Mattei, 2023). Interestingly, the National Health and Nutrition Examination Survey 2009-2018 conducted on 744 infants aged 6 to 12 months examined the dietary habits of infants and evaluated the relationships between those habits and the results of weight status. Three-quarters of the infant population was at risk of being overweight or obese, and 42% of them gained weight quickly. The majority of infants (65.5%) were weaned early onto solid food. There were three primary dietary patterns identified. The first pattern, marked Natural or Minimally Processed Foods, showed positive loadings for a wide range of natural or minimally processed foods, several processed culinary ingredients, and a few processed and ultra processed foods. The second pattern, Infant Formula, showed a high unfavorable loading for breast milk and a high positive loading for infant formula and breakfast cereal. The third pattern, titled "Ultraprocessed Foods," featured negative loadings for processed ingredients and natural or minimally processed foods, positive loadings for various ultra processed foods and other processed foods, and negative loadings for baby formula. Findings showed that there was a higher likelihood of rapid weight gain (adjusted odds ratio 1.3, 95% CI 1.1 to 1.5) and overweight/obesity risk (adjusted odds ratio 1.2, 95% CI 1.0 to 1.4) in infants following the Ultraprocessed Foods dietary pattern (Neri et al., 2024).

To compare an intervention based on lowering UPF in accordance with the Dietary Guidelines for the Brazilian Population (DGBP) with and without recommendations regarding energy intake, a randomized controlled trial was conducted in parallel with children aged 7 to 12 years old who were obese. Every month, participants in the control (CG) and intervention (IG) groups engaged in six standardized educational activities that were based on the DGBP's ten steps. The IG was also given a customized meal plan. By the study's end, the IG's BMI decreased (Δ = -0.27 kg/m2) while the CG's increased (Δ = + 0.53 kg/m2) (p =.0002). Up until the fourth month, both groups' grams of UPF decreased. Then, they gradually increased in the months that followed. Reducing childhood obesity was found to be possible by combining the DGBP's qualitative approach with dietary plan counseling on energy restriction (Brandão et al., 2024). However, a study into the correlates of ultra-processed food (UPF) intake and its relationship to body mass index in children aged 3-5 years was conducted as part of a secondary analysis of a randomized field trial conducted in Brazil. The trial screened 667 parent-child dyads, of which 624 were enrolled and followed up with 90% between 2014 and 2016. Ultra-processed foods comprised 67.6% of total caloric intake. In adjusted models, children's UPF intake was positively associated with more frequent parent soda/fast-food consumption. However, no correlation was found between UPF consumption and weight (Carroll et al., 2024).

A negative impact of UPFs consumption on the overall diet quality was observed. In particular, it was highlighted the high prevalence of children's usual dietary intakes of almost all types of fats above the upper limits (i.e., >63%) and alongside the high prevalence of inadequate fibre intake (i.e., 70%) according to recommendations by AHA (Krauss et al., 2000). Furthermore, our findings in all age groups showed the highest prevalence of inadequacy (>65%) for the intake of vitamins D, E, K and potassium and the exceeded limits of sodium intake according to the Institute of Medicine's (IOM) recommendations (National Academies of Sciences, Engineering, and Medicine, 2019).

Recent studies have also reported an association between UPF intake and the unhealthier nutrient content of the diet (Araya et al., 2021; Moubarac et al., 2017; Martini et al., 2021). Our results showed that an increase in the dietary consumption of UPFs was associated with increases in the dietary content of NCD-promoting nutrients such as total CHO, added sugars, saturated fats, and sodium and decreases in the dietary content of NCD-protecting nutrients such as PUFA, dietary fibre, and potassium. The study of Moubarac et al. (2017) showed a significant positive association between the dietary contribution of UPFs and the dietary content in energy density, carbohydrates, free sugars, total and saturated fats, and an inverse association with the dietary content in protein, fiber, vitamins A, C, D, B6 and B12, niacin, thiamine, riboflavin, as well as zinc, iron, magnesium, calcium, phosphorus and potassium (Moubarac et al., 2017). Similar results were also preschoolers in the highest UPF tertile consumed more energy, carbohydrates, total sugars, saturated and monounsaturated fats, and vitamin D and less proteins, polyunsaturated fats, dietary fibre, zinc, vitamin A, and sodium than those in the lowest (Araya et al., 2021). Finally, a recent meta-analysis observed a global trend towards poorer nutritional quality (increased free sugars, total fats, and saturated fats, as well as decreased in fiber, protein, potassium, zinc, magnesium, and vitamins A, C, D, E, B12, and niacin), with higher consumption of UPFs (Martini et al., 2021).

A significant finding of our study indicated that most children did not meet the AHA's recommended values for the prevention of NCDs, even in the lowest tertile of UPFs consumption. These percentages significantly rose as the consumption of UPFs in the diet increased. In the highest tertile of UPFs consumption, about 40% of participants exceeded the upper limits (i.e., <10%) recommended by the WHO for added sugars (World Health Organization, 2015). The same findings were reported in a study among 9,317 US participants aged 1 year and above. In the highest quintile, 82.1% of Americans exceeded the recommended limit of 10% energy from added sugars, compared with 26.4% in the lowest (Martínez Steele et al., 2016). Finally, our study found that sodium content was also higher than the adequate intake in all tertiles (National Academies of Sciences, Engineering, and Medicine, 2019). Similar results were found in the UK (Rauber et al., 2018). However, studies from the USA (Martínez Steele et al., 2017), Canada (Moubarac et al., 2017) and Chile (Cediel et al., 2021) did not indicate a positive association between the dietary share of UPFs and sodium content. These could be due to differences in the types of ultra-processed foods consumed in each country, with salted products being more popular in Greece than sweetened products more typically consumed in the USA (Martínez Steele et al., 2017) and Canada (Moubarac et al., 2017).

A cross-sectional study conducted on 797 school children aged 8-12 years in Brazil examined the relationship between the consumption of NOVA food groups and the intake of macro- and micronutrients as well as energy. Findings showed that in 2050.18 ± 966.83 kcal/d, the average energy intake was composed of 25.8% ultra-processed foods, 56.7% unprocessed or minimally processed foods, 8.9% processed culinary ingredients, and 8.6% processed foods. Ultra-processed foods had a higher energy contribution that was positively associated with total energy, lipid, and Na intake ($P < 0{\cdot}001$) and negatively associated with the intake of protein, fiber, vitamin A, Fe, and Zn ($P < 0{\cdot}001$). In conclusion, increased UPFs consumption had a negative impact on children's nutrient intake profiles (de Lacerda et al., 2023). Furthermore, another cross-sectional study conducted on 806 children aged 4-5 years in Spain investigated the relationship between UPF consumption and insufficient intake of 20 micronutrients. The UPF accounted for 37.64% (SD: 9.59) of the average energy intake. A negative correlation was observed ($p < 0.01$) between the consumption of UPF and the intake of 15 of the 20 micronutrients that were assessed. Following the adjustment for family and individual confounders, children in the third tertile of UPF consumption had a higher likelihood of inadequate intake of ≥3 micronutrients [OR 2.57; 95%CI (1.51-4.40)] in comparison to those in the first tertile. In the first, second, and third tertiles of UPF consumption, the adjusted proportions of children with an inadequate intake of ≥3 micronutrients were 23%, 27% and 35%, respectively (García-Blanco et al., 2023).

In Brazil, another cross-sectional study among 36,952 adolescents aged 12-17 years examined the association between UPF consumption and cardiometabolic risk factors. The consumption of sodium, trans fat, and saturated fat was found to be higher in adolescents with high UPF consumption (defined as the top tertile, ≥38.7% daily), while intake of proteins, fibers, polyunsaturated fats, vitamins, and minerals was found to be lower. Higher UPF consumption was found to be inversely correlated with low HDL-c (PR = 0.972; 95% CI: 0.952-0.993) and directly correlated with high LDL-c (PR = 1.012; 95% CI: 1.005-1.029) after controlling for potential confounders. Consuming UPF did not appear to be associated with other cardiometabolic risk factors (Madalosso et al., 2023). The Childhood Obesity Risk Assessment Longitudinal Study (CORALS), a cross-sectional study conducted on 1,426 children aged 3-6 years old in Spain, examined the relationship between consumption of UPFs and cardiometabolic risk factors. The individuals in the highest tertile of energy-adjusted UPF consumption had lower z scores for HDL cholesterol (β coefficient, -0.19; 95% CI, -0.36 to -0.02) and higher z scores for BMI (β coefficient, 0.20; 95% CI, 0.05-0.35), waist circumference (β coefficient, 0.20; 95% CI, 0.05-0.35), fat mass index (β coefficient, 0.17; 95% CI, 0.00-0.32), and fasting plasma glucose (β coefficient, 0.22; 95% CI, 0.06-0.37) compared to participants in the lowest tertile. Lower BMI, fat mass index, and fasting plasma glucose were found when 100g of UPFs were substituted with 100g of unprocessed or minimally processed foods. According to these results, adiposity and other cardiometabolic risk factors were linked to young children's high UPF consumption (Khoury et al., 2024). Furthermore, a randomized trial in Brazil among 305 children aged 3 and 6 years investigated the association between UPF consumption and blood pressure levels in 6-year-old children. At three years and six years, UPF accounted for 40.3% and 45.2% of the total energy intake, respectively. The results of the adjusted linear regression analyses indicated that while diastolic blood pressure was linked to UPF consumption at 3 and 6 years ($P=0.01$ and $P<0.01$, respectively), systolic blood pressure was associated with UPF consumption at 6 years ($P = 0.05$). Consequently, these findings implied that the consumption of UPF contributed to the rise in blood pressure in 6-year-old children (Valmorbida et al., 2023).

The impact of decreasing UPF consumption (455 participants, median follow-up, 12 weeks) was assessed through a systematic review of three educational intervention studies and one controlled feeding trial. This study's objective was to ascertain whether randomized controlled trials (RCTs) could validate these associations. Of the 42 outcomes assessed, 30 showed no discernible effects. In adults with stable weight, the controlled feeding trial demonstrated a decrease in body weight, total cholesterol and HDL cholesterol, as well as in energy intake, fat, carbohydrates and body weight. In the educational intervention studies, women with obesity showed improvements in certain aspects of their quality of life and a decrease in body weight and waist circumference. While pregnant women who were overweight did not experience a decrease in UPF consumption, no discernible changes were seen in children or adolescents who were obese. Therefore, it is possible that other aspects of the intervention contributed to the benefits that were seen (Aramburu et al., 2024). Interestingly, a systematic review of 9 studies assessed the relationship between the consumption of UPFs and increased metabolic syndrome and body fat in children and adolescents. In children and adolescents, the consumption of ultra-processed foods was linked to an increase in body fat and metabolic syndrome components, according to a systematic review of nine studies. Six of the nine articles found a positive correlation between high consumption of ultra-processed foods and total cholesterol; three found a positive correlation with BMI; two with waist circumference; two with body fat; one with diastolic blood pressure; one with low-density lipoprotein cholesterol and one with triacylglycerols. Out of nine studies, seven discovered at least one correlation with elements of the metabolic syndrome (Frías et al., 2023).

There are several potential mechanisms that describe the association between UPFs consumption and the risk of overweight/obesity. First, UPFs are estimated to provide a significant amount of total daily energy intake. In Chile, preschoolers consumed 49% of their total energy intake from UPFs (Araya et al., 2021). In a cross-sectional study on children aged ≥ 1.5 years, Rauber et al. (2018) showed that 56.8% of total energy intake came from UPFs (Rauber et al., 2018). This high UPF intake leads to a diet of high energy-density, saturated and trans fats, carbohydrates, and total sugars consumption, and lower content of fiber, zinc, vitamin A and folate (Araya et al., 2021). It has been found that consumption of trans fats was related to weight gain and abdominal obesity, as well as an increased risk of coronary heart disease and type 2 diabetes (Astrup et al., 2008). In addition, as Viola et al. (2020) found in a study involving 1,525 adolescents, this unbalanced nutritional composition from excessive consumption of UPFs is associated with a lower protein intake, which contributes to lower muscle mass (Viola et al., 2020). Furthermore, increasing the consumption of UPFs leads to a high intake of refined carbohydrates, which the body can absorb easily and rapidly and may cause an increase in insulin secretion. This causes increased adipose tissue storage, which is related to a high risk of obesity (Asfaw, 2011; Ludwig & Ebbeling, 2018).

Beyond nutritional values, UPFs are frequently distinguished by the presence of artificial food additives, notably flavours, colours, sweeteners, and emulsifiers. It has been hypothesized that additives might have harmful effects on health. Another mechanism, yet investigated only in mice, supported that the alteration of the original food matrix and the added cosmetic additives, such as sugar alcohols, artificial sweeteners and fructose of these products, were associated with changes in the composition and metabolic behavior of the gut microbiota that promote inflammatory diseases (Payne et al., 2012; Suez et al., 2014). Furthermore, emulsifiers involved in the manufacture of UPF have shown deleterious health effects. It has been shown that even in low concentrations, they played a role in inducing low-grade inflammation and obesity or metabolic syndrome in mice (Chassaing et al., 2015).

Another potential non-nutritional mechanism is that UPFs are characterized as hyper-palatable, packaged with large portion sizes, and aggressively marketed, which may promote obesity through overconsumption (Louzada et al., 2015; Herman et al., 2015). Their physical and structural characteristics may conduct to lower satiety and higher glycemic response (Fardet, 2016). As UPFs are convenient and ready-to-eat, they may change eating habits, encouraging eating while doing other activities such as eating while watching television (Louzada, M. L. et al., 2015). These eating patterns encourage inattentive and fast-paced eating, which can disrupt the neural and digestive mechanisms that signal satiation and satiety may promote overeating (Rauber et al., 2015; Robinson et al., 2014). Chemical process contaminants (neo-formed contaminants) are the result of processes that UPFs went through, such as high-temperature heating and extruding. Acrylamide, acrolein and furan are some common compounds. During the preparation of UPF at high temperatures, starchy foods produce acrylamide, fats create acrolein, and sugars give furan, a potentially carcinogenic substance, respectively. It has been shown a positive relationship between acrylamide (Lin et al., 2009) and acrolein (Feroe et al., 2016) and insulin resistance. According to the European Food Safety Authority, furan can cause hepatotoxicity and induce oxidative stress in animals (EFSA Panel on Contaminants in the Food Chain et al., 2017). Finally, since UPFs are usually packaged in plastic packages, and several plasticizers, such as bisphenol A have been related to obesity in both adults and animals, likely that will also apply in children and adolescents (Thayer et al., 2012; Heindel et al., 2015). Interestingly, many prospective studies have adjusted the relation of UPF consumption with adverse health outcomes, using diet quality, fat, sugar, or salt intake as covariates, and found that healthy or unhealthy dietary patterns had little impact on this association. It indicates that UPFs' negative impact on human health cannot be attributed only to the displacement of healthy foods and poor diet quality. Perhaps the nature and extent of processing should also be considered as significant factors of UPFs' health consequences (Dicken & Batterham, 2021).

Nevertheless, the relation of classification of foods by their 'extent of processing' and adverse health outcomes is a topic of debate in nutrition science. Advocates of the concept argue that the processing characteristics of UPF, rather than their nutritional characteristics are linked to harms (Astrup & Monteiro, 2022; British Nutrition Foundation, 2023; Mialon, 2023). All current front–of–pack nutrition labeling (FoPL) models only consider nutrients and calories but no other ingredients and additives or the degree of processing to restrict foods (Mialon, 2023). UPFs are non-nourishing formulations that have been produced without any or very little of the matrix of whole foods (Monteiro et al., 2019). Additives commonly used to formulate UPFs (emulsifiers, colors, flavor enhancers, and non-sugar sweeteners) made them hyper-palatable. As a result, these foods are consumed faster than minimally processed foods (Forde et al., 2020), which leads to higher energy intake (Hall et al., 2019). Recent in vivo, in vitro, and epidemiologic studies have raised concerns about potential negative health effects such as obesity, type 2 diabetes, cardiovascular diseases, cancer and all-cause mortality (Astrup & Monteiro, 2022; British Nutrition Foundation, 2023). However, advocates support that more studies on the negative effects of UPF intake, including mechanistic and longitudinal studies, will and should be conducted, and RCTs should be carried out whenever possible (Astrup & Monteiro, 2022). Even if there are several studies that give a completely different picture of the association between UPFs consumption and health outcomes, based on the body of research compiled by investigators worldwide, proponents argue that NOVA contributes to dietary guidelines beyond conventional classifications that ignore food processing (British Nutrition Foundation, 2023; Monteiro & Astrup, 2022). In conclusion, for the purpose of directing policies and actions intended to decrease diet-related health problems and thereby promote health and well-being, both conventional and NOVA nutrient-based systems are crucial (Astrup & Monteiro, 2022).

On the other hand, critics argue that the emphasis should remain on high consumption of foods with poor nutrient profiles, such as those that are high in fat, salt, and sugar and low in healthy ingredients, where there is more convincing evidence linking these foods to negative health problems (Astrup & Monteiro, 2022; British Nutrition Foundation, 2023). Several studies have shown positive associations between higher consumption of UPF and adverse health outcomes. However, they are based on observational studies that, by design, cannot prove cause and effect. Therefore, to prevent incorrect conclusions and negative effects on public health, strong evidence from RCTs is required (Astrup & Monteiro, 2022; British Nutrition Foundation, 2023; Monteiro & Astrup, 2022). Another issue is that all classification systems based on the 'extent of processing', are not accepted worldwide. NOVA classification has been criticised by many scientists for being too broad across and within categories, providing no objective distinctions to guide classification involving ingredients (Levine & Ubbink, 2022). There is a high level of discordance in coding foods according to the UPF classification (Monteiro & Astrup, 2022; Gibney & Michael 2022). For example, meals made of similar ingredients in industrial preparation are considered UPFs, but when the preparation is at home, it is not (Monteiro & Astrup, 2022). Moreover, UPFs include foods and beverages required for medical or nutritional reasons, such as gluten-free or fortified products, for which there is frequently no accessible or convenient substitute (British Nutrition Foundation, 2023). Critics also argue that NOVA rejects the idea of food reformulation on the grounds that it is impossible to transform an unhealthy food into a healthy one (Monteiro et al., 2012). It disregards the significant initiatives taken by governments to promote food reformulation to improve the nutritional profile of products (British Nutrition Foundation, 2023; Gibney & Michael, 2022). In conclusion, nutrients and nutrient profiling systems to assess the quality of foods have been proposed as the most evidence-based method for the basis of dietary policy and recommendations (British Nutrition Foundation, 2023).

In conclusion, unhealthy dietary habits, as well as their main consequences, such as obesity and cardiometabolic co-morbidities, developed in childhood and adolescence, tend to track into adulthood. Therefore, it is of great importance to investigate the overconsumption of UPFs and its consequences in children.

5.1. Strengths of the study

This study has several strengths. The main advantage is its originality as it examines the intake of UPFs as well as its relationship with overweight/obesity in children and adolescents in Greece. It is the first nationwide study investigating UPFs consumption based on food categorization according to the NOVA system among children. The NOVA food classification system has been recognized as a valid tool for nutrition and public health research and policy. It makes it easier to compare our survey results with those of other countries. Furthermore, evaluating the dietary UPF proportion and their main food contributors is important because the effects on weight and health may vary by the nutritional profile of the food or the amount consumed, which may vary between countries. Our studies are ongoing to examine other parameters related to the consumption of UPFs.

Although numerous studies have been conducted that demonstrate the change in dietary patterns and the nutritional profile of foods in children and adolescents, no study has been conducted to highlight the role that food processing plays in childhood obesity in Greece. The estimation of dietary intake was conducted using 24-hour recalls, which is recognised as one of the most comprehensive methods of assessing dietary intake and as the least-biased self-report instrument available (Thompson & Subar, 2001). Dietary recalls happen after the food has been consumed, as opposed to record methods, and due to the short recall period, participants are able to recall most of their dietary intake. The 24-hour recall was not designed to categorize foods based on industrial processing characteristics. Although the HNNHS gathers specific information on food processing (e.g., meal locations and product brands), this information is not collected consistently for all food products, potentially leading to an underestimation of UPF intake.

5.2. Limitations of the study

The present epidemiological study is governed by some limitations. Due to its cross-sectional retrospective nature, no causal relationship can be established based on the results. It is not possible to draw conclusions about the timing of the association between UPF consumption and obesity.

Furthermore, due to the small sample size, data were not stratified by age groups, with children and adolescents grouped in one category. This means that the results cannot be generalized to all children in Greece.

Finally, a potential limitation is the NOVA classification. Even though the HNNHS collects specific information on food processing (such as meal locations and product brands), this information is not consistently gathered for all food products. It is, therefore, important to consider any potential NOVA categorization misclassifications of food items, although this was highly minimized with the methodology followed.

CHAPTER 6 CONCLUSIONS

The current PhD thesis revealed that almost half of the dietary energy came from UPFs, notably ready-to-eat/heat dishes, sweet grain products, savoury snacks, and sweets. Greater dietary intake of UPF demonstrated a poor quality of diet, characterized by a higher dietary content of NCD-promoting nutrients such as CHO, added sugars, saturated fats, and sodium, and a lower dietary content of NCD-protecting nutrients such as protein, dietary fibre and potassium. Additionally, no association was found between the dietary contribution of UPFs and the likelihood of being overweight/obese. However, savoury snacks & baked goods increased the likelihood of being overweight and obese. The major barriers to understanding the relationship between UPFs consumption and obesity are the lack of a universally accepted definition and classification scheme of UPFs, the lack of specific dietary assessment methods to collect information about food processing level, and finally, the need for more RCTs because the cross-sectional design of the majority of studies is not examined the causal effect. The UPF concept is being embraced by nutrition policymakers more and more because it provides useful assistance for creating nutrition policy initiatives to address unhealthy and unsustainable diets. Recommendations to choose a balanced diet emphasizing the intake of minimally processed foods, as well as freshly prepared dishes and meals, and the reduction of UPF consumption should be incorporated into national dietary guidelines. It is necessary to implement practices to make healthy choices more affordable, accessible, available, and valuable by giving people access to more information, which is further enhanced by the food profiling software (e.g., Open Food Facts) that uses barcode scanning (Touvier et al., 2023). Moreover, there is a need for more policy actions such as the taxation of UPFs (e.g., sugar-sweetened beverages and snacks), marketing restrictions via television advertising content during children's programs, and more media campaigns against UPFs consumption. The UPF industry is extremely profitable due to the low-cost supply chains and aggressive marketing strategies that encourage excessive consumption, which constitute the main barrier to these policies in all the studied countries. Nowadays, some countries use NOVA in their dietary guidelines, such as the 2014 Dietary Guidelines for the Brazilian Population (Ministry of Health of Brazil, 2015) and the 2016 Dietary Guidelines for the Uruguayan Population (Food and Agriculture Organization of the United Nations, 2016), which emphasize consuming foods that have been minimally or not at all processed, as well as limiting processed foods and staying away from ultra-processed foods. At the same time, the US has no policies concerning UPFs as a group, and the processing level is not included in the Dietary Guidelines for Americans (US Department of Agriculture and US Department of Health and Human Services, 2020). International organizations could contribute to creating barriers to the interests and participation of transnational food corporations in the definition of international recommendations and agreements, as well as promoting discussions that conduct the establishment of international rules to induce the approval of policies by countries to curb UPF consumption. Consequently, only mandatory policy actions and strategies that target UPFs holistically could address the increasing UPFs consumption in relation to childhood obesity worldwide.

More specifically, based on the findings of the current study, the first thing that public health policymakers could do is the nutritional education of children and adolescents through educational programs in schools. These programs should focus on children's nutritional education and contribute to creating an environment that promotes healthy eating habits and physical activity so that they acquire the ability to apply them in their daily lives. It could be particularly effective in the prevention and treatment of OW/OB during childhood and adolescence in our country.

Furthermore, the role of parents in such programs, either through the state and/or through mass media campaigns, should be studied as parental involvement is likely to influence children's eating behaviour, which would lead to the avoidance of UPFs consumption with consequent results in weight management and control. In addition, among the goals should be the education of the parents on how to integrate the knowledge they have in their daily lives, how to deal with food temptations and how to manage the daily routine.

Finally, those responsible for public health should develop intervention programs for children and adolescents, which will be financed and will be part of strategic planning by the responsible ministries. In any case, further studies are needed at a nationwide level to confirm the findings of the present study with the aim of making the intervention programs more specific and more effective.

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Appendix 1 (Systematic reviews)

<u>Systematic review I</u>: Overweight and Obesity among Children Aged 9-12 Years in Europe and the Nutritional and Environmental Factors of Child Obesity: A Systematic Review

Title page

Overweight and Obesity among Children Aged 9-12 Years in Europe and the Nutritional and Environmental Factors of Child Obesity: A Systematic Review

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Abstract

Background: Obesity, a multifactorial disease, results from the complex interaction of genetic, hormonal, physical, nutritional, environmental, and social factors. This review aimed to determine the impact of nutritional and environmental factors on the BMI of overweight and obese European children aged 9–12 years from 2010 to 2019 and to analyze these estimations by gender, country, and specific nutritional and environmental factors.

Methods: The protocol was guided by the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) and the Cochrane Collaboration Handbook. Electronic databases used included Cochrane Library, CINAHL, EMBASE/SCOPUS, MEDLINE, and the e-library of the University of Nicosia. Searches were conducted from database inception until January 2019, including RCTs, cross-sectional studies, and baseline measurements of cohort studies with overweight and obesity defined according to the International Obesity Task Force criteria. Based on fixed inclusion and exclusion criteria, only RCTs were examined. A total of 4 RCTs were identified for data extraction and quality assessment. This review investigates three main interventions: nutrition, physical activity, and behavior, which impacted children's BMI or weight loss.

Results: The results supported that children could achieve a better SDS-BMI score or weight loss following nutritional and physical activity interventions. Among different behavioral techniques, only 'control over eating' by parents showed a statistically significant interaction. After the follow-up period, the rates of indices increased in all studies.

Conclusions: Findings indicate a decrease in SDS-BMI score and weight loss during the intervention period, suggesting that changes in children's lifestyle with healthier dietary habits and increased physical activity can maintain their weight at lower rates. A total of 4 studies (n = 848 children) from 3 countries were included. The included studies suggest that lifestyle interventions, including physical activity, diet, and behavior modifications, can lead to improvements in BMI and other obesity-related measures in children and adolescents. However, the effectiveness of these interventions can vary, and some studies noted weight regain over time. Long-term follow-up and sustained intervention efforts may be necessary to maintain the benefits of these programs. Further measures to address the obesity epidemic in childhood should be recognized in European countries and worldwide in the case of high child obesity incidence.

Keywords: excess weight, overweight, obesity, school-aged children, Europe, prevalence, BMI, food, nutritional and environmental factors for obesity, systematic review

Introduction

The global prevalence of obesity has nearly tripled between 1975 and 2016. Over 340 million children and adolescents aged 5-19 were overweight or obese in 2016, a significant rise from 4% in 1975 to over 18% population (World Health Organization, 2024). Less than 1% of children and adolescents aged 5-19 were obese in 1975, whereas more than 124 million were obese in 2016 (World Health Organization, 2024). European statistics show that the prevalence of overweight ranged from 18% to 57% for boys and from 18% to 50% for girls, while 6-31% of boys and 5-21% of girls were obese (Wijnhoven et al., 2014). The highest obesity rates were observed in girls from Malta and boys from Greece, estimated at 11.3% and 16.7%, respectively (World Health Organization, 2017). Countries around the Mediterranean Basin, such as Greece, Italy, Spain, Malta, and Portugal, have the highest prevalence of childhood overweight and obesity (Wijnhoven et al., 2014).

The World Health Organization has identified the prevention of childhood obesity as a public health priority for preventing chronic diseases (World Health Organization, 2016). The steady increase in overweight and obesity among children and adolescents has become a major public health problem, reaching epidemic proportions in most low/middle-income countries over the past two decades (Ng et al., 2014; de Onis, Blössner & Borghi, 2010; Wang & Lobstein, 2006). Moreover, excess weight in early life is associated with physical and mental health disorders in both childhood (Franks et al., 2010; Sánchez-López et al., 2009) and adulthood (Franks et al., 2010; Herva et al., 2006; Baker, Olsen & Sørensen, 2007).

As a multifactorial disease, obesity results from the complex interaction of genetic, hormonal, physical, nutritional, environmental, and social factors (Chan & Woo, 2010). A multicomponent intervention model that includes nutritional aspects, physical activity, sedentary time reduction, and behavioral changes can yield better outcomes than isolated interventions (Rajmil et al., 2017; Kumar, Kelly, 2017).

The Mediterranean Diet (MD) is a well-known and nutritionally balanced dietary pattern. It has been associated with a reduced risk of mortality and the incidence of chronic diseases such as cancer, type 2 diabetes, metabolic syndrome, obesity, neuropsychological diseases, and cardiovascular diseases by decreasing risk factors and improving health and quality of life (Serra-Majem et al., 2004; Sofi et al., 2010; Romaguera et al., 2010; Trichopoulou, Bamia & Trichopoulos, 2009). In the Go4it study, an 18-month follow-up showed that healthier dietary changes had a significant long-term effect on SDS-BMI compared to regular care in obese adolescents (Hofsteenge et al., 2014).

Few interventions have considered changes in diet quality and nutrient adequacy. Studies have shown that lifestyle interventions can improve diet quality and reduce BMI-

SDS in children and adolescents with abdominal obesity (Waling et al., 2010, Waling, Larsson, 2012, Ojeda-Rodríguez et al., 2018). Higher diet quality scores were linked to lower nutrient inadequacy (Ojeda-Rodríguez et al., 2018).

Regular physical activity is crucial for healthy growth and development in children (Biddle, Gorely & Stensel, 2004; Stanner, 2004). However, many young people do not meet the physical activity guidelines of 60 minutes on most days (Stanner, 2004). The GreatFun2Run program (GF2R) demonstrated short-term changes in physical activity and body composition through an intervention primarily focused on physical activity (Gorely et al., 2011).

Children from families with limited resources are more likely to be obese, have poor dietary patterns and face greater health risks compared to children from more affluent families (Barnes, 2012). The Eat Mediterranean Program (EM program) showed a positive effect, with 76.0% of participants reporting optimal adherence to the MD (Rito et al., 2019). Socioeconomic and lifestyle factors, such as parental occupational status, maternal education level, and income, significantly influence children's eating habits (Lissner et al., 2016; Arriscado et al., 2014; Taylor, Evers & McKenna, 2005; Fauquet et al., 2016). Higher socioeconomic status and mother's educational level positively impact diet quality (Rito et al., 2019). A multidisciplinary, family-based lifestyle intervention can lead to positive lifestyle changes in both children and adolescents with overweight or obesity (Ranucci et al., 2017).

Objective

This systematic review seeks to evaluate the impact of nutritional and environmental factors on the Body Mass Index (BMI) of overweight and obese children aged 9–12 years across Europe from 2010 to 2019. We aim to explore how variations in daily contributing factors, including dietary and environmental influences, may affect future trends in obesity rates among this age group. Specifically, our research focuses on understanding how these factors influence obesity rates, considering gender differences, country-specific contexts, and distinct nutritional and environmental elements.

Research Questions and Main Objectives

Our primary research question is: *How do changes in daily nutritional and environmental factors influence future obesity rates among European children?*

To address this question, the study's main objectives are to:

1. Identify Contributing Factors: Investigate the various nutritional and environmental factors contributing to obesity in this population, including dietary habits, physical activity levels, and other relevant lifestyle elements.
2. Evaluate Obesity Levels: Analyze the extent of childhood obesity using BMI as a measure, differentiating by country and gender to provide a comprehensive view of the issue.
3. Examine Weight Loss Outcomes: Evaluate the effectiveness of interventions and lifestyle changes on weight reduction, assessing how modifications in diet and environment impact children's weight management.

By fulfilling these objectives, this review aims to provide valuable insights into the factors driving childhood obesity and guide future public health strategies and interventions.

Methods

Overview

This systematic review, guided by the Cochrane Handbook and the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P), aims to collate and synthesize empirical evidence according to predefined eligibility criteria to address a specific research question (Higgins & Thomas, 2019). The review follows rigorous systematic methods to provide reliable findings and draw robust conclusions (Higgins & Thomas, 2019). The PRISMA checklist has been utilized to design and structure this review (Moher et al., 2009).

A meta-analysis, which statistically synthesizes and recalculates results from individual studies, was considered. However, due to the limited number of studies, a meta-analysis could not be conducted (Harris & Taylor, 2009).

Eligibility Criteria

Inclusion Criteria:

1. Studies involving healthy children aged 9-12 years with no additional health issues, specifically focusing on obesity.
2. Randomized Controlled Trials (RCTs).

3. Studies assessing interventions related to environmental and nutritional factors, including nutrition, physical activity, and behavior.
4. Outcomes measured included BMI, dietary intake, and physical activity.
5. Studies published in the last 10 years.
6. Full-text articles available and written in English.

Exclusion Criteria:

1. Studies involving populations with morbidities related to weight, such as diabetes or incorrect body posture.
2. Non-RCT studies.
3. Studies published before 2010.
4. Interviews, reviews, and meta-analyses.

Information Sources and Search Strategy

The literature search was conducted using three scientific databases: PubMed, Cochrane Library, and Scopus. Results from each database were exported to RefWorks for further evaluation. Keywords used with Boolean operators included: "child obesity" AND BMI, "child obesity" AND "nutrition", and "child obesity" AND "nutrition" AND ("European Union" OR EU). Additionally, reference lists of retrieved publications were reviewed for further relevant studies, systematic reviews, and meta-analyses.

Selection of Studies and Data Extraction

Two independent reviewers screened titles and abstracts to determine eligibility for this systematic review. Full-text articles were retrieved and reviewed for inclusion. Disagreements were resolved through consensus, with a third reviewer consulted if necessary. The PRISMA flow diagram (Figure 1.6.1) illustrates the selection process. Data extraction was performed using the Cochrane data form for RCTs and included: authors' names, title, country, study design, sample size, participants, study period, intervention, follow-up, outcomes assessed, and findings. Risk estimates and quality scores were also recorded. Disagreements were resolved by consensus.

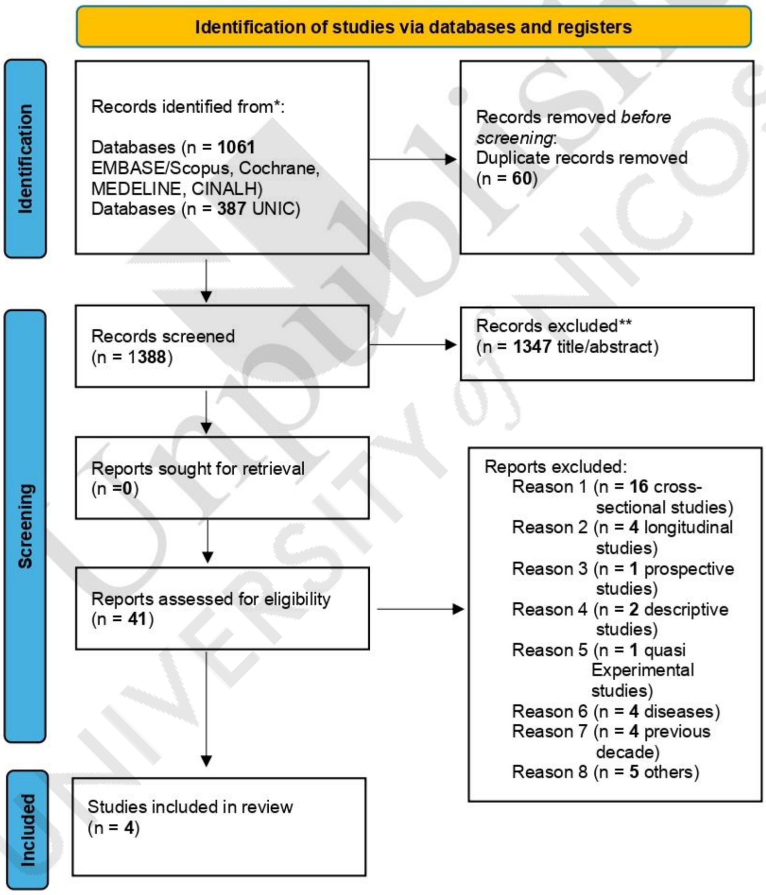
Risk of Bias

The risk of bias for included studies was assessed using the Jadad score for RCTs (Jadad et al., 1996). The Jadad score evaluates the quality based on: (1) randomization (2 points), (2) double-blinding (2 points), and (3) withdrawals (1 point). Points could be deducted for inadequate randomization and blinding (-1 point each). Scores ranged from 0-5 points: 5 points indicate high quality, scores above 3 denote good quality, and below 3 suggest poor quality. Quality assessments facilitated comparison and evaluation of study results. Disagreements were resolved by consensus.

Statistical Analysis

Due to the small number of studies meeting the inclusion criteria, a meta-analysis was not feasible. The limited number of studies prevented the aggregation of data for statistical synthesis, which is typically necessary for meta-analysis to derive more precise and generalizable conclusions.

Figure 1.6.1 PRISMA 2020 Flow Diagram



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Results

Study Selection and Characteristics

The PRISMA flow diagram (Figure 1.6.1) summarizes the study selection process. Out of the full-text articles reviewed, four RCTs met the inclusion criteria and were included in the systematic review (Hofsteenge et al., 2014; Ojeda-Rodríguez et al., 2018; Gorely et al., 2011; Halberstadt et al., 2017). These studies were conducted in the UK (Gorely et al., 2011), the Netherlands (Hofsteenge et al., 2014; Halberstadt et al., 2017) and Spain (Ojeda-Rodríguez et al., 2018) encompassing a total of 848 children aged 9-12 years. The studies were published between 2009 and 2019, with sample sizes ranging from 30 to 589 participants (Table 1.6.1).

Risk of Bias

The risk of bias was evaluated using the Jadad scale (Jadad et al., 1996). All studies were categorized as having good quality: two studies scored 3 (Gorely et al., 2011; Halberstadt et al., 2017), one study scored 4 (Hofsteenge et al., 2014), and one study scored 5 weeks (Ojeda-Rodríguez et al., 2018). None of the studies met the criteria for double blinding, indicating limitations in reliable measurement (Table 1.6.2).

Interventions

The four included studies evaluated interventions on BMI through: (i) nutrition, (ii) physical activity, or (iii) multicomponent behavioral interventions (Table 1.6.3). Intervention durations ranged from 8 weeks to one year. While three studies reported a successful decrease in BMI during the intervention phase, weight was subsequently regained post-intervention. The results suggest that behavioral modification may be necessary for sustained outcomes.

Data Synthesis

Dietary Intake Intervention

Three studies assessed BMI changes related to dietary intake. Two studies showed a reduction in SDS-BMI during the intervention, but an increase was observed during the 6-12 months follow-up period (Hofsteenge et al., 2014; Ojeda-Rodríguez et al., 2018). For instance, Hofsteenge's et al. (2014) study reported a decrease in SDS-BMI from 2.96 at baseline to 2.81 at 6 months and 2.86 at 18 months (95% CI, P<0.05) (Hofsteenge et al., 2014). Halberstadt and colleagues' study showed a decrease from 3.44 at baseline to 3.03 after one year and 3.18 after two years (P<0.001) (Halberstadt et al., 2017). The study by Ojeda-Rodríguez et al. (2018) specifically measured nutrient adequacy and diet quality with obesity indices. A calorie restriction varied from 10% to 40% had an improvement for SDS-BMI (a difference of -0,5, 95% CI, P<0,001) between baseline and after eight weeks (Ojeda-Rodríguez et al., 2018).

Physical Activity Intervention

One study examined the impact of physical activity on weight loss activity. The intervention included a comprehensive approach with a CD-ROM for teachers, an interactive website for pupils, teachers, and parents, a local media campaign, a summer activity planner, and two major physical activity events (1-mile school runs/walks). At the 20-month follow-up, the BMI of the intervention group increased from 17.9 at baseline to 18.8, indicating no significant weight loss despite the increased physical activity (Gorely et al., 2011).

Behavior Intervention

Another study investigated the effects of a behavioral intervention on weight loss. This intervention combined nutrition, exercise, and behavioral strategies aimed at improving self-regulation. It addressed various themes including disordered eating behavior, self-worth, self-efficacy, and parental feeding styles. The only statistically significant result was related to the 'control over eating' subscale of the Parental Feeding Style Questionnaire, showing a change (β= −0.0022; CI 95%= −0.0041, –0.0004; P=0.023) after one year of treatment (Halberstadt et al., 2017).

Table 1.6.1 Summary of Included Studies

Authors	Title	Country	Study Design	Sample Size	Participants	Study Period	Intervention	Follow-Up	Outcome Assessed / Adjustments	Findings	Quality Score
Gorely 2011	Physical activity and body composition outcomes of the GreatFun2Run intervention at 20-month follow-up	UK	RCT	589 (287 boys, 302 girls) (7-11 years)	Intervention group (n=310) Control group (n=279)	Not specified	Physical Activity	10 months/ 20 months	BMI, Physical Activity	Significant increase in BMI (17.8 with CI 17.3-18.2). Both groups increased physical activity but no group-by-time interaction (control: +2726 steps/day; intervention: +3404 steps/day, $p > .05$). Increases in body fat, skinfolds, waist circumference, and BMI with age.	3
Hofsteenge 2014	Long-term effect of the Go4it group treatment for obese adolescents: A randomised controlled trial	Netherlands	RCT	122 (54 boys, 68 girls)	Intervention group (n=71) Control group (n=51)	2006-2008	Diet, Physical Activity	3 months / 6 months / 18 months	SDS-BMI	Significant decrease in SDS-BMI from 2.96 ± 0.6 to 2.86 ± 0.7.	4
Halberstadt 2017	The association of self-regulation with weight loss maintenance after an intensive combined lifestyle intervention for children and adolescents with severe obesity	Netherlands	RCT	30 (8-13 years) 90 (13-19 years)	Severe obese 8-13 years 13-19 years	2009-2013	Behaviour	1 year / 2 years	SDS-BMI	Average SDS-BMI decreased from 3.44 to 3.03 during treatment; slight weight regain to 3.18 at 2 years. Average weight loss of 0.41 SDS-BMI points during treatment; 0.26 SDS-BMI points at 2 years follow-up.	3

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Authors	Title	Country	Study Design	Sample Size	Participants	Study Period	Intervention	Follow-Up	Outcome Assessed / Adjustments	Findings	Quality Score
Ojeda-Rodriguez 2018	Improved diet quality and nutrient adequacy in children and adolescents with abdominal obesity after a lifestyle intervention	Spain	RCT	107 (37% boys, 63% girls)	Usual care group (n=26) Intensive care group (n=81)	2018-today	Nutrient Adequacy, Diet Quality, Lifestyle Intervention	8 weeks / 22 months	Body Weight, SDS-BMI	Significant decrease in body weight and SDS-BMI in both groups.	5

Note: RCT-like indicates that while the methodology used was similar to RCT, a randomized version was not ultimately feasible.

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Table 1.6.2 Quality Assessment of RCTs Using the Jadad Scale

Jadad Score Calculation	Gorely 2011	Hofsteenge 2014	Halberstadt 2017	Rodriguez 2018
Was the study described as randomized (e.g., randomly, random, randomization)?	1	1	0	1
Was the method used to generate the sequence of randomization described and appropriate (e.g., table of random numbers, computer-generated)?	1	1	0	1
Was the study described as double blind?	0	0	0	0
Was the method of double blinding described and appropriate (e.g., identical placebo, active placebo, dummy)?	0	0	0	0
Was there a description of withdrawals and dropouts?	0	1	1	1
Deduct one point if the method used to generate the sequence of randomization was inappropriate (e.g., patients allocated alternately, according to date of birth)?	1	1	1	1
Deduct one point if the study was described as double blind but the method of blinding was inappropriate (e.g., comparison of tablet vs. injection without double dummy)?	0	0	1	1
Total Score	3	4	3	5

Note: RCT-like indicates that while the methodology used was similar to RCT, a fully randomized version was not ultimately feasible.

Table 1.6.3 Summary of the baseline characteristics of the included studies

Authors	Country	Study Design	Sample Size	Age (years)	Sex (F)	Tanner Stage	Weight (kg)	Height (cm)	BMI	BMI-SDS	Findings
Gorely 2011	UK	RCT	589	7-11	51.3%	Not specified	Not specified	Not specified	17.8 (CI 17.3-18.2)	Not specified	Significant increase in BMI. Both groups increased physical activity but no group-by-time interaction. Increases in body fat, skinfolds, waist circumference, and BMI with age.
Hofsteenge 2014	Netherlands	RCT	122	Adolescents	55.7%	Not specified	Not specified	Not specified	Not specified	2.96 ± 0.6	Significant decrease in SDS-BMI from 2.96 ± 0.6 to 2.86 ± 0.7.
Halberstadt 2017	Netherlands	RCT	120	8-13, 13-19	Not specified	Not specified	Not specified	Not specified	Not specified	3.44	Average SDS-BMI decreased from 3.44 to 3.03 during treatment; slight weight regain to 3.18 at 2 years. Average weight loss of 0.41 SDS-BMI points during treatment; 0.26 SDS-BMI points at 2 years follow-up.

Authors	Country	Study Design	Sample Size	Age (years)	Sex (F)	Tanner Stage	Weight (kg)	Height (cm)	BMI	BMI-SDS	Findings
Ojeda-Rodriguez 2018	Spain	RCT	107	Children and Adolescents	63%	Not specified	Not specified	Not specified	Not specified	Not specified	Significant decrease in body weight and SDS-BMI in both groups.

Note: Gorely 2011: The study included 287 boys and 302 girls; **Hofsteenge 2014**: The study included 54 boys and 68 girls; **Halberstadt 2017**: The study included 30 participants aged 8-13 years and 90 participants aged 13-19 years; Ojeda-Rodriguez **2018**: The study included 37% boys and 63% girls

Discussion

This systematic review evaluated the effects of nutritional, physical activity, and behavioral interventions on BMI in children. The findings underscore the importance of lifestyle changes for reducing BMI, although the results show that many children experienced weight regain after the intervention period.

The quality of the studies was assessed using the Jadad score, and all included studies were considered of good quality, with scores ranging from 3 to 5. Specifically, Gorely et al. (2011) and Halberstadt et al. (2017) scored 3 (Gorely et al., 2011; Halberstadt et al., 2017), Hofsteenge et al. (2014) scored 4 (Hofsteenge et al., 2014), and Ojeda-Rodriguez et al. (2018) scored 5 (Ojeda-Rodríguez et al., 2018), indicating generally robust methodologies.

Two studies demonstrated that improvements in diet quality can positively impact BMI. Ojeda-Rodríguez et al. (2018), despite having a moderate risk of bias, reported reductions in weight and BMI during an 8-month intervention. However, the lack of a long-term follow-up limits the ability to evaluate the sustainability of these outcomes (Ojeda-Rodríguez et al., 2018). Hofsteenge and colleagues although presenting a high risk of bias and being conducted before 2010, showed initial weight loss but a return to baseline BMI levels after 18 months (Hofsteenge et al., 2014). Another intervention study was carried out to assess the efficacy of the school nutrition program (SNP), which combined nutrition education and a healthy school canteen environment with BMI-for-age. This study among 523 Malaysian children aged 7 to 11 years old showed that after 3-month follow-up, the intervention group had a lower BMI than the control group ($p < 0.05$) (Teo et al., 2021). However, a clustered randomized control trial of 245 Taiwanese schoolchildren examined the effects of an intervention program adapted from NASA's Mission X (MX) program on children's Healthy Eating Active Living (HEAL) knowledge and behaviors, as well as their anthropometry. The intervention was an eight-week program. The authors demonstrated that while the BMI did not change for the intervention group, it increased for the control group from 18.4 to 18.6 ($p < 0.05$) (Lin et al., 2019).

Collado-Soler et al. (2023) proposed that school-based nutrition intervention programs have a significant influence on children's eating habits because the primary aim of their systematic review was to determine how well these programs affected participants' knowledge and behavior related to nutrition. As they have demonstrated, these programs, increase students' understanding of healthy diets and encourage positive attitudes and behaviors in their daily lives (Collado-Soler et al., 2023). Promoting healthy habits and changing dietary behaviors requires the support of families and school environments (Schlechter et al., 2016). However, since attitude, which is influenced by motivation

(Sabramani et al., 2015), mediated eating behaviors (van Stralen et al., 2011), it is more crucial to incorporate enjoyable and engaging activity-based nutrition sessions (Sharif et al., 2016).

In terms of physical activity, Gorely and colleagues observed that while increased physical activity led to initial improvements in BMI, these benefits were not sustained over a 10-month follow-up period, and BMI increased subsequently. This indicates that without continuous engagement in physical activity, short-term improvements may not be maintained (Gorely et al., 2011). A randomized clinical trial was conducted in Granada among 92 overweight or obese children aged 8 to 11 years to examine the effects of a 20-week exercise program on cardiometabolic health. For 20 weeks, the exercise program consisted of 3 to 5 aerobic and resistance training sessions per week (90 minutes each). Findings showed that a combination of aerobic and resistance exercise resulted in a significant decrease in body mass index (-0.59 [95% CI, -1.06 to -0.12]) in the intervention group compared to the control group. Additionally, kids in the exercise group lost visceral and total body fat, improving their body composition (Migueles et al., 2023). These findings about the decreases in body mass index and fat mass are consistent with earlier research on obese children (Feng et al., 2017). Similarly, findings from a network meta-analysis showed that in children and adolescents who were overweight or obese, aerobic or combined aerobic and resistance training effectively reduced adiposity outcomes with a similar magnitude (Kelley, Kelley & Pate, 2019). A cluster randomized clinical trial involving 1,392 eligible children aged 8 to 10 years was carried out over a single school year. A multimodal intervention supported children's behavioral changes by involving families, schools, and the community in addition to encouraging children to eat a healthy diet and exercise regularly. The intervention group's mean BMI decreased from baseline to the trial's closing, while the control group's mean BMI increased. The multimodal intervention successfully lowered the average body mass index and enhanced dietary, sedentary, and physical activity habits as well as knowledge about obesity; however, it had no effect on physical fitness or moderate-to-intense physical activity (Liu et al., 2022). Furthermore, a systematic review that assessed the association between physical fitness, physical activity, and overweight in adolescents found that overweight and obesity had an inverse relationship with physical activity (Rauner, Mess & Woll, 2013).

The study by Halberstadt et al. (2017) focused on behavioral interventions aimed at enhancing self-regulation. It found that the only statistically significant factor associated with weight loss maintenance was parental control over eating behaviors. This highlights the limited efficacy of behavioral changes alone in maintaining weight loss, suggesting that other factors might also be crucial (Halberstadt et al., 2017). A Victorian Government initiative called Healthy Together Victoria included an embedded cluster randomised trial of a system thinking approach to obesity prevention among adolescents aged 13–15 years and 15–16 years old. In the final analysis, 4,242 children received intervention and 2,999 control children. After two years of intervention, the authors found no discernible effect on BMI between the intervention and control group (Strugnell et al., 2024). Furthermore, a systematic review and meta-analysis of 12 randomized controlled trials assessed the effect of parental involvement on the management and prevention of childhood obesity, with an emphasis on outcomes such as BMI z-score. The BMI z-score significantly decreased, according to the meta-analysis. Subsequently, parental involvement in programs aimed at reducing childhood obesity significantly affects the BMI z-score (Aleid et al., 2024). According to the "4 your family" intervention study, family-based interventions can lead to positive changes in dietary and behavioral habits, as well as body weight and fat status. Personalized family-based interventions were found to be the most effective approach overall. Two factors could account for this: general health guidelines are given to all children regardless of their underlying problem(s) and time constraints parents may have for maximum engagement. This result implies that public health intervention programs ought to be tailored to the specific requirements and attributes of a given population. More planning is needed for certain eating habits, even though fundamental lifestyle factors like screen time and physical activity are simple to understand and change. Screening and categorizing parents and kids based on shared traits, eating habits, behaviors, and preferences may help adjust the intervention plan. This will tailor the intervention to the unique needs of the family (Varagiannis et al., 2021).

Family participation is especially crucial for kids under the age of twelve (Ho et al., 2012). Families have, not always been included in school-based obesity interventions. For instance, two cluster RCTs in the UK attempted to lower BMI by implementing school-based obesity interventions but were unsuccessful (Adab et al., 2018; Lloyd et al., 2018). The low level of family involvement in these earlier interventions may have contributed to their failure (Okely, Hammersley, 2018). According to a review, family-based interventions have demonstrated significant effects right away at the finish of the intervention (Oude Luttikhuis et al., 2009). It is widely acknowledged that early health habits are shaped by the family and home environments and that parents are critical in helping their children develop healthy eating and physical activity habits. Parents choose what kinds of foods to keep in the house and give opportunities for physical activity (Karmali et al., 2019), so these environments play a significant role in the cause and prevention of childhood obesity.

Furthermore, a recent systematic review suggests that parents who participated in interventions that involved education sessions on nutrition and physical activity could successfully improve the lifestyle of their children (Chai et al., 2019).

This review provides evidence that interventions promoting better diet quality, increased physical activity, and parental control over eating can lead to weight loss. However, achieving lasting weight loss requires sustained lifestyle changes. Healthcare providers should emphasize the importance of continuous lifestyle modifications to ensure long-term weight management.

Overall discussion of the four studies

Gorely 2011: The study found a significant increase in BMI (17.8 with CI 17.3-18.2) over the study period. Both the intervention and control groups increased their physical activity, but there was no significant group-by-time interaction (control: +2726 steps/day; intervention: +3404 steps/day, $p > .05$). Additionally, increases in body fat, skinfolds, waist circumference, and BMI were observed with age.

Hofsteenge 2014: The study reported a significant decrease in SDS-BMI from 2.96 ± 0.6 to 2.86 ± 0.7 in the intervention group.

Halberstadt 2017: The study observed an average decrease in SDS-BMI from 3.44 to 3.03 during treatment, with a slight weight regain to 3.18 at 2 years. The average weight loss was 0.41 SDS-BMI points during treatment and 0.26 SDS-BMI points at 2 years follow-up.

Ojeda-Rodriguez 2018: The study found a significant decrease in body weight and SDS-BMI in both the usual care and intensive care groups.

Challenges and Observations

The findings from these studies highlight a critical issue: while interventions can lead to weight loss, maintaining these outcomes over time is challenging. This is a common theme in the literature, suggesting that interventions often achieve initial success but struggle with long-term adherence and sustainability. The need for ongoing support and sustained lifestyle changes is evident.

Limitations in Current Research

A significant limitation observed across the studies is the variability in study quality and the broad age ranges of participants. The inclusion of both younger children and adolescents complicates the interpretation of results, as their growth patterns and nutritional needs differ. Future research should aim to target more homogeneous age groups and address these limitations.

Future Directions

Future studies should focus on extending the duration of interventions and follow-ups to better understand how lifestyle changes impact long-term weight management. Additionally, exploring how interventions can be adapted to ensure continued engagement and support for children and their families is crucial.

Conclusion

Gorely 2011: The GreatFun2Run intervention led to increased physical activity in both groups, but it did not significantly impact BMI or other body composition measures compared to the control group.

Hofsteenge 2014: The Go4it group treatment for obese adolescents was effective in reducing SDS-BMI over the study period, indicating a positive impact on obesity management.

Halberstadt 2017: The intensive combined lifestyle intervention was effective in reducing SDS-BMI in children and adolescents with severe obesity, although some weight regain was noted at the 2-year follow-up.

Ojeda-Rodriguez 2018: The lifestyle intervention improved diet quality and nutrient adequacy, leading to significant reductions in body weight and SDS-BMI in children and adolescents with abdominal obesity.

Overall Conclusions

The findings of this review, despite the limitations, suggest that lifestyle changes, including improved nutrition, increased physical activity, and parental control over eating, can contribute to weight loss in children. Enhancing lifestyle habits can positively influence weight management, but for sustained results, these changes need to be enduring. Future research should extend the duration of interventions and follow-ups to better understand how long-term lifestyle modifications affect weight and to develop strategies that promote lasting behavioral changes in children.

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Declaration of interest

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<u>Systematic review II</u>: The impact of ultra-processed foods on obesity and cardiometabolic co- morbidities in children and adolescents: A systematic review

Systematic Review

The impact of ultra-processed foods on obesity and cardiometabolic comorbidities in children and adolescents: a systematic review

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Context: *Over the past few decades, traditional foods have been displaced by ultra-processed foods (UPFs), with the latter being associated with health problems.* ***Objective:*** *This scoping systematic review aimed to identify the relationship between UPF intake and overweight/obesity as well as other cardiometabolic risk factors during childhood and adolescence.* ***Data Sources:*** *The guidance for this protocol is the Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P). A systematic search was undertaken on PubMed, Scopus, and Cochrane Library electronic databases based on prespecified inclusion and exclusion criteria up to 6 February 2022.* ***Data Extraction:*** *A total of 17 observational studies—9 cross-sectional, 7 cohort-longitudinal, and 1 study reporting both cross-sectional and longitudinal outcomes—among children and adolescents aged ≤18 years were eligible for inclusion in this review. Fourteen studies evaluated the consumption of UPFs in association with overweight/obesity and 9 studies examined the association of UPF consumption and cardiometabolic-related risk factors.* ***Data Analysis:*** *Most studies (14/17) showed that an increase in UPFs was associated with a higher prevalence of overweight/obesity and cardiometabolic comorbidities among children and adolescents, whereas 4 of 17 studies (3 cross-sectional and 1 cohort) found no association. Most cohort and cross-sectional studies showed good quality according to the National Institutes of Health and Newcastle-Ottawa quality assessment, respectively.* ***Conclusion:*** *The positive association found between UPFs and overweight/obesity and cardiometabolic comorbidities among children and adolescents raises concerns for future health. Further investigation is recommended to explore the role of specific types of UPFs on cardiometabolic conditions and to identify the amount of daily intake that increase risk in order to shape appropriate public health policies.*
Systematic Review Registration: *PROSPERO registration no. CRD42022316432.*

Key words: *adolescence, cardiometabolic risk, childhood obesity, ultra-processed foods.*

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INTRODUCTION

The prevalence of childhood and adolescent obesity has increased over the last 3 decades,[1] and dietary patterns, one of the most important modifiable lifestyle factors, have transitioned from traditional to Western.[2] This transition has been linked to childhood obesity and its related cardiometabolic disorders, including dyslipidemia, diabetes, and hypertension. The causes of this transition are multifactorial, with sociocultural changes, industrialization, and the globalization of food production being among the most dominant factors.[3]

The quality of the dietary pattern that individuals follow is determined not only by its content in specific nutrients or food items but also by other important factors such as its content in processed foods.[4,5] Evidence suggests that modern diets are characterized by a high consumption of many foods that have undergone some degree of processing. The NOVA system, a food classification system based on the nature, extent, and purpose of industrial food processing,[4] is a system designed to divide foods into 4 groups: unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods (UPFs). UPFs are manufactured using several ingredients, they contain little or no whole food, follow a series of processes, and they are combined with a sophisticated use of additives to increase their shelf-life and their palatability. They are ready-to-consume or ready-to-heat and thus require little or no culinary preparation, which makes them easily accessible and convenient.[6,7] Therefore, investigation of the impact of modern industrial food systems and consequently food processing on human health is important.

Over the last few decades, in several countries, traditional foods and freshly prepared dishes and meals have been displaced by UPFs, and therefore modern diets are characterized by high energy density, sugar, sodium, saturated fats, and *trans* fats and low fiber and micronutrient content, which is evidenced in children, adolescents, and adults.[6,8] Many studies have found a direct association between the consumption of UPFs and health problems. A systematic review conducted in adults showed that, in most studies, there was a positive association between UPF consumption and cardiometabolic risk factors, such as excess body weight, hypertension, increased total cholesterol and low-density-lipoprotein cholesterol, and metabolic syndrome (MetS)[9]—associations that lead to higher mortality in the general population.[10] With regard to children, there are currently only a few studies investigating the role of UPFs on body weight and cardiometabolic risk factors. A cross-sectional study conducted in 386 children aged 4–6 years highlighted the association of UPF consumption with poor diet quality, since high energy intake from UPFs was inversely associated with adherence to the Mediterranean diet among preschoolers.[11] In a systematic review on solely the role of UPFs on body fat accumulation in children and adolescents, the authors concluded that the majority of studies showed a positive association; however, children's body weight was not accounted for.[12] Furthermore, results remain controversial with respect to UPF intake and cardiometabolic conditions, with the majority showing unfavorable associations[13,14] and others showing null effects.[15]

It is crucial to also understand the association between UPF consumption with obesity and cardiometabolic comorbidities in children and adolescents, since many studies in adults have shown a positive effect. The existing knowledge about UPFs and childhood obesity was summed up in a systematic review by Costa et al[12] that studied children's body fat, where a positive association was found, while another systematic review[16] reported conflicting data between UPF consumption and obesity and adiposity parameters among children and adolescents. To the best of our knowledge, no review has been published on the association of UPFs and cardiometabolic comorbidities in children and adolescents.

The increasing rates of childhood obesity and cardiometabolic comorbidities, the high consumption of UPFs worldwide among children and adolescents, and the lack of systematic reviews on this issue led us to conduct the present scoping systematic review aiming to gather all existing knowledge regarding the association between the consumption of UPFs with obesity and cardiometabolic risk factors among children and adolescents.

METHODS

This scoping systematic review of observational studies, as defined in the *Cochrane Handbook* and based on Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P) is "an overview that attempts to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question."[17] The research question is "What is the relationship between UPF consumption and childhood obesity and its cardiometabolic comorbidities?" To summarize and communicate results, providing reliable findings to draw new conclusions, valid systematic methods were used[17] and the PRISMA checklist supported the effort to design this systematic review (Table S1; *see the Supporting Information online*).[18] This review has been registered with PROSPERO (registration no. CRD42022316432)

Table 1 **Definition of PICOS and inclusion of studies**

Parameter	Inclusion criteria	Exclusion criteria
Participants	Individuals aged 2–18 years	Individuals with health problems like cancer, hepatic disease, renal disease, Individuals >18 years, UPF intake not evaluated not clearly defined/measured, ecological studies, case-control studies, intervention studies, animal studies, interviews, commentaries, case-series, letters to the editor, editorials, reviews and meta-analysis
Interventions	None	
Comparisons based on exposure level	Level/amount of UPF intake	
Outcomes	Overweight/obesity -BMI -Waist circumference -Body fat percentage Cardiometabolic factors -Blood pressure -Dyslipidemia -Diabetes -Metabolic syndrome	
Study design	Prospective cohort studies, cross-sectional studies	

Abbreviations: BMI, body mass index; PICOS, Population, Intervention, Comparison, Outcome, Study design; UPF, ultra-processed food.

and the protocol is shown in Appendix S1 (*see the Supporting Information online*).

Eligibility criteria

Inclusion criteria were as follows: (1) population consisting of children and adolescents aged 2–18 years, (2) cross-sectional and longitudinal study design, (3) consideration of UPFs as classified with the NOVA classification system,[19–21] (4) English language, and (5) anthropometric indices for overweight/obesity or 1 or more cardiometabolic comorbidities included in the outcome (ie, blood pressure [BP], dyslipidemia, diabetes, and MetS). (See the PICOS [Population, Intervention, Comparison, Outcomes and Study design] criteria for inclusion and exclusion of studies; Table 1).

Exclusion criteria were as follows: (1) groups with health problems like cancer, hepatic disease, renal disease, etc, and (2) ecological, case-control, and intervention studies, as well as animal studies. Interviews, commentaries, case-series, letters to the editor, editorials, reviews, and meta-analyses were also excluded (Table 1).

Information sources and search strategy

For the literature search, 3 scientific databases were used: PubMed, Scopus, and the Cochrane Library. The results from each database were then exported to the RefWorks program by ProQuest to be further evaluated. The keywords used in Boolean operators were as follows: ("ultra-processed foods" OR "ultraprocessed foods" AND child* OR adolescen*). Also, keywords like BMI, obesity, and overweight, and cardiometabolic risk factors like blood pressure, dyslipidemia, diabetes, and metabolic syndrome were used in the aforementioned search strategy to confirm that no articles were left out. Furthermore, the reference list of the retrieved publications and the "similar or related articles" for each article in every database were checked for additional related studies, systematic reviews, and meta-analyses. All studies that were published until 6 February 2022 were utilized for the systematic review.

Selection of studies and data extraction

The eligibility for this systematic review was identified by 2 independent reviewers (E. Petridi and K.K.), who screened the studies by title and abstract. The full articles were selected for retrieval after excluding studies considered ineligible. Disagreement between the 2 reviewers was discussed and resolved by consensus. Where there was disagreement that was not resolved by consensus, a third reviewer (E.M.) was consulted. The process of included and excluded articles was performed according to the PRISMA flow diagram.[18] The extracted data included information for the author's name, year of publication, title, country of origin, study design, sample size, participants, period of study, dietary assessment, outcome assessed, results regarding obesity, and results regarding other comorbidities.

Risk of bias

Risk of bias for the full text of studies included was assessed independently using the National Institutes of Health (NIH) Quality Assessment Tool for cohort studies[22] and the Newcastle-Ottawa scale[23] adapted for cross-sectional studies.[24] The NIH Quality Assessment Tool includes 14 parameters: 1 parameter on the aim of the study, 4 parameters about the population, 4 parameters refer to the exposure measures, 2 parameters refer to the outcome measures, 2 parameters are about blinding of outcomes and follow-ups, and finally 1 parameter refers to statistical analysis. The options for the answers are "yes," "no," "cannot determine," "not applicable,"

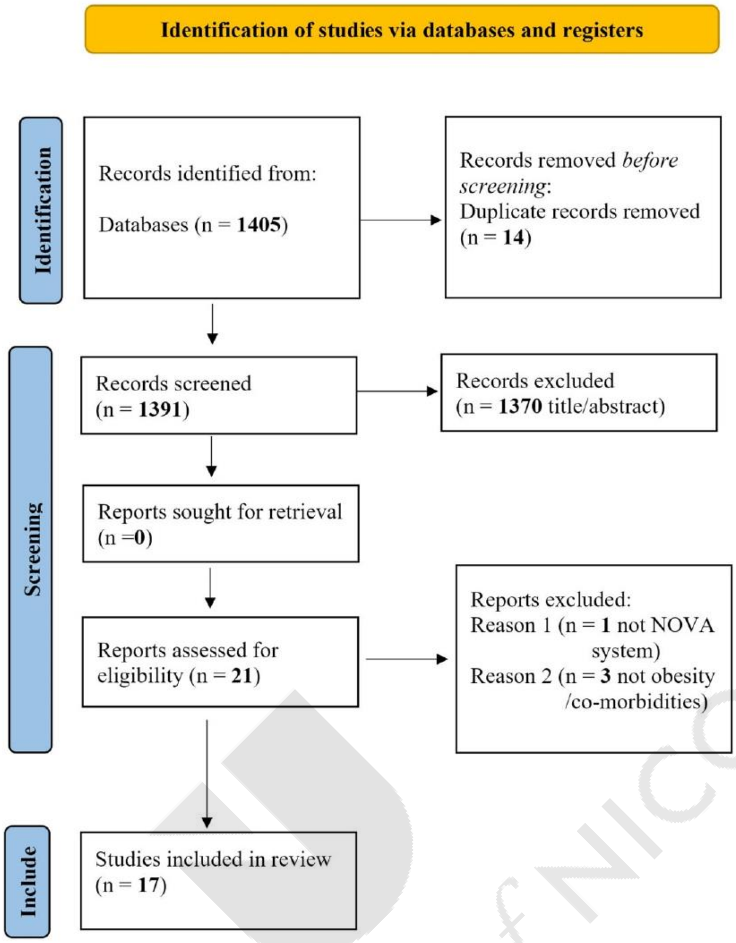

Figure 1 **PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 flow diagram.**

and "not reported." This quality-assessment tool determines poor, fair, and good quality levels.[22] The Newcastle-Ottawa scale (adapted for cross-sectional studies) includes 3 parameters: 1 parameter on selection with 4 subparameters, 1 refers to comparability, and 1 parameter refers to outcome with 2 subparameters. This quality assessment has 3 domains and a scale from 1 to 10 stars; the first domain has a maximum of 5 stars, the second a maximum of 2 stars, and the last a maximum of 3 stars.[24] Any disagreement was discussed and resolved by consensus.

RESULTS

Study selection

As shown in Figure 1, overall, 1405 studies were identified through database searching, of which 14 were excluded as duplicates. Following that, 1391 studies were screened for eligibility according to title and abstract, and reference lists and related articles were also thoroughly screened and retrieved no additional studies. Of these, 21 articles were scanned based on full text, 1 study was excluded based on food classification that was not conducted according to the NOVA system and 3 articles were excluded because they did not provide outcomes regarding overweight/obesity or cardiometabolic comorbidities. A total of 17 articles were included in the present systematic review.

Study characteristics

The study characteristics are shown in Table 2. All studies included children of both genders. Twelve of the studies were conducted in Brazil,[13–15,25–33] 2 studies were conducted in the United States,[34,35] 1 study in Spain,[36] 1 in England[37] and 1 study was conducted in Portugal[38]. Furthermore, the design of 9 studies was cross-sectional,[14,15,25,28,29,31,33–35] 7 were longitudinal,[13,26,27,30,32,37,38] and 1 study reported on both cross-sectional and longitudinal outcomes.[36] With regard to the range of participants' ages, 7 studies examined children younger than 12 years,[13,26–28,30,36,38] from which 4 examined preschoolers[13,27,30,36]; 7 studies included participants aged 12 to 18 years[14,15,25,31,32,34,35]; and in 3 studies, individuals were 7 to 24 years old.[29,33,37] With regard to the study sample, half of the studies (n = 8) included fewer than 1000 participants,[13–15,25,27,28,30,33] whereas the other 9 studies had more than 1000 children and/or adolescents.[26,29,31,32,34–38]

Main exposures and outcomes

Across the 17 included studies, children's overweight/obesity and other risk factors for cardiometabolic comorbidities were examined. Nutritional assessment was conducted with food-frequency questionnaires, 24-hour recalls (with 1, 2, or 3 d), or food diaries. The evaluation of UPF consumption was done by considering their contribution as a percentage of total energy intake, grams per day, number of weekly servings, and grams of macronutrients of UPFs per day. The risk of overweight/obesity was assessed using anthropometric indices such as weight, height, body mass index (BMI), waist circumference (WC), waist-to-height ratio, waist-to-hip ratio, sagittal abdominal diameter, and tricipital and subscapular skinfold thickness, and through body composition indices such as fat mass, lean mass, fat mass index, lean mass index, percentage of body fat, and fat-free mass. The indices that were used for the assessment of cardiometabolic comorbidities were total cholesterol, high-density-lipoprotein cholesterol, low-density-lipoprotein cholesterol, non–high-density-lipoprotein cholesterol, triglycerides, BP, systolic BP, diastolic BP, serum glucose (Glu), insulin, and homeostatic model assessment for insulin resistance (HOMA-IR).

Overweight/obesity

Thirteen of the identified studies examined the association of UPF consumption with the risk of overweight/obesity.[15,25–29,31–33,35–38] Seven of these studies indicated that higher consumption of UPFs is associated with an increased risk of overweight/obesity using BMI as a predictor.[25,29,31,35–38] More specifically, 1 study showed that higher consumption of UPFs at breakfast or dinner was associated with a higher BMI-for-age *z*-score (β = 0.23 [95% CI: 0.01–0.46] and β = 0.27 [95% CI: 0.02–0.54], respectively).[25] Similarly, Louzada et al[29] showed that participants of the highest vs lowest quantile of consumption of UPFs had a significantly higher BMI (0.94 kg/m^2; 95% CI: 0.42–1.47 kg/m^2), odds of being obese (odds ratio [OR] = 1.98; 95% CI: 1.26–3.12), and odds of excess weight (OR = 1.26; 95% CI: 0.95–1.69). Also, a cohort study showed that increasing consumption of UPFs was associated with a higher BMI by an additional 0.06 kg/m^2 (95% CI: 0.04–0.08 kg/m^2) per year.[37] Vedovato et al[38] indicated that a higher consumption of UPFs at the age of 4 years was associated with a higher BMI *z*-score at 10 years (β = 0.028; 95% CI: 0.006–0.051).

Three studies examined the relationship of UPFs and indicators of central adiposity (WC, sagittal abdominal diameter).[27,35,37] Costa et al[27] showed that higher UPF consumption by preschoolers was associated with increasing WC from preschool to school age (β = 0.07; 95% CI: 0.01–0.14). Another longitudinal study also indicated that UPF consumption was positively associated with WC and with an increased risk of high WC by an additional 0.17 cm (95% CI: 0.11–0.22 cm) per year.[37] Finally, Neri et al[35] in a cross-sectional analysis of the National Health and Nutrition Examination Survey (NHANES) 2011–2016 concluded that higher consumption of UPFs was associated with 52% and 63% higher odds of abdominal and visceral overweight/obesity, respectively, compared with lower consumption. It was also indicated that a 10% increase in UPF consumption increases the risk of both abdominal overweight/obesity (OR = 1.07; 95% CI: 1.01–1.13) and visceral overweight/obesity (OR = 1.07; 95% CI: 1.02–1.13).

The association of UPF consumption and the risk of overweight/obesity using indicators of body composition was also studied. Among 4 relevant studies,[25,26,31,37] 1 study showed an increase in percentage of body fat by 1.21% (95% CI: 0.23–2.64%) in

Table 2 **Characteristics and findings of the included studies investigating the association between consumption of UPFs and overweight/obesity and cardiometabolic comorbidities in children and adolescents**

Reference	Country	Study design	Sample size, n	Participants' age, y	Period of study	Dietary assessment	Outcome assessed	Results for obesity	Results for cardio-metabolic comorbidities
Bawaked et al, 2020[36]	Spain	Cross-sectional, longitudinal	1480	First phase: 4 y; second phase: 7 y	First phase, 2003; second phase, 2008	Semi-quantitative FFQ	BMI, BP, lipid profile	↑ UPFs at 4 y were associated with higher BMI *z*-score at 7 y (β = -0.07; 95% CI: −0.18, 0.03).	↑ UPFs at 4 y were associated with higher DBP *z*-scores at 7 y (β = -0.17; 95% CI: -0.31, 0.03)
Chang et al, 2021[37]	England	Longitudinal	9025	7–24 y	1998–2017	Food diaries, 3 d	BMI, anthropometric indices, BF%, FMI, LMI	Highest vs lowest quintile of UPF consumption was associated with: ↑ BMI by an additional 0.06 (95% CI: 0.04, 0.08) per year ↑ FMI by an additional 0.03 (95% CI: 0.01, 0.05) per year ↑ WT by an additional 0.20 (95% CI: 0.11, 0.28) per year ↑ WC by an additional 0.17 (95% CI: 0.1, 0.22) per year	—
Costa et al, 2019[27]	Brazil	Longitudinal	First phase, 354; second phase, 315	First phase: 4 y; second phase: 8 y	2001–2002	24-h recall, 2 d	BMI, anthropometric indices, Glu	↑ UPF consumption at preschool age was associated with ↑ ΔWC from preschool to school age (β = 0.07; 95% CI: 0.01, 0.14)	No significant association between UPF consumption and glucose profile was observed at age 8 y
Costa et al, 2021[26]	Brazil	Longitudinal	First phase, 3128; second phase, 3454	First phase: 6 y; second phase: 11 y	First phase, 2010–2011; second phase, 2015	Semi-quantitative FFQ	FMI	↑ 100 g UPFs daily was associated with a gain of 0.14 kg/m^2 in FMI from 6 to 11 y	—

(continued)

Table 2 **Continued**

Reference	Country	Study design	Sample size, n	Participants' age, y	Period of study	Dietary assessment	Outcome assessed	Results for obesity	Results for cardio-metabolic comorbidities
Cunha et al, 2018[32]	Brazil	Longitudinal	1035	15–17 y	First phase, 2010; second phase, 2011; third phase, 2012	Semi-quantitative FFQ	BMI, %BF	↑ UPF consumption was associated with ↓ BMI (23.1 in first quartile vs 21.3 in fourth quartile at baseline) and (24 in first quartile vs 22.4 in fourth quartile after 2 y follow-up) ↓ %BF (25.1% in first quartile vs 21.9% in fourth quartile at baseline) and (25.9% in first quartile vs 22.1% in fourth quartile after 2 y follow-up) both at baseline and at follow-up	—
Enes et al, 2019[33]	Brazil	Cross-sectional	200	10–18 y	2016	Semi-quantitative FFQ for adolescents	BMI, anthropometric indices	No association between UPF consumption and anthropometric indices	—
Leffa et al, 2020[13]	Brazil	Longitudinal	308	First phase: 3 y; second phase: 6 y	First phase, 2011–2012; second phase, 2014–2015	24-h recall, 2 d	BMI, lipid profile	—	↑ 10% in TDEI of UPFs was associated with: ↑ TC (β = 2.76 mg/dL; 95% CI: 0.04, 5.44); ↑ TG (β = 3.44 mg/dL; 95% CI: 0.46, 6.42)
Louzada et al, 2015[29]	Brazil	Cross-sectional	7534	10–19 y	2008–2009	24-h recall, 2 d	BMI	Adolescents in the highest quintile of consumption of UPFs had: ↑	—

(continued)

Table 2 **Continued**

Reference	Country	Study design	Sample size, n	Participants' age, y	Period of study	Dietary assessment	Outcome assessed	Results for obesity	Results for cardio-metabolic comorbidities
								higher mean BMI 0.84 kg/m^2 (95% CI: -0.16, 1.85); ↑odds of being obese (OR = 2.74; 95% CI: 0.78,9.60); ↑odds of excess WT (OR = 1.52; 95% CI: 0.75,3.07)	
Melo et al, 2017[15]	Brazil	Cross-sectional	249	14–19 y	—	Semi-quantitative FFQ	BMI, anthropometric indices, BP	No association between UPFs and excess WT or high WC	No association between UPFs and high BP
Neri et al, 2022[35]	USA	Cross-sectional	3587	12–19 y	2011–2016	24-h recall, 2 d	BMI, anthropometric indices	Highest vs lowest consumption of UPFs was associated with 45%, 52%, and 63% higher odds of total, abdominal, and visceral overweight/obesity, respectively (OR: 1.45; 95% CI: 1.03, 2.06; OR: 1.52; 95% CI: 1.06, 2.18; OR: 1.63; 95% CI: 1.19, 2.24, respectively); ↑10% of TDEI of UPFs was associated with ↑ risk of both abdominal overweight/obesity (OR: 1.07; 95% CI: 1.01, 1.13) and visceral overweight/obesity (OR: 1.07; 95% CI: 1.02, 1.13)	—

(continued)

Table 2 **Continued**

Reference	Country	Study design	Sample size, n	Participants' age, y	Period of study	Dietary assessment	Outcome assessed	Results for obesity	Results for cardio-metabolic comorbidities
Neves et al, 2022[25]	Brazil	Cross-sectional	790	14–19 y	2018–2019	24-h recall, 2 d	BMI, body fat	↑ UPFs at breakfast were associated with: ↑ BMI-for-age (*z*-score) ($\beta = 0.23$; 95% CI: 0.01, 0.46) and ↑ body fat (1.21%; 95% CI: 0.23%, 2.64%); ↑ UPFs at dinner were associated with: ↑ BMI-for-age (*z*-score) ($\beta = 0.27$; 95% CI: 0.02, 0.54)	—
Oliveira et al, 2020[28]	Brazil	Cross-sectional	164	7–10 y	2018–2019	24-h recall, 3 d	BMI, anthropometric indices, BP	No association between the caloric contribution of food groups and BMI, WC, WHtR	No significant association between UPF consumption and BP
Rauber et al, 2015[30]	Brazil	Longitudinal	First phase, 345; second phase, 307	First phase: 3–4 y; second phase: 7–8 y	2001–2002	24-h recall, 2 d	Lipid profile	—	UPF consumption was a predictor of a higher increase in TC ($\beta = 0.430$; 0.008–0.853) and LDL cholesterol ($\beta = 0.369$; 0.005–0.733) from preschool to school age
Tavares et al, 2012[14]	Brazil	Cross-sectional	210	12–19 y	2006– 2007	Semi-quantitative FFQ	MetS	—	↑ UPFs were associated with a higher prevalence of MetS (prevalence ratio = 2.5; $P = .012$)

(continued)

Table 2 **Continued**

Reference	Country	Study design	Sample size, n	Participants' age, y	Period of study	Dietary assessment	Outcome assessed	Results for obesity	Results for cardio-metabolic comorbidities
Vedovato et al, 2021[38]	Portugal	Longitudinal	1175	First phase: 4 y; second phase: 7 y; third phase: 10 y	First phase, 2009–2011; second phase, 2012–2014; third phase, 2015–2017	Food diaries, 3 d	BMI	UPF consumption at 4 y old was associated with ↑ BMI *z*-score at 10 y old ($\beta = 0.028$; 95% CI: 0.006, 0.051)	—
Viola et al, 2020[31]	Brazil	Cross-sectional	1525	18–19 y	2016	Semi-quantitative FFQ	BMI, LMI, muscle mass	BMI, muscle mass, and LMI were inversely associated with UPF consumption; ↑ 1% of TDEI of UPFs was associated with a 0.04-kg decrease in muscle mass ($\beta = -0.04$; 95% CI: -0.06 to -0.02) and a 0.01-kg/m^2 decrease in lean body mass ($\beta = -0.01$; 95% CI: -0.02 to -0.01).	—
Zhang et al, 2022[34]	USA	Cross-sectional	5565	12–19 y	2007–2018	24-h recall, 2 d	CVH metrics	—	↑ 5% in UPF calories was associated with 0.13 points lower CVH scores ($P < .001$)

All reported outcomes used diagnosed or measured values.

Abbreviations: BMI, body mass index; BP, blood pressure; CVH, cardiovascular health; DBP, diastolic blood pressure; FFQ, food-frequency questionnaire; FMI, fat mass index; Glu, glucose; LDL, low-density-lipoprotein; LMI, lean mass index; MetS, metabolic syndrome; OR, odds ratio; TC, total cholesterol; TDEI, total dietary energy intake; TG, triglycerides; UPF, ultra-processed food; WC, waist circumference; WHtR, waist-to-height ratio; WT, weight; %BF, body fat percentage; ↑ increase; y, years.

adolescents who consumed more UPFs at breakfast.[25] Viola et al[31] indicated that an increase of 1% of total dietary energy intake of UPFs was associated with a 0.04-kg decrease in muscle mass (β = –0.04; 95% CI: –0.06, –0.02) and a 0.01-kg decrease in lean body mass (β = –0.01; 95% CI: –0.02, –0.01). Furthermore, fat mass index was found to increase by an additional 0.03 kg/m^2 (95% CI: 0.01–0.05 kg/m^2) per year in the highest quintiles of UPF consumption compared with the lowest.[37] Similarly, Costa et al[26] indicated that an increase in daily UPF consumption by 100 g was associated with a gain of 0.14 kg/m^2 in fat mass index from 6 to 11 years.

On the other hand, even if the majority of studies showed a positive association between UPFs and overweight/obesity, 3 studies found opposite results. In these studies that examined BMI and WC as predictors of overweight/obesity and abdominal obesity, no association between UPF consumption and the prevalence of overweight/obesity or abdominal obesity was seen.[15,28,33] Contrary to all previous studies, Cunha et al[32] in a longitudinal analysis reported that the consumption of UPFs was inversely associated with BMI and percentage of body fat in 1037 adolescents aged 15–17 years old.

Cardiometabolic comorbidities

Most of the studies included in the present systematic review, apart from overweight/obesity, also looked at other cardiometabolic comorbidities associated with UPF consumption, such as dyslipidemia, BP, glucose (Glu), and MetS. Three studies examined the relationship between UPF consumption and dyslipidemia and indicated that an increase in UPFs is associated with an increase in total cholesterol, low-density-lipoprotein cholesterol, and triglycerides.[13,30,34] Three studies[15,28,36] examined the possible association of UPF consumption with BP in children and adolescents. In 2 of these studies,[28,36] it was reported that higher consumption of UPFs had a greater impact on BP, while Melo et al[15] showed no such association. Costa et al[27] showed that UPFs had no impact on the glucose profile of children aged 4–8 years old. However, Tavares et al[14] investigated the relationship between UPFs and metabolic syndrome and indicated that an increase in UPFs is associated with a higher prevalence of MetS in adolescents.

Risk of bias

The evaluation of the risk of bias by the NIH Quality Assessment Tool for cohort studies,[22] as shown in Table 3, showed that no study was of poor quality, 3 studies were categorized as being of fair quality,[32,36,37] and 5 studies as good quality.[13,26,27,30,38] Considering the cross-sectional studies, the evaluation of the risk of bias using the Newcastle-Ottawa quality-assessment scale[23] adapted for cross-sectional studies[24] showed that 1 study had 5/10 stars,[15] 3 studies had 6/10 stars,[14,31,33] 1 study had 7/10 stars,[29] 4 studies had 8/10 stars,[25,28,35,36] and 1 study had a quality rating of 9/10 stars[34] (Table 4). Since the study of Bawaked et al[36] included both a cohort and a cross-sectional design, the total number of assessments was 18 rather than 17.

DISCUSSION

The consumption of UPFs has increased during the last decade across all age groups. Although there are many studies examining the association of UPF consumption and obesity or cardiometabolic risk factors among adults, only a few have investigated this association in children and adolescents, a group characterized by an alarming continuous increase in the prevalence of overweight/obesity and several cardiometabolic risk factors. Taking this into account, the present systematic review highlighted the role of UPF consumption on childhood overweight/obesity and, to the best of our knowledge, is the first that investigated the impact of UPF consumption on cardiometabolic risk factors in these age groups. It was shown that, in the majority of the included studies, there was a positive association of UPF consumption with childhood overweight/obesity. Also, UPFs were associated with cardiometabolic comorbidities such as dyslipidemia, BP, diabetes, and MetS among children and adolescents.

Findings from cross-sectional and longitudinal studies included in this review reported that the consumption of UPFs was associated with overweight/obesity among children and adolescents.[25–27,29,31,35–38] Costa et al,[12] in a previous systematic review in children and adolescents, also revealed a positive association between the consumption of UPFs and body fat. However, De Amicis et al,[16] in a recent systematic review, reported that findings are conflicting regarding UPF consumption and adiposity parameters among children and adolescents. It is of note that relevant studies in adults revealed more robust results showing a positive association between UPF consumption and obesity.[39–43]

There are several mechanisms that describe the association between UPF consumption and the risk of overweight/obesity. First, UPFs are considered to account for a large part of total daily energy intake. In Chile, UPF consumption was 49% of the total energy intake among preschoolers.[44] Rauber et al,[7] in a cross-sectional study in children aged 1.5 years and older,

Table 3 **Quality assessment for cohort studies (NIH Quality Assessment Tool)**

Criteria in studies	Leffa et al, 2020[13]	Bawaked et al, 2020[36]	Costa et al, 2019[27]	Rauber et al, 2015[30]	Chang et al, 2021[37]	Cunha et al, 2018[32]	Vedovato et al, 2021[38]	Costa et al, 2021[26]
1. Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y	Y	Y	Y	Y
2. Was the study population clearly specified and defined?	Y	Y	Y	Y	Y	Y	Y	Y
3. Was the participation rate of eligible persons at least 50%?	Y	Y	Y	Y	Y	Y	Y	Y
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Y	Y	Y	Y	Y	Y	Y	Y
5. Was a sample-size justification, power description, or variance and effect estimates provided?	Y	CD	Y	N	N	N	N	N
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	N	N	N	N	N	N	N	N
7. Was the time frame sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	Y	Y	Y	Y	Y	Y	Y	Y
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (eg, categories of exposure, or exposure measured as continuous variable)?	Y	Y	Y	Y	Y	Y	Y	Y
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	N	Y	Y	N	N	N	N
10. Was the exposure(s) assessed more than once over time?	Y	Y	Y	Y	Y	N	Y	Y
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y	Y	Y	Y	Y
12. Were the outcome assessors blinded to the exposure status of participants?	Y	N	Y	Y	NA	NA	NA	NA
13. Was loss to follow-up after baseline 20% or less?	NA	N	N	N	N	N	Y	Y
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Y	Y	Y	Y	Y	Y	Y	Y
Score	Good	Fair	Good	Good	Fair	Fair	Good	Good

Abbreviations: CD, cannot determine; N, no; NA, not applicable; NIH, National Institutes of Health; Y, yes.

Table 4 **Quality assessment for cross-sectional studies (Newcastle-Ottawa)**

Criteria in studies	Neves et al, 2022[25]	Bawaked et al, 2020[36]	Oliveira et al, 2020[28]	Louzada et al, 2015[29]	Melo et al, 2017[15]	Tavares et al, 2012[14]	Viola et al, 2020[31]	Enes et al, 2019[33]	Zhang et al, 2022[34]	Neri et al, 2022[35]
Selection										
1. Representativeness of the sample:										
a) Truly representative of the average in the target population* (all subjects or random sampling)									*	*
b) Somewhat representative of the average in the target population* (nonrandom sampling)	*	*	*	*						
c) Selected group of users								–		
d) No description of the sampling strategy					–	–	–			
2. Sample size:										
a) Justified and satisfactory*	*	*	*						*	*
b) Not justified				–	–	–	–	–		
3. Nonrespondents:										
a) Comparability between respondents and nonrespondents characteristics is established, and the response rate is satisfactory*	*								*	
b) The response rate is unsatisfactory, or the comparability between respondents and nonrespondents is unsatisfactory										
c) No description of the response rate or the characteristics of the responders and the nonresponders		–	–	–	–	–	–	–		–
4. Ascertainment of the exposure (risk factor):										
a) Validated measurement tool**										
b) Nonvalidated measurement tool, but the tool is available or described*	*	*	*	*	*	*	*	*	*	*
c) No description of the measurement tool										
Comparability										
1. The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled.										
a) The study controls for the most important factor (select 1)*	*	*	*	*	*	*	*	*	*	*
b) The study controls for any additional factor*		*	*	*	*	*	*	*	*	*
Outcome										
1. Assessment of the outcome:										
a) Independent blind assessment**										
b) Record linkage**	**	**	**	**	**	**	**	**	**	**
c) Self-report*										
d) No description										
2. Statistical test:										
a) The statistical test used to analyze the data is clearly described and appropriate, and the measurement of the association is presented, including confidence intervals and the probability level (*P* value)*	*	*	*	*		*	*	*	*	*
b) The statistical test is not appropriate, not described or incomplete					–					
Score	8/10	8/10	8/10	7/10	5/10	6/10	6/10	6/10	9/10	8/10

Abbreviation: NIH, National Institutes of Health.

found that 56.8% of total energy intake came from UPFs. This high consumption of UPFs results in a diet with high energy density, saturated and *trans* fats, carbohydrates, and total sugars and a lower content of fiber, zinc, vitamin A, and folate.[44] Also, this unbalanced nutritional composition from excessive consumption of UPFs is associated with a lower protein intake, which contributes to lower muscle mass, as Viola et al[31] reported in a study conducted in 1525 adolescents. Furthermore, increased UPF consumption results in a high intake of refined carbohydrates, which can be easily and rapidly absorbed by the body and may lead to increased insulin secretion. This leads to elevated storage of adipose tissue, which is associated with a high risk of obesity.[45,46] Another mechanism, which has only been investigated in mice, supports that the alteration of the original food matrix and the added cosmetic additives of these products are associated with changes in the composition and metabolic behavior of the gut microbiota that promote inflammatory diseases.[47,48] Finally, UPFs are typically packaged in plastic, and several plasticizers, such as bisphenol A, have been found to be associated with obesity in both animals and adults; thus, it is very likely that this could also apply in children and adolescents.[49,50] It is of note that a large number of prospective studies have performed adjustments in the association of UPF consumption with unfavorable health consequences using diet quality, fat, sugar, or salt intake as covariates, which showed that healthy or unhealthy dietary patterns have a minimal impact on this association. This implies that the negative role of UPFs on human health cannot be solely attributed to the displacement of healthy foods and to diet quality impairment. Perhaps the nature and extent of processing should also be considered as a significant factor of health consequences related to UPFs.[51]

Cardiometabolic comorbidities represent another field of interest for children and adolescents. Saturated and *trans* fats are commonly used to improve the palatability and texture of a product by the food industry. In the present review, 3 studies found a positive association between UPFs and dyslipidemia.[13,30,34] The same findings were reported in US adults where an inverse association was observed between percentage of energy (%kcal) from UPFs and cardiovascular health.[39] Another main problem related to industrial food processing is the high content of salt in UPFs, which is associated with elevated BP. In the present systematic review, 2 studies reported that higher consumption of UPFs was associated with higher BP levels,[28,36] while 1 study by Melo et al[15] showed no such association among adolescents. Also, Scaranni et al,[52] in a longitudinal analysis of 8754 adults, found that higher consumption of UPFs is associated with a higher risk of hypertension. Furthermore, high amounts of added sugars in UPFs can lead to energy imbalance and an unhealthy blood glucose profile. There was only 1 study among children that found a positive relationship between UPFs and glucose profile.[27] This is in accordance with studies in adults worldwide, which reported a higher prevalence of type 2 diabetes with a higher consumption of UPFs.[53–55] The MetS includes all the above risk factors, and Tavares et al[14] indicated that an increase in UPFs leads to MetS among adolescents. In a cross-sectional study in the United States, it was also shown that a higher dietary contribution of UPFs is associated with a higher prevalence of MetS among 6385 young adults.[56]

Unhealthy dietary habits as well as their main consequences such as obesity and cardiometabolic comorbidities followed in childhood and adolescence tend to track into adulthood. Therefore, it is of great importance to investigate overconsumption of UPFs and its consequences in children. Additionally, the main causes related to this type of diet, such as the family and social environment, should be highlighted, so that future public health initiatives will most effectively tackle this unhealthy dietary behavior. This review highlighted this necessity considering the overall good quality of most of the studies included and also the fact that the majority of them used the percentage of total energy intake to evaluate the consumption of UPFs.

The strength of the present review is that it is the first to demonstrate the impact of UPF consumption in overweight/obesity risk and cardiometabolic comorbidities considering several anthropometric and cardiometabolic indices among children and adolescents. Also, the NOVA food-classification system was used for the identification of UPFs, which has been recognized as a valid tool for nutrition and public health research and policy.[19–21] Moreover, the majority of studies had a moderate quality regarding their risk of bias, which enables the outcomes to be considered as valid.

Potential limitations of this research include that many studies considered participants aged older than 12 years as children and participants younger than 12 years as adolescents, and there were 3 studies[29,33,37] that included children and adolescents at the same time and thus reported combined results for all ages (7–24 y). Finally, the studies used different methods to estimate the consumption of UPFs. Food-frequency questionnaires are less detailed in terms of specific food items compared with 24-hour recalls or food diaries, due to food grouping, which might have led to grouping together UPFs and less-processed food items into 1 food group.[57]

CONCLUSION

The findings of this review provide information about the association between the consumption of UPFs and overweight/obesity or cardiometabolic risk–related outcomes among children and adolescents. The majority of the studies showed a positive association either in the risk of obesity or in cardiometabolic comorbidities, although the type and quantity of processed foods consumed have not been evaluated. As consumption of UPFs may directly increase weight and cardiometabolic risk factors during childhood and since childhood dietary habits may also track to adulthood, more longitudinal studies are essential to further investigate these findings, identify facilitating factors and potential barriers for this dietary behavior in children and adolescents, and thus use this information to promote effective policies for reducing intake.

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Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

Appendix S1 **PROSPERO protocol**

Table S1 **PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist 2020**

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PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	p.1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Not applicable (N/A)
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p.3-5
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p.3-5
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Table 1 p.5-6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p.6
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	p.6
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Figure 1 and p.6-7
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p.6-7
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p.6-7
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	p.6-7
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p.7
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Table 1 and p.5-6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	p.6
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	p. 6-7
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	p. 6-7
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
assessment			
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/A
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure 1 and p. 7-8
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	N/A
Study characteristics	17	Cite each included study and present its characteristics.	p.8 Table 2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Tables 3 and 4 and p 11-12
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Table 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Tables 3 and 4
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	p 8-11
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	N/A
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	N/A
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p.12-15
	23b	Discuss any limitations of the evidence included in the review.	p.15
	23c	Discuss any limitations of the review processes used.	p.15
	23d	Discuss implications of the results for practice, policy, and future research.	p.15-16
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p.5
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Supporting information
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	p.16
Competing interests	26	Declare any competing interests of review authors.	p.16

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Not publicly available, can be produced upon request

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Appendix 2 (Article under review)

Ultra Processed food consumption in children and adolescents: main food group contributors and associations with weight status

Short title: Ultra-processed foods and weight status

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Abstract

Consumption of ultra-processed foods (UPFs) plays an important role in the development of childhood obesity worldwide. The aim of this study was to assess the main food groups contributing to UPF consumption and their association with weight status. Following exclusion of children with implausible intakes and misreporters, the final sample included 443 of 484 eligible (children and adolescents aged 2-18 years old) (91.5%), from the Hellenic National Nutrition and Health Survey (HNNHS). UPF items reported in 24hr recalls were identified according to the NOVA4 system and the proportion of their contribution to the daily energy intake was calculated. Main UPF food contributors were derived for the total population and by weight status. The association between weight status and UPF intake for the main contributors was examined using generalized linear models. The percentage of total daily energy provided by UPFs was 42.6%. Four major food groups were found to contribute > 10% of total UPF intake: ready-to-eat/heat dishes (36.2%), sweet grain products (21.4%), savoury snacks (15.4%) and sweets (12.9%). These provided 86% of the total UPF intake, with no significant differences between children's weight status. The high contribution of UPFs, however, to children's daily energy intake emphasizes the need for public food awareness campaigns for health promotion. Evaluation of contribution of food groups and not only total UPF intake is also important.

KEYWORDS

Ultra-processed foods (UPF), children, adolescents, overweight, obesity, NOVA classification system.

INTRODUCTION

Increasing evidence suggests that the population of southern Europe is transitioning away from traditional eating habits, such as the Mediterranean diet in favor of more "Westernized" eating patterns (Grosso et al. 2014). These modern dietary habits tend to promote unhealthy behaviors related to weight gain, including high consumption of readily available palatable foods with low nutritional value (Pereira-da-Silva et al. 2016) and an increased reliance on ultra-processed food (UPF) (Vedovato et al. 2021). The latter foods are designed to be consumed on the go and frequently without utensils. They are sold as ready-to-eat dishes, snacks and drinks and usually displace homemade meals. Furthermore, the techniques and the additives used to produce them make them highly palatable, increasing the tendency of overeating and cravings and affecting appetite and satiety regulation (Schulte et al. 2015). Consequently, this may lead to overconsumption, especially of foods rich in simple carbohydrates and fat, resulting to weight gain (Hall et al. 2019) and obesity.

Obesity has become a global epidemic, in 2022, 43% of adults aged 18 years and over were overweight and 16% were living with obesity (World Health Organization 2024). The number of children affected by obesity has also increased by a tenfold in the past four decades (World Health Organization 2017). This is of great importance since childhood obesity is associated with an increased risk of obesity later in life (Ward et al. 2017) and early onset of adverse cardiometabolic health conditions (Chung et al. 2018). Increasing evidence suggests that the key risk factor for overweight and obesity is unhealthy dietary habits and eating contexts (Sirkka et al. 2021, Neves et al. 2022) behaviors found to be associated with high percentage of UPF intake (Neves et al. 2022). Furthermore, ad lib UPF intake was reported to be correlated with higher energy intake compared to their unprocessed counterpart (Hall et al. 2019).

Recent studies have shown that high consumption of UPFs is associated with a higher prevalence of obesity in adults (Juul et al. 2018, Rauber et al. 2021), and in children (Menezes et al. 2023, Costa et al. 2018), although evidence remain controversial (Enes et al. 2019, Oliveira et al. 2020). Despite the controversy, the concern is that the majority of UPFs contain little or no whole food and a significant number are of very low nutritional value and a high content of energy, sugars, saturated fats (Menezes et al. 2023), factors linked to chronic disease (Rauber et al. 2018). UPF intake have been associated with increased risk of arterial hypertension (Mendonça et al. 2017), metabolic syndrome (MetS) in adolescents (Tavares et al. 2012) and abnormalities in the lipid profiles in children (Rauber et al. 2015). The most widely used method to assess the degree of food processing is the NOVA classification system (Monteiro et al. 2019). Many studies, using this method, showed that UPF contributes about 50% to the total energy intake in children and adolescents (Araya et al. 2021, Moubarac et al. 2017, Rauber et al. 2018). However, it remains controversial whether the degree of processing alone makes a difference or whether the meal patterns or overall food matrix is of matter.

Specifically, a prospective study in children showed that those consuming a specific dietary pattern diet, characterized high in white bread, crisps and sugary drinks, was significantly associated with increased risk for childhood overweight at 10 years, compared to a minimally processed pattern high in vegetables, sauces, rice/pasta and savory dishes (Sirkka et al. 2021). The authors used Principal Component Analysis, of their populations dietary pattern and not the NOVA classification, and descripted the minimally processed pattern, the one characterised by whole grains and vegetables, despite the presence of sauces as well. Most studies provide data mostly related to total UPF intake and contribution to daily energy intake, through NOVA classification of dietary although the proportion of main food contributors to UPF intake may be of great importance as well and, may shed light on these controversial findings.

Therefore, the present study is to our knowledge, the first study in Greece that aims to assess the proportion of UPFs in daily energy intake and identify the main food groups contributing to UPF consumption among children and adolescents, utilising data from the Hellenic Nutrition and Health Survey (HNNHS). The association between total UPF intake, specific UPF food types, and weight status, was secondly explored.

METHODS

2.1 Study design and population

The HNNHS is a population-based study designed to assess the health and nutritional status of Greek children and adults. It was carried out between September 2013 and May 2015. A nationally representative sample was selected with a random stratified design based on the 2011 census data. The study's details have been published elsewhere (Magriplis et al. 2019). Trained interviewers using the Computer Assisted Personal Interview (CAPI) method, collected data on anthropometric, sociodemographic and lifestyle parameters with an in-person interview at the participant's residence. Written consent form was derived by the legal guardian of all children and adolescents.

For the purpose of this study, all children and adolescents aged 2-18 years (from now on referred to as children) who had provided at least one 24-hour dietary recall were primarily included (n=733). Exclusion criteria included implausible intakes set at ≥6000 & ≤600 kcal (n=15), and mis-reporters assessed using Goldberg's equations, as modified by Black (Black 2000). This methodology is based on the ratio of reported Energy Intake and the estimated Basal Metabolic Rate (BMR) as per Schofield's age- and sex-specific equations (Koletzko et al. 2005), multiplied by a specific standard of Physical Activity Level. A total of 172 children were classified as over-reporters and 62 were classified as under-reporters and therefore removed from the dataset leading to a sample size of 484 children. Details regarding calculations of over-reporters and under-reporters have been published (Mitsopoulou et al. 2020). Furthermore, although missing anthropometric data were imputed children that had missing information for both weight and height no imputation were performed to minimise bias, and children were excluded (n=41). More specifically, missing data on weight and height were imputed modelling the variable distribution by age (for each child with missing information on weight or height), under the assumption of Missing at Random (MAR) upon first screening. The derived datasets (12 in total) derived with missing values were combined to produce the final analysis. Imputed data were checked to assure they are reasonable compared to the observed non-missing data distribution. The final sample included in this study was 443 children (91.5% of children with plausible intakes).

2.2. Data collection

2.2.1. Dietary Assessment

Assessment of dietary intake was done through a 24-hour recall (24hR) by trained interviewers using the Automated Multi-pass Method (AMPM) (Blanton et al. 2006). Two 24hR were conducted on non-consecutive days, the first in-person and the second over the telephone 8-20 days later. Dietary data were collected from parents who were used as proxies for children <12 years. Adolescents ≥12 years old completed the dietary recall by themselves. Portion sizes were estimated by using age-specific food atlases and household measures (e.g. cups, glasses, spoon sizes). Energy and nutrients for each food were derived from the Nutrition Data System for Research (NDSR) (developed by the University of Minnesota) (University of Minnesota 2024) and the Greek food composition tables for traditional Greek recipes (e.g., baklavas) (Trichopoulou & Georga 2004).

The total daily energy intake (TEI) of NOVA 4 food classified foods was calculated by summing the energy content of each food item and then the average intake per child per day was estimated.

2.2.2. Food Grouping & Nutrient intake estimation

Food and beverage items were classified according to the NOVA 4 food classification system. NOVA is a system that categorizes food into 4 groups based on the degree and purpose of processing each food has undergone. Specifically, NOVA1 includes unprocessed or minimally processed foods, NOVA2 includes processed culinary ingredients, NOVA 3 contains processed foods and NOVA 4 foods that have encountered a high degree of processing not regularly performed at home such as refining, hydrolyzation, and pre-frying (Monteiro et al. 2019, Khandpur et al. 2021). For this study foods in NOVA 4, usually defined as ultra-processed, were evaluated.

A four-step process was performed to identify UPFs. In the first step a list of all food consumed by each child was compiled from the 24 hR. In Step 2 UPF foods were identified and categorized as NOVA 4 the procedure of gathering information (brands where possible) from 24-h recalls, the eating location (bakeries compared to home and other food specific facets. At this step, foods that were of unclear classification were flagged and were categorized following team consultation. For the decision to be made reported food details from the child's 24hR were evaluated (where it was consumed, if a recipe was homemade or ready to eat, etc). In Step 3, all foods were categorised into specific food groups based on their main food ingredient, as per nutritional guidelines belong to a greater category. For example, the food group 'breakfast cereals' contains all reported cereals that are refined or whole grain but contain added sugar, hence categorised in another food group compared to the main food group ‘grains and cereals’. Details of the food groups created can be seen in Table 1. In Step 4, the energy of all food per food group was summed, for each recall (in kcal, as per each food nutrient profile) and was then averaged for children with two 24hRs. The energy derived from all food groups of NOVA 4 was summed and the value was divided by the total mean daily energy intake of each child to calculate the total proportion of the diet consisting of UPFs. Food group contribution was derived as percent total energy per food group (kcal) divided by the total energy (kcal) from all NOVA 4 food groups consumed by each child and then multiplied by 100 (Block et al. 1985). Proportions were calculated for the total sample and by children’s weight status groups.

2.3. Anthropometric and Other variables

2.3.1. Weight Status Assessment

Body Mass Index (BMI) was used to evaluate the children’s weight status. Body weight and height were measured by the parent or guardian for children <12 years and for adolescents ≥12 years by themselves. A total of 107 data were imputed for children when at least one of the two was available, using the Missing at Random (MAR) process (information stated previously). BMI was calculated by dividing weight in kg by height in meters squared (kg/m^2). To categorize children and adolescents according to their BMI, the extended International Obesity Task Force (IOTF) tables were used (Cole & Lobstein 2012). These tables are a set of growth reference charts and cutoffs, that consider age and sex differences in growth patterns, specifically designed to monitor and address childhood obesity on a global scale. Children who were overweight and children living with obesity were grouped for further analysis to have adequate power of analysis.

2.3.2. Other Variables

Demographic, lifestyle and socio-economic data such as sex, age, physical activity, screen time for children parental educational level and employment status were collected. Physical activity was evaluated using validated age-specific questionnaires (i) Preschool-aged Children Physical Activity Questionnaire (Pre-PAQ Home Version) (Dwyer et al. 2011) for children 2-12 years old (Timmons et al. 2007) and (ii) the International Physical Questionnaire – Adolescents (IPAQ-A) for those 12- 18 years old (Hagströmer et al. 2008). Similarly, the IPAQ-A is a 7-day recall tool that estimates total metabolic equivalents (METs) based on data collected on activities carried out at school (formal physical education lessons and recess/beak times), at home, at leisure time and during transport/journeys. The physical activity level was estimated by multiplying the time spent on each activity by the corresponding MET-value of the specific activity, using published values (Arvidsson et al. 2005). Screen time was defined as the average time spent in front of any type of screen per week, not including active gaming and a mean daily average was estimated. Parental education level was categorised by school years (elementary school, middle school and higher level of education) and their employment status was categorised as employed, unemployed (including homemakers) orretired.

2.4. Statistical Analyses

The proportion of total daily energy intake from UPFs was estimated according to NOVA 4 food groups and their specific food subgroups. P-P plots were used to assess the normality of the distribution. Numerical variables following normal distribution were presented with a mean (standard deviation) and those that were skewed were presented as medians and range (P25 and P75). Categorical variables were described as relative frequencies. Between-group differences were estimated with parametric (student t-test) or non-parametric methods (Mann Whitney U-test) for numerical and with chi-square test for categorical data. A general linear model (GLM) for maximum logistic likelihood analysis was used, of the binomial family, to assess the likelihood of being overweight/living with obesity compared to normal weight according to dietary contribution of % total energy intake (%TEI) of NOVA 4 food group, categorised in tertiles. The model was adjusted for age (continuous by 4-year increase), sex (binary), the area of residence (main metropolitan areas, islands & Crete, mainland), total screen time (continuous) and %TEI. The predicted probability of overweight and obesity was examined by main NOVA 4 food group contributors in a continuous approach, to address potential food group effects. Outcomes are presented according to corresponding 95% confidence intervals. Significance was set at alpha 5% ($p < 0.05$) being considered statistically significant. The statistical software package STATA 17.0 was used for analysis (Stata Corp LLC., College Station, TX, USA).

RESULTS

The children's anthropometric, lifestyle and sociodemographic characteristics are shown in Table 2. Among 443 for which weight and height were available or reported (336 and 107 respectively) , 75% (n=332) were categorised as normal weight and 25% (n=111) as overweight/living with obesity. Between groups significant differences were found only for screen time with overweight children/children living with obesity (27%) having a 2.5-hour median screen time (27%) compared to normal-weight children (73%) who had a 2.2-hour median screen time, although in both cases it was above the daily 2-hour level recommended by the American Pediatric Association (Daniels et al. 2015). Most primary guardians were employed, and their average level of education was more than 12 years, with no distribution differences by weight status observed.

Table 3 shows the percentages of total energy intake from NOVA 4 food group that were consumed in total and by normal weight and overweight/obese children. No significant differences were observed between the groups; for the total population the proportion was 39.8%, for normal weight and overweight/obese children the percentages of total energy intake from NOVA 4 food group were 39.5% and 40.2%, respectively. Moreover, differences in percentage of total energy intake contribution from NOVA 4 food subgroups between normal weight and overweight children/children living with obesity were not statistically significant, except from the subgroup of "other" 2.1% (which includes the food subgroups reconstituted meats, pre-prepared potatoes, spreads and sauces distilled alcoholic drinks, sparkling water, chocolate powder). Consequently, normal weight children eat more reconstituted meats, pre-prepared potatoes, fats, spreads, and sauces than overweight children/those living with obesity.

To increase understanding of specific food group intake, the percent of each (sub)-food group of UPF to total energy provided by all NOVA 4 food groups was calculated. These are presented in total and by weight status in a bar graph (Figure 1). Four food groups contributed >10% to total NOVA 4 adding up to 86% of total UPF intake. Ready-to-eat/heat dishes are the most prominent with 36.2% of the total population (34.7% among normal weight children and 40.7% among overweight children/children living with obesity followed by sweet grain products (21.4%), savory snacks and baked goods baked goods such as savory pies with cheese, spinach or meat sweets in contrast to sweet grain products such as short & puff pastry sweet pies or baklava (15.4%) and sweets (12.9%).

The adjusted Odd Ratio (AOR) between weight status and tertile of NOVA 4 consumption (as % of total caloric intake) is depicted in Table 4. No significant differences were found by tertile of NOVA 4 intake as a proportion of calories. The model was adjusted for sex, age category, total energy intake and total screen time.

Lastly, specific food groups highly contributing to NOVA 4 as a percentage of total energy intake were modelled in relation to the probability of overweight and obesity (Figure 2). The results showed that the only food group that were associated with increased probability of being overweight/obese were savoury snacks and baked goods for children and adolescents who consumed these >62% of their total daily energy intake. Although the percentage of children found to exceed this level was small (0.4%, n=2), a significant effect was found potentially indicating the magnitude on their effect on weight status over and above this level of consumption. The total proportion of all NOVA 4 subgroups was not significantly associated with weight in accordance with logistic regression results (see Table 4).

DISCUSSION

The current study aimed to assess the proportion of ultra-processed foods (UPFs) in the daily energy intake of a sample of Greek children, using the NOVA food classification system. Additionally, the study sought to identify the primary food groups contributing to UPF intake and examine their association with the likelihood of overweight and obesity. The primary finding of this investigation was the prevalence of a high UPF diet among most Greek children, with UPFs accounting for between 19% and 61% of their total daily energy intake. The major contributor to UPF intake was ready-to-eat dishes, including various sandwiches and other street food options. Four food groups collectively contributed to over 80% of total UPF intake, specifically sweets and sweet grain products, savory snacks and baked goods (excluding ready-to-eat/heated dishes). Notably, only the consumption of savory snacks & baked goods was statistically associated with an increased likelihood of overweight and obesity when it exceeded 62% of total caloric intake. However, this latest observation needs further investigation, due to the small sample size (n=2). A similar trend was observed for ready-to-eat/heat dishes, though statistical significance was not reached.

The findings from this study align with existing research indicating a high prevalence of UPF consumption among children (Juul et al. 2022, Rauber et al. 2018, Moubarac et al. 2017, Araya et al. 2021, Detopoulou et al. 2023). In particular, the reported range from studies conducted in North America was from 47.7% of total energy (Moubarac et al. 2017) to 57% (Juul et al. 2022) with the latter study also reporting an increase in average UPF intake in the population over a 16 years period [from 53.5% of kcal in 2001–2002 to 57% of kcal in 2017–2018] (Juul et al. 2022). A cross-sectional study from the U.K. National Diet and Nutrition Survey (2008–2014) population aged 1.5 years or over, revealed that ultra-processed foods (UPF) accounted for 56.8% of their daily energy intake (Rauber et al. 2018). Subsequent research indicated the highest levels of UPF consumption among children aged 4 to 10 years were also recorded in the UK, according to data from the National Diet and Nutrition Survey (NDNS) (Onita et al. 2021), with these foods comprising an estimated 65% of their daily caloric intake. Another study conducted in Greece found that 40.7% of the daily caloric intake was derived from UPFs (Detopoulou et al. 2023), among a convenience sample of young adults (specifically university students aged 18-22 years old). However, no other studies in Greece have evaluated UPF intake in children.

This study did not find a significant association between UPF consumption and obesity in children which is consistent with previous studies (Enes et al. 2019, Oliveira et al. 2020) but contrary to others which have indicated that higher consumption of UPFs is associated with an increase in risk of overweight/obesity (Neves et al. 2022, Vedovato et al. 2021, Neri et al. 2022). More specifically, a Brazilian cross-sectional study among 790 adolescents aged 14-19 years old observed that UPF consumption was higher among adolescents who had an inappropriate eating context regarding the habits of eating out for these meals, eating in noisy places or in bed, standing or walking, in front of screens and without company and was associated with an increased likelihood of obesity (Neves et al. 2022). The authors did not assess the actual amount but only the frequency of consumption. Furthermore, in Portugal, a longitudinal study with 1175 children showed that higher consumption of UPFs at 4 years of age was associated with a higher BMI z-score at 10 years of age (Vedovato et al. 2021), in agreement with another prospective study conducted in 3 year-olds in the Netherlands (Sirkka et al. 2021), even though the latter examined a UPF type diet based on principal component analysis and not on NOVA system categorization. A combination of the NOVA system with dietary pattern derivation from a food frequency questionnaire was used by Neri et al., in adolescents and found that higher consumption of UPFs was associated with 52%, and 63% higher odds of abdominal, and visceral overweight/obesity respectively, compared to lower consumption (Neri et al. 2022). Results were based on the proportion of the population following a UPF-like dietary pattern and not on the proportion of UPF in the total daily energy intake.

A large proportion of UPF are nutritionally unbalanced (Moubarac et al. 2013) and categorised by a high density of energy, sugars, saturated trans fats and sodium, and low content of protein, fibers and micronutrients (Rauber et al. 2018, Araya et al. 2021, Costa de Miranda et al. 2021). Hence, the main problem that may explain associations between high UPF intakes and poor health outcomes reported in other studies is their potentially low nutritional value which fails to meet the WHO recommendations for the prevention and control of obesity (Moubarac et al. 2013). However, the past years newly derived foods from the food industry have been found to be "healthier" with regards to nutritional composition compared to their minimally processed counterparts, although they remain higher in energy, total sugar, salt and saturated fats (Dicken et al. 2024). It is noteworthy that children and adolescents with normal-weight preferred sweet grain products, sweets and sugar-sweetened beverages, as well as bakery products compared to overweight children/children living with obesity who reported a preference towards foods such as ready to eat/heat dishes, flavored dairy products and savory snacks. Based on the nutritional content and potentially quality of UPF foods, and associations with health status later in life the large proportion of consumption, makes it a potential public health concern.

It has been proposed that another issue with UPFs is that their high-intensity flavoring makes them extremely palatable, less satiating than less processed foods and may even override endogenous satiety mechanisms (Neves et al. 2022). The issue with UPFs is in their intense flavoring, due to their content in fat, sugar, salt, and/or artificial additives. This makes them very appetising but less filling compared to meals that are less processed. This can result in excessive consumption of food and interfere with the body's normal signals of fullness, so making it more difficult for individuals to cease eating once they are satisfied. Moreover, UPFs have a higher caloric density and lower fibre content, which can lead to overeating and unhealthy eating patterns (Juul et al. 2018). Finally, it has been suggested that large portion sizes, ubiquitous availability, and affordability of UPFs encourage constant snacking and unintentional overeating and may exclude less processed and healthier foods from the diet (Moubarac et al. 2017). These results along with the results of our study depicted the large contribution of UPF in the daily consumption and the potential increased likelihood of overweight and obesity for children exceeding 62% (despite the small number), underline the potential short and long-term health implications. Other studies have found that higher UPF consumption per daily energy intake is associated with not only the risk of obesity (Juul et al. 2018, Rauber et al. 2021) but also of chronic diseases, such as type 2 diabetes (Levy et al. 2021), dyslipidemias (Rauber et al. 2015) and hypertension (Mendonça et al. 2017).

Overall, the type of UPF consumed and the total dietary pattern needs to be examined, and not only total consumption. For example, in Greece higher intakes of free sugars was associated with two different meal patterns; one caracterised of higher consumption of sweets, SSB's, fast food and fries and another consisting of whole fruits, 100% fruit juice, vegetables, legumes and honey/jam spreads (Magriplis et al. 2021). The specific study examined added sugar intake association with children's weight status, showed the main contributors to added sugar intakes were sweets, including those made at home, processed cereals and SSB's. An association with overweight and obesity was found only among children and adolescents that exceeded the 10% upper recommended level of total calories intake from added sugars regardless of source (Magriplis et al. 2021). Carbohydrates and total fat intake were also associated with higher weight of Greek toddlers since a substantial percentage exceeded the adequate distribution range (Manios et al. 2008). Furthermore, recent evidence suggests that not all UPFs classified as NOVA 4 have the same effects on health. It is also noteworthy that in another very recent study, in a subgroup analysis, animal-based products and artificially and sugar-sweetened beverages were associated with an increased risk of multimorbidity of cancer and cardiometabolic diseases but on the other hand, associations were not observed with ultra-processed bread and cereals or plant-based alternatives (Cordova et al. 2023).

This study has several strengths. To our knowledge, this is the first study to evaluate dietary UPF proportion and their main food contributors among Greek children. As per the study results, this is an important area to examine since the effect of UPFs on body weight and potentially on health, possibly varies by type and amount of food group consumed. A crude NOVA 4 classification in one pool may lead to wrongful results, and based on data to date, this may be the reason why controversial findings on weight are reported between studies. Most of the studies to date and to our knowledge have evaluated UPFs in total. The effects however on weight and health may vary by the nutritional profile of the food or by the amount consumed which may vary between countries. For example, the mean intake of added sugar in children from the USA was 12.4% of the total daily energy intake and SSB's (Ricciuto et al. 2022) were the main contributor whereas in Greece, the median was 9.4% and the main contributors were sweets and refined cereals (Magriplis et al. 2021). These were considered important variables to depict and were evaluated in this study, to provide more food-specific population effects.

The results of our study should be interpreted with caution due to its retrospective nature. Inference on the time sequence of the association between UPF consumption and obesity cannot be made. The results of this study however, underline that even 10 years ago, UPF intake was very high among a large proportion of the population, in Greece and other countries, which one can assume has further increased the past years. Based on recent evidence as per UPF and nutritional assessment of foods, further information on food categorization are necessary and recent consumption data are needed. A recent study however that evaluated food reformulation post-trans ban policy in Greece, using laboratory analysis through random savory baked goods sampling performed in March 2021, found that although trans-fat content decreased per 100 gr of food portion, this was replaced by saturated fat (Marakis et al. 2023) therefore these foods remain of public health concern. Also, due to the small sample size, data were not stratified by age groups, having children and adolescents grouped in one category. Self-reported data may also lead to errors; however, information was validated with random measurements performed in a subsample of the population (n=88 children). Overall, although there are discrepancies in the literature between the validity of self-reported measures, a recent SR that evaluated the validity of measured vs self-reported weight and height, found good agreement between measured and self-reported weight and height based on intra-class correlation coefficient (>0.9) and Bland–Altman plots (Fayyaz et al. 2024). To further decrease bias, missing data on weight or height were imputed as recommended following valid techniques (Little & Rubin 2020). It is also important to consider any potential NOVA categorization misclassifications of food items, although this was highly minimised with the methodology followed.

CONCLUSION

The contribution of UPFs to total energy intake was high for all children irrespective of weight status. In addition to their total daily contribution, the type of

UPFs in various populations should be derived and those highly consumed should be further evaluated. Awareness public health campaigns of food group intake and not only of total energy balance are important because despite the lack of association with overweight and obesity, the high consumption of UPFs, low nutritional value, may lead to public health consequences.

AUTHORS CONTRIBUTIONS

E.P. (Evgenia Petridi) contributed to study conception, design, data analysis and drafted the manuscript. E.M. is the supervisor of the data analysis of HNNHS and contributed to study conception and design, data analysis, supervised the work and provided critical input into the final draft of the manuscript. K.K., E.C and E.P. (Elena Philippou) supervised the work and provided critical input into the final draft of the manuscript. A.Z. is the principal investigator of HNNHS, contributed to the concept and design of the work, and provided critical input into the final draft of the manuscript. All authors have read and agreed to the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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TABLES

Table 1. NOVA 4 Food Group derivation with types of food & beverages included in each group.

NOVA 4 Subgroups	Foods and Beverages included in each subgroup
Ready to eat/heat dishes	
Ready-to-eat/heat sandwiches	Hotdogs, wheat Arabic pita, crepes, baguettes, sandwiches, tortillas, toast
Ready-to-eat/heat pizza	Pizza
Savory pies/tarts	Pies (cheese, ham, sausage, vegetables)
Other ready-to-eat/heat-mixed dishes	Stuffed pasta, Greek meat or poultry (souvlaki), meat products (schnitzel, gyros)
Flavored dairies products	
Milk	Condensed sweetened milk
Yoghurt	Flavored yoghurt
Flavored dairy drinks	Milkshake, hot chocolate
Sugar-sweetened beverages	
Sugar-sweetened and diet soft drinks	Sugar-sweetened and diet soda, iced tea
Fruit drinks	Fruit juices with added sugars or concentrated fruit remixed with water
Branded breads	
Grain products	slices of bread
Pita breads	Arabic pita, pita bread with additives, tortillas, sesame bread rings

Savory snacks and baked goods	
Savory snacks	Salted crackers, breadsticks, rice cakes, sesame bread rings with cheese, Cheetos, chips (potato, tortillas), popcorn, bread with cheese
Baked goods	Butter croissant, short & puff pastry savoury pies (e.g. cheese pie, spinach pie, meat pie, etc)
Sweet grain products	
Bakery sweet products	Chocolate croissants, short & puff pastry sweet pies, 'tsoureki', baklava, 'melomakarono'
Cereal bars and biscuits	bars, biscuits
Waffles and crepes	waffles, crepes
Breakfast cereals	cereals (wheat, whole grain, oat) with added sugar
Sweets	
Desserts	Gelatin desserts, traditional sweets with sirup, sweets with chocolate, puddings (chocolate, vanilla), mille-feuille, loukoumi, cakes, cheesecake, profiterole, ice-creams, halva (sesame), Honey sesame bars, chocolate-pie
Sweet pies and tarts	Pies (lemon pie), sweet tarts

Candies & chocolate bars	Candies, jellies, chewing gums, chocolate, chocolate waffle bars, syrups, jams
Other sweet UPFs	Sweet spreads (praline, sesame, peanut butter)
Other	
Fast-food or reconstituted meat, poultry, and fish products	Ham from reconstituted meat or poultry, bacon, meat (pate), sausages, nuggets (chicken, cheese)
Fast food or pre-prepared potato products	Fast food, pre-prepared, frozen French fries
Fats, spreads and sauces	Margarin (with or without butter), cheese spread, sauces, dips, cream cheese
Other UPFs	Distilled alcoholic drinks, sparking water, chocolate powder, baby formulas (milk, creams, chamomile formula)

Table 2. Anthropometric, lifestyle characteristics of children and adolescents, and guardians' sociodemographic information.

	Total	Normal weight	Overweight/Obesity	p-Value
Total sample, n (%)	443	332 (74.9)	111 (25.1)	
Age (years), [median, (range)]	9 (6, 14)	9 (5, 14)	9 (6, 12)	0.000
Weight (kg), [median (range)]	36 (21, 55)	32.7 (19, 52)	42 (28.5, 65)	0.000
Height (m), mean (SD)	1.4 (0.3)	1.4 (0.3)	1.4 (0.2)	0.451
BMI (kg/m^2), mean (SD)	18.7 (4.0)	17.4 (3.0)	22.6 (4.2)	0.000
Group Age, n (%)				0.456
Children	258 (58.2)	190 (57.2)	68 (17.8)	
Adolescents	185 (41.8)	142 (42.8)	32 (7.2)	
Sex, n (%)				0.763
Male	221 (49.9)	167 (37.7)	54 (12.2)	
Female	222 (50.1)	165 (37.2)	57 (12.9)	
Total screen time (hours), [median, (range)]	2.2 (1.2, 3.5)	2.2 (1.12, 3.5)	2.5 (1.5, 3.5)	0.024
Primary Guardian Education level, n (%)				0.303
≤6 years	12 (3.8)	10 (3.2)	2 (0.6)	
6-12 years	124 (39.6)	86 (27.5)	38 (12.1)	
≥12 years	177 (56.5)	135 (43.1)	42 (13.4)	

Primary Guardian Professional Status, n (%)				0.849
Employed	216 (70.4)	159 (51.8)	57 (18.6)	
Unemployed/Homeworkers	76 (24.8)	57 (18.6)	19 (6.2)	
Pension	15 (4.9)	12 (3.9)	3 (1.0)	

$p < 0.05$; Student t-test for normally distributed values and Mann-Whitney test for skewed numerical variables (two group comparison); chi-square test for categorical variables IQR: Interquartile range.

Table 3. Percent of NOVA 4 foods consumed (as total and by subgroup) with mean energy intake; results presented for all children and by children's weight status.

%E NOVA Foods, median, (range)	Total	Normal weight	Overweight/Obesity	p-value
NOVA 4	39.8 (25.4, 55.0)	39.5 (24.5, 54.3)	40.2 (27.0, 57.3)	0.535
[a]Ready to eat/heat dishes	22.9 (14.2, 35.5)	22.1 (13.7, 35.5)	26.2 (16.7, 36.9)	0.197
[b]Flavored dairy products	4.3 (2.0, 8.3)	3.02 (1.6, 7.2)	6.6 (3.5, 10.7)	0.183
[c]Sugar-sweetened beverages	3.0 (1.8, 5.0)	3.5 (1.9, 5.1)	2.6 (1.3, 3.4)	0.20
[d]Branded breads	6.3 (3.6, 10.1)	6.62 (4.0, 10.2)	4.6 (3.3, 9.9)	0.409
[e]Savoury snacks	13.0 (5.7, 24.0)	12.6 (5.7, 23.2)	13.4 (8.4, 26.8)	0.504
[f]Sweet grain products	10.8 (5.8, 19.5)	10.8 (5.8, 19.4)	10.8 (5.6, 19.7)	0.98
[g]Sweets	8.5 (4.2, 13.9)	8.3 (4.1, 13.7)	9.93 (4.5, 14.2)	0.959
[h]Other	2.1 (0.7, 7.0)	2.5 (0.8, 7.4)	0.9 (0.5, 4.0)	0.02

$p < 0.05$; Mann-Whitney test for skewed numerical variables (two group comparison); %E: total daily energy intake; Range: 25th – 75th percentiles of the distribution, [a] Sandwiches, pizza, pies, tarts, mixed dishes, [b] Milk, yoghurt, drinks, [c] Sugar-sweetened drinks, fruit drinks, [d] Grain products, pita bread, [e] Savoury snacks, bakery pies, [f] Bakery sweets, cereal bars and biscuits, waffles and crepes, cereals, [g] Desserts, sweet pies and tarts, candies, jams, other sweet UPFs, [h] Reconstituted meats, pre-prepared potatoes, fats, spreads and sauces, other UPFs (distilled alcoholic drinks, sparkling water, chocolate powder, baby formulas)

Table 4. Multiple logistic regression between weight status and ultra-processed foods consumption (%kcal/day) in children of HNNHS

Weight status[a]	Odds ratio	[95% Confidence Interval]	
NOVA 4[b], (%kcal/day) [median, range of first tertile: 19.6 (13.4-25.5)]	-	-	-
2nd Tertile [38.6 (33.9, 44.4]	1.5	0.85	2.51
3rd Tertile [60.8 (54.8, 60.8)]	1.1	0.71	1.68

Results following logistic regression by tertile of NOVA 4 (based on % energy contribution) and adjusted for sex, energy intake, age category (Children: 2-11 years and Adolescents: 12-18 years) and residence area.

NOVA 4 tertile distributions between children and adolescents did not differ (p for all tertiles > 0.2).

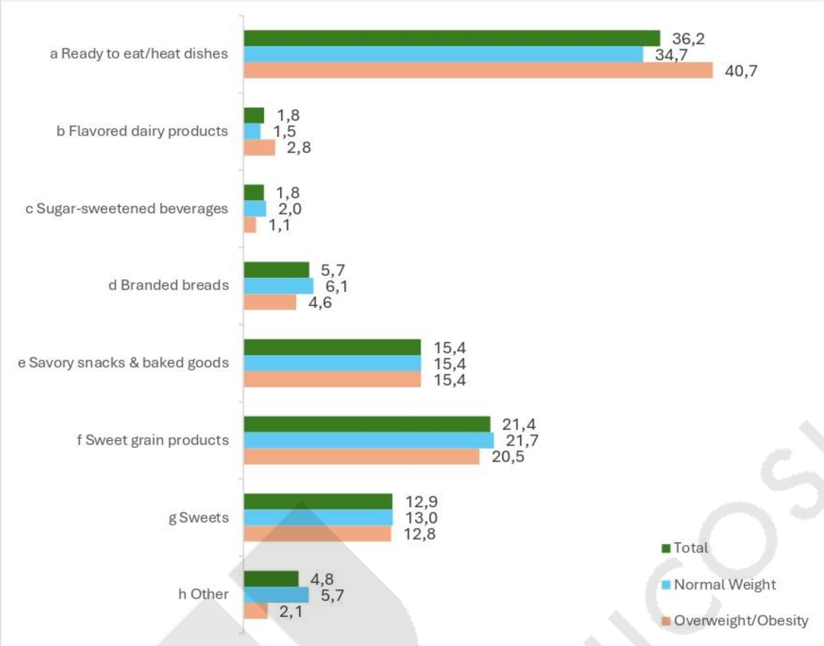
[a]Weight status was normal weight and overweight participants/participants living with obesity.

[b]Reference tertile for % energy NOVA 4 was the 1st tertile.

*Significant at a=5%

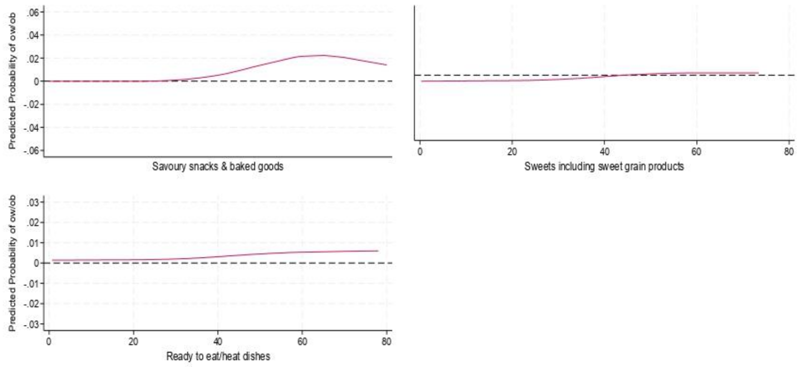
FIGURE LEGENDS

Figure 1. Main food groups contributors to NOVA 4 category* in children and adolescents; results depicted by weight status.



*derived as percent total energy per food group (kcal) divided by the total energy (kcal) from all NOVA 4 food groups consumed by each individual, and then multiplied by 100. [a] Sandwiches, pizza, pies, tarts, mixed dishes, [b] Milk, yoghurt, drinks, [c] Sugar-sweetened drinks, fruit drinks, [d] Grain products, pita bread, [e] Savoury snacks & baked goods, [f] Bakery sweets, cereal bars and biscuits, waffles and crepes, cereals, [g] Desserts, sweet pies and tarts, candies, jams, other sweet UPFs, [h] Reconstituted meats, pre-prepared potatoes, fats, spreads and sauces, other UPFs (distilled alcoholic drinks, sparkling water, chocolate powder, baby formulas)

Figure 2. Predictive probability (margins) of overweight or obesity among children by specific NOVA 4 food group intake (% of total energy).



Cubic spline graphs based on generalized linear models (GLM) of the binomial family and logit link; adjusted for sex, age, mean daily energy intake and area of residence. The three main NOVA 4 contributors are depicted (NOVA4 group seen on the x-axis for each graph displayed). The vertical dotted line represents no effect. The red line represents the measure of effect (Predicted odds of overweight/obesity by an increased level of energy-adjusted consumption).

Savoury snacks & baked goods: salted crackers, breadsticks, all crisps & Cheetos, shortcrust and puff pastry type savory pies

Ready-to-eat/heat dishes: Sandwiches, pizza, pies, tarts, mixed dishes,

Sweets include sweet grain products: Desserts, sweet pies and tarts, candies, jams, bakery sweets, cereal bars and biscuits, waffles and crepes and breakfast cereals.

Appendix 3 (Abstract presented in conference)

Πέμπτη
αίθουσα: **AEGLE B**

16:00 - 17:00: Ελεύθερες Ανακοινώσεις

Νευρολογική Νοσηλευτική - Νοσηλευτική Ψυχικής Υγείας - Δημόσια Υγεία & Επιδημιολογία (Web)

Συντονισμός: Γεωργία Δουλούδη, Νίτσα Σβουρίδου, Βαλερί Γιαννιώτη

Εισηγητές:

«Ε017 ΧΡΗΣΗ ΕΞΥΠΝΩΝ ΣΥΣΚΕΥΩΝ ΓΙΑ ΤΗΝ ΠΑΡΑΚΟΛΟΥΘΗΣΗ ΑΣΘΕΝΩΝ ΜΕ ΝΟΣΟ ΠΑΡΚΙΝΣΟΝ: ΤΟ ΠΡΟΓΡΑΜΜΑ ALAMEDA», *Χρύσα Χρυσοβιτσάνου (WEB), Νίκος Παπαγιαννάκης, Χρήστος Κορός, Αναστασία Μπουγέα, Αθηνά Σιμιτσή, Λεωνίδας Στεφανής*

«Ε018 ΧΡΗΣΗ ΠΕΡΙΟΡΙΣΤΙΚΩΝ ΜΕΘΟΔΩΝ ΓΙΑ ΤΗΝ ΑΝΤΙΜΕΤΩΠΙΗΣΗ ΤΗΣ ΕΠΙΘΕΤΙΚΟΤΗΤΑΣ ΑΣΘΕΝΩΝ ΣΤΟ ΓΕΝΙΚΟ ΝΟΣΟΚΟΜΕΙΟ», *Ευανθία Γεραγώτη (WEB), Πολυξένη Μαγγούλια*

«Ε019 ΤΡΟΠΟΙ ΑΝΤΙΜΕΤΩΠΙΣΗΣ ΤΟΥ ΜΕΤΑΤΡΑΥΜΑΤΙΚΟΥ ΣΤΡΕΣ, ΟΦΕΙΛΟΜΕΝΟ ΣΤΟ ΣΕΙΣΜΟ», *Μαρία Κούρτη, Μάρθα Παπανικολοπούλου (WEB)*

«Ε020 ΔΙΕΡΕΥΝΗΣΗ ΤΗΣ ΨΥΧΟΣΩΜΑΤΙΚΗΣ ΥΓΕΙΑΣ ΤΩΝ ΝΟΣΗΛΕΥΤΩΝ ΚΑΤΑ ΤΗΝ ΚΛΙΝΙΚΗ ΠΡΑΞΗ - Ο ΡΟΛΟΣ ΤΗΣ ΑΝΘΕΚΤΙΚΟΤΗΤΑΣ», *Δέσποινα Παππά (WEB), Ελένη Ευαγγέλου, Ιωάννης Κουτελέκος, Χρυσούλα Νταφογιάννη*

«Ε021 Ο ΡΟΛΟΣ ΤΩΝ ΥΠΕΡ - ΕΠΕΞΕΡΓΑΣΜΕΝΩΝ ΤΡΟΦΙΜΩΝ ΣΤΗΝ ΕΜΦΑΝΙΣΗ ΠΑΧΥΣΑΡΚΙΑΣ ΚΑΙ ΚΑΡΔΙΟΜΕΤΑΒΟΛΙΚΩΝ ΣΥΝ - ΝΟΣΗΡΟΤΗΤΩΝ ΣΕ ΠΑΙΔΙΑ ΚΑΙ ΕΦΗΒΟΥΣ: ΣΥΣΤΗΜΑΤΙΚΗ ΑΝΑΣΚΟΠΗΣΗ», *Ευγενία Πετρίδη (WEB), Αντώνης Ζαμπέλας*

The role of ultra-processed foods in obesity and cardiometabolic co- morbidities in children and adolescents: A systematic review

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2. Professor in Department of Food Science and Human Nutrition, Agricultural University of Athens

Introduction: The quality of dietary patterns followed in recent decades is determined not only by the content of specific nutrients or foods, but also by other important factors such as their presence in processed foods. Modern dietary patterns are associated with high consumption of ultra-processed foods (UPF), which has been related to obesity and cardiometabolic risk factors.

Objective: The aim of this systematic review was to investigate the relationship between UPF consumption and childhood obesity as well as cardiometabolic co-morbidities in children and adolescents.

Methods: The systematic search included studies published up to February 2022 and was conducted using the Preferred Reporting Items for Systematic Review (PRISMA-P) criteria. Based on the inclusion and exclusion criteria, the final number of articles included in this review consisted of seventeen observational studies involving children and adolescents aged ≤18 years. Of these, 9 were cross-sectional studies, 7 were cohort studies, and one study combined the results of both cross-sectional and cohort studies. In particular, 14 studies investigated the relationship between UPFs intake and overweight/obesity, while 8 examined the relationship between UPFs and cardiometabolic risk factors.

Results: Most studies (14/17) found that increased UPF consumption was associated with a higher prevalence of overweight/obesity and cardiometabolic risk factors such as dyslipidemia, blood pressure, and metabolic syndrome in children and adolescents, while 4/17 (3 cross-sectional studies and 1 cohort study) did not show any correlation. According to study quality assessment tools, the majority of cohort and cross-sectional studies were classified as good quality based on NIH (National Institutes of Health) and NewCastle-Ottawa, respectively.

Conclusions: The positive relationship between UPF intake and overweight/obesity, as well as cardiometabolic co-morbidities in children and adolescents, raises current and future public health concerns. More longitudinal studies are needed to investigate these findings so

that this knowledge can be used to promote effective policies to reduce their intake and, as a result, the need for care and services from health professionals such as nurses, doctors, dieticians, and others.

Keywords: Ultra-processed foods, childhood obesity, cardiometabolic risk, adolescence