Harokopio University

School of Health Sciences & Education

Department of Nutrition and Dietetics

Postgraduate Program “Applied Nutrition and Dietetics”

Discipline: Clinical Nutrition

Prevalence of childhood obesity by country, socio-demographic characteristics and parental obesity in Europe. The Feel4Diabetes study

Master’s Research Thesis

Koutra Evangelia

RN: 4521928

Athens 2022

Χαροκόπειο Πανεπιστήμιο

Σχολή Επιστημών Υγείας και Αγωγής

Τμήμα Επιστήμης Διαιτολογίας – Διατροφής

Πρόγραμμα Μεταπτυχιακών Σπουδών «Εφαρμοσμένη Διαιτολογία – Διατροφή»

Κατεύθυνση: Κλινική Διατροφή

Επιπολασμός παιδικής παχυσαρκίας ανά χώρα, κοινωνικο-δημογραφικά χαρακτηριστικά της οικογένειας και γονεϊκή παχυσαρκία στην Ευρώπη.

Μελέτη Feel4Diabetes.

Μεταπτυχιακή εργασία

Κούτρα Ευαγγελία

ΑΜ: 4521928

Αθήνα, 2022

Harokopio University

School of Health Sciences & Education

Department of Nutrition and Dietetics

Postgraduate Program "Applied Nutrition and Dietetics"

Discipline: Clinical Nutrition

Prevalence of childhood obesity by country, socio-demographic characteristics and parental obesity in Europe. The Feel4Diabetes study

Master's Research Thesis

EXAMINATION COMMITTEE

Ioannis Manios (Supervisor)

Professor of Nutritional Assessment, Counseling and Health Promotion,

School of Health Science and Education,

Department of Nutrition and Dietetics, Harokopio University

Constantine Tsigos

Professor of Nutrition and Metabolism,

School of Health Science and Education,

Department of Nutrition and Dietetics, Harokopio University

Konstantinos Anastasiou

Assistant Professor of Diet, Exercise and Health,

School of Health Science and Education

Department of Nutrition & Dietetics, Harokopio University

I, Koutra Evangelia, responsibly declare that:

Firstly, I own the copyright of this original work, which to the best of my knowledge, does not defame people, nor does it violate the intellectual property rights of third parties.

Secondly, I accept that the “Harokopio University Library and Information Center” may, without changing the content of my work, make it available electronically through its Digital Library, copy it in any media and/or any format and keep more than one copy for maintenance and safety purposes.

Acknowledgements

Completing this thesis, I feel gratitude for all the people that helped me along the way. Throughout the writing of this dissertation, I have received a great deal of support and assistance.

At first, I would like to thank my supervisor – Professor Ioannis Manios for his invaluable help and encouragement. Thanks to your assistance, my project was done under your supervision.

I would also like to thank Mr Constantinos Anastasiou for providing guidance and feedback throughout this project. Your insightful feedback pushed me to sharpen my thinking and brought my work to a higher level.

Besides my supervisor, I would like to thank the rest of my thesis committee, Professor Constantine Tsigos, for reading my thesis and giving me enlightening and valuable comments.

I wish to extend my special thanks to my friends and to my future husband who endured this long process with me, always offering support and understanding.

Finally, I would also like to thank my parents for their immerse love, wise counsel and support.

Table of Contents

Περίληψη

Εισαγωγή: Η παιδική παχυσαρκία είναι ένα βασικό πρόβλημα δημόσιας υγείας που έχει λάβει διαστάσεις επιδημίας και επηρεάζει παιδιά και εφήβους ανά τον κόσμο. Ως αποτέλεσμα, είναι καίριας σημασίας η δημιουργία αποτελεσματικών στρατηγικών πρόληψης. Εφόσον τα χαρακτηριστικά της οικογένειας διαδραματίζουν ένα βασικό ρόλο στη διαμόρφωση του βάρους σώματος των απογόνων, ιδιαίτερο ενδιαφέρον έχει να διερευνηθούν οι συγκεκριμένοι κοινωνικο-δημογραφικοί παράγοντες της οικογένειας που εμφανίζουν θετική συσχέτιση με την παιδική παχυσαρκία. Επιπλέον, εφόσον η επίπτωση της παιδικής παχυσαρκίας διαφέρει αναλόγως της κοινωνικο-οικονομικής κατάστασης της χώρας, είναι σημαντικό να διερευνηθεί η επίπτωση του κοινωνικο-οικονομικού επιπέδου της χώρας στον επιπολασμό της.

Σκοπός: Ο σκοπός της παρούσας μελέτης είναι να εξετάσει την πιθανή συσχέτιση μεταξύ κοινωνικο-οικονομικών χαρακτηριστικών της οικογένειας με την παιδική παχυσαρκία, καθώς και την επίπτωση της παιδικής παχυσαρκίας αναλόγως του φύλου, της παχυσαρκίας των γονέων και της κοινωνικο-οικονομικής κατάστασης της χώρας σε ένα μεγάλο δείγμα από 6 Ευρωπαϊκές χώρες.

Μέθοδοι: 9576 άτομα συμπεριλήφθηκαν στην παρούσα μελέτη (δεδομένα από τη μελέτη Feel4Diabetes). Λογιστική παλινδρόμηση χρησιμοποιήθηκε για να εκτιμήσει τις πιθανές συσχετίσεις μεταξύ κοινωνικο-δημογραφικών χαρακτηριστικών της οικογένειας με την παιδική παχυσαρκία, καθώς και να υπολογίσει την επίπτωση της παιδικής παχυσαρκίας αναλόγως του φύλου, της παχυσαρκίας των γονέων και της οικονομικής κατάταξης της χώρας σε δύο χαμηλού/μεσαίου εισοδήματος χώρες (Βουλγαρία, Ουγγαρία), δύο υψηλού εισοδήματος χώρες (Βέλγιο, Φινλανδία) και δύο χώρες με εφαρμογή μέτρων λιτότητας (Ελλάδα, Ισπανία).

Αποτελέσματα: Παρατηρούνται διαφορές στην επίπτωση παχυσαρκίας αναλόγως του φύλου, με περισσότερα κορίτσια να είναι υπέρβαρα συγκριτικά με τα συνομήλικα αγόρια. Όσον αφορά την κοινωνικο-οικονομική κατάσταση της χώρας, παιδιά από χώρες υψηλού κοινωνικο-οικονομικού επιπέδου έχουν τις μισές πιθανότητες να πάσχουν από παιδική παχυσαρκία. Αναλόγως των κοινωνικο-

δημογραφικών χαρακτηριστικών της οικογένειας, παιδιά από οικογένειες με πιο μακρόχρονη πατρική εκπαίδευση είχαν τις μισές πιθανότητες να πάσχουν από παιδική παχυσαρκία, παιδιά με τουλάχιστον ένα παχύσαρκο γονέα ήταν 2,5 φορές πιο πιθανό να είναι παχύσαρκα ενώ παιδιά των οποίων και οι 2 γονείς είναι παχύσαρκοι έχουν 7 φορές μεγαλύτερη πιθανότητα για παιδική παχυσαρκία. Όλα τα ανωτέρω αποτελέσματα παρέμειναν στατιστικά μετά την προσαρμογή τους ως προς τις υπόλοιπες μεταβλητές.

Συμπεράσματα: Η παρούσα μελέτη αναδεικνύει τη διαφορά στην επίπτωση της παιδικής παχυσαρκίας αναλόγως του φύλου, με περισσότερα κορίτσια να είναι παχύσαρκα συγκριτικά με τα αγόρια. Ανέδειξε επίσης ότι τα παιδιά από υψηλού χώρες υψηλού εισοδήματος έχουν λιγότερες πιθανότητες να πάσχουν από παιδική παχυσαρκία συγκριτικά με τους συνομηλίκους τους από χώρες χαμηλού εισοδήματος ή από χώρες με εφαρμογή μέτρων λιτότητας. Όσον αφορά τα κοινωνικο-δημογραφικά χαρακτηριστικά της οικογένειας, η μεγαλύτερης διάρκειας πατρική εκπαίδευση συσχετίζεται αρνητικά με την παιδική παχυσαρκία, ενώ η παρουσία τουλάχιστον ενός παχύσαρκου γονέα εμφανίζει θετική συσχέτιση. Εφόσον η παιδική παχυσαρκία είναι ένα από τα σημαντικότερα προβλήματα δημόσιας υγείας των ημερών μας, οι παρεμβάσεις οφείλουν να επικεντρώνονται στην οικογένεια και να στοχεύουν σε συγκεκριμένους πληθυσμούς υψηλού κινδύνου προκειμένου να αυξηθεί η ευαισθητοποίηση σχετικά με τη σημασία των αλλαγών στον τρόπο ζωής.

Λέξεις-κλειδιά: παιδική παχυσαρκία; παράγοντες κινδύνου; Feel4Diabetes; παχυσαρκία γονέων

Abstract

Background: Childhood obesity is a major public health issue which has reached epidemic levels globally and is affecting children and adolescents worldwide. As a result, building effective preventive strategies is of outmost importance. Since family characteristics play an important role in affecting the offspring's weight status, it is of special interest to investigate the specific socio-demographic characteristics of the family are positively associated with childhood obesity. Furthermore, since obesity prevalence varies greatly according to country's socio-economic position, it is imperative to explore the impact of country's socio-economic status on obesity prevalence.

Objectives: The aim of the present study is to examine possible association between socio-economic factors of the family and childhood obesity, as well as the prevalence of childhood obesity according to sex, parental obesity status and country's economic classification in a large sample from 6 European countries.

Methods: 9576 people were included in the study (data from the Feel4Diabetes study). Logistic regression analysis was used to assess the possible association between sociodemographic characteristics of the family with childhood obesity, and to calculate the prevalence of childhood obesity according to sex, parental obesity status and country's economic classification in two low/middle-income countries (Bulgaria, Hungary), two high-income countries (Belgium Finland) and two countries under austerity measures (Greece, Spain).

Results: There are gender differences between obesity prevalence with more girls being overweight than their male counterparts. As far as country's socio-economic status is concerned, children from high-income countries are half as likely to suffer from childhood obesity. When family's socio-demographic characteristics are taken into consideration, children from families with longer paternal education are half as likely to suffer from childhood obesity, whereas children with at least one obese parent are 2.5 times as likely to be obese and children whose both parents are affected by obesity are approximately 7 times more likely to be obese. All of the

above stated facts remained of statistical significance when adjusted for all other variables.

Conclusions: The present study highlighted the difference on childhood obesity prevalence according to gender, with more girls being obese than boys. It also indicated that children from high-income countries are less likely to be afflicted by childhood obesity than their peers from low-income or countries under austerity measures. As far as family's socio-demographic characteristics are concerned, longer paternal education is negatively associated with childhood obesity, whereas the presence of even one obese parent is positively associated with childhood obesity. As childhood obesity is one of the most pressing public health problems of our time, interventions should be family-centered and targeted to specific in-risk populations in order to increase awareness on the importance of lifestyle changes.

Key words: childhood obesity; risk factors; Feel4Diabetes; parental obesity

List of tables

List of figures

List of Abbreviations

WHO	**World Health Organization**
BMI	Body Mass Index
DOHaD	Developmental Origins of Health and Disease
SES	Socioeconomic status
T2DM	Type 2 Diabetes Mellitus
OSA	Obstructive Sleep Apnea
NAFLD	Non-Alcoholic Fatty Liver Disease

1.Introduction

1.1Introduction to childhood obesity and its definition

Childhood obesity has emerged as one of the most pressing medical and public health problems of our day (1). It is a leading cause of disability and is associated with increased all-cause mortality globally (2). Recent estimates suggest that approximately 40 million children under the age of 5 years and more than 330 million children and adolescents aged 5 to 19 years were overweight or obese in 2016, whereas childhood obesity has dramatically increased since 1975, namely 8- to 8.7-fold (8, 3). The number of school-aged children and adolescents living with obesity is predicted to rise to over 250 million by 2030 (4).

A recent review with data from 27 European countries and a total sample of 197,755 children about prevalence of overweight and obesity among European pre-school boys and girls highlighted the fact that prevalence of overweight and obesity in children in Europe, aged 2 to 7 years, during the period 2006-2016 was as high as 17,9% (5).

World Health Organization (WHO) defines overweight and obesity as abnormal or excessive fat accumulation that may impair health (6). The most widely accepted method to screen for excess adiposity is calculation of body mass index (BMI), a mathematical formula of weight-for-height index (7). A BMI between the 85th and 94th percentiles is defined as overweight, and a BMI ≥95th percentile is defined as obesity (8). Severe obesity is defined as BMI of 120% of the 95th percentile (9). For children younger than 2 years of age, BMI percentiles are not available; thus, obesity is defined as a weight ≥95th percentile for height (10).

It is of great importance to note that BMI can sometimes be inaccurate because it does not quantify total body adiposity, does not distinguish between fat and muscle, nor does it predict body fat distribution (11). Therefore, it is possible that there might be an adiposity overestimation in a child with increased muscle mass, as may be the case

in an athletic child, or an adiposity underestimation in a child with reduced muscle mass, such as a sedentary child (11).

1.2 Etiology of childhood obesity

Obesity is a multifactorial condition which has also been described as a phenotype of numerous pathologies (12). It is the consequence of an interaction among a complex set of factors that are related to the environment, genetics, and ecological effects such as the family, community, and school (13).

1.2.1 Environmental factors

1.2.1.1 Intrauterine and postnatal factors

Substantial evidence from epidemiologic and experimental animal studies suggests that fetal and early postnatal environmental exposures impact significantly on the development of obesity (14). The "developmental origins of health and disease (DOHaD)" hypothesis posits a stimulus or insult to an organism during a critical period of development can alter gene expression via epigenetic modifications (15). For example, being either small or large for gestational age is associated with an increased risk of developing childhood obesity (15).

Prenatal exposure to gestational diabetes mellitus (hyperglycemia, hyperinsulinemia), maternal smoking, and high maternal adiposity are correlated with increased incidence of childhood obesity, independent of birth size (16).

On the contrary, breast-feeding correlates with a lower incidence of childhood obesity as it is depicted clearly in a recent meta-analysis including 25 studies (17). A decreasing risk of obesity with increasing duration of breastfeeding was also observed (17).

1.2.1.2 Nutrition/feeding behaviors and physical activity

In children and adolescents, the overweight status is in general caused by a lack of physical activity and unhealthy eating patterns resulting in excess calorie intake, or a combination of the two resulting in energy excess (12). Several dietary factors

including higher caloric food intake during infancy, higher consumption of sweetened drinks (juice, soda), increased fast food consumption, eating while watching television (TV), skipping breakfast, reduced family meal times eating together, and lower vegetable and fruit intake have all been associated with increased rates of childhood obesity (18).

In addition, sedentary behavior, in particular time spent at the TV or computer screen, is also associated with higher BMIs (19). The above stated effect of increased screen time is depicted clearly on a recent systematic review and meta-analysis including 16 studies, which showed that when compared with screen time of less than 2 hr/day, an increased overweight/obesity risk among children is prevalent in screen time of above than 2 hr/day (20).

As far as physical activity is concerned, most guidelines recommend 60 minutes of moderate to vigorous daily physical activity for children and adolescents (19). Data from a recent review which included 153 RCTs from USA and Europe highlighted that interventions focusing on physical activity can effectively reduce the BMI of children aged 6 to 12 years and adolescents 13 to 18 years (21).

1.2.1.3 Obesity and sociodemographic influences

Socioeconomic status (SES) plays a significant role on the prevalence and effect of multiple risk factors for the development and persistence of obesity in childhood (22). There are several main consequences of low SES that are of particular relevance to obesity: mental health (depression, anxiety), low self-esteem and self-worth, insecurity, stress, negative belief systems, and negative emotions (anger, apathy, hopelessness, frustration, shame, guilt, etc.) (23).

Another hallmark of low SES is financial hardship, making healthy lifestyle choices less accessible, indirectly promoting unhealthy lifestyle choices, such as consuming more calorie-dense foods and less physical activity (24). Another stamp of low SES is also a

lack of critical thinking and higher education, which promotes susceptibility to junk food marketing (27).

The most common SES measures in the literature are parental education, income, occupation and parental BMI, although many different variables are used with no real standardization across the literature (28).

A recent review including 33 studies from the past decade shows that adiposity and socioeconomic position are negatively associated in high-income countries and positively associated in medium to low-income countries, meaning that SES groups with greater access to energy-dense diets (low-SES in industrialized countries and high-SES in developing countries) are at increased risk of being obese than their counterparts (28).

As far as parental BMI is concerned, a recent systematic review of 28 studies highlighted that elevated parental BMI is an important mediator of the association between socioeconomic position and adiposity, with elevated parental weight being an important risk factor of obesity in children (29).

Referring to socioeconomic position when parental education is concerned, a recent systematic review which included 158 papers and covered the period 1990 to 2005 showed that the majority of studies observed an inverse relationship between weight status and family SES, i.e. the measure of weight status registered the highest and lowest magnitudes in participants of low and high SES, respectively, and the SES indicator that yields the highest proportion of inverse relationships is parents' education (30).

When household income is taken into consideration, a recent meta-analysis of a representative sample of US children and adolescents showed that children and adolescents from middle- and high-income households were less likely to be overweight and obese compared to their low-income peers, whereas analyses within

each income stratum indicated that race/ethnicity was not related to the prevalence of overweight and obesity in low-income households (31).

1.2.2 Pathologic causes of obesity

1.2.2.1 Genetic factors

Heritable factors are responsible for 30% to 50% of the variation in adiposity, as common genetic variants associated with greater adiposity and obesity have been identified by a variety of studies (32). Over the previous decade, genome-wide association studies have been used to identify various genetic markers that increase predisposition to weight gain, with the ultimate goal of explaining the biological mechanisms leading to obesity (33). For example, the FTO gene is recognized as being of great importance to the regulation of energy intake, with variants predisposing individuals to greater caloric intake and reduced feelings of satiety (33).

Although polygenetic obesity is the most commonly observed, several single gene defects and syndromes associated with obesity have been identified as well, such as Prader Willi syndrome (34). However, these account for less than 1% of childhood obesity (34). Rare single gene defects, which specifically result in obesity, are those that affect the leptin-melanocortin regulating pathway (35).

However, the above stated obesity-associated genes cannot explain the rapid onset and magnitude of the current obesity epidemic, even if genetic predisposition makes some individuals more susceptible to the obesogenic environment (33).

1.2.2.2 Endocrine causes

Endocrine disorders, such as hypothyroidism, Cushing syndrome, growth hormone deficiency, and pseudohypoparathyroidism, can present with weight gain and delayed

growth (36). Of these, only Cushing syndrome typically presents with severe obesity; however, all disorders may lead to a more central pattern of weight deposition (36).

Endocrine causes of obesity are rare and are found in less than 1% of children and adolescents with obesity, with hypothyroidism being the most common cause of endocrine-related weight gain (36).

1.2.3 Other causes of obesity

Central nervous system tumors located in the hypothalamic region can result in reduced satiety, resistance to insulin and leptin, and enhanced insulin secretion due to autonomic dysregulation (16). The result of these physiologic changes leads to rapid and unrelenting weight gain (16). Lastly, medication-induced obesity can occur from the use of a variety of medicines, such as antipsychotics and high-dose glucocorticoids (18).

1.3 Comorbidities of childhood obesity

Obesity-related comorbidities start as early as in childhood: about half of obese children and adolescents have at least one biochemical or clinical cardiovascular risk factor and one quarter of them have more than two (37). Childhood obesity is a proinflammatory state associated with comorbidities affecting almost every system in the body including the endocrine, gastrointestinal, pulmonary, cardiovascular, and musculoskeletal systems and many obese adolescents remain obese into adulthood, with increased morbidity and mortality (37, 38).

Many of the comorbidities encountered in children with obesity, including dyslipidemia, type 2 diabetes mellitus (T2DM), steatohepatitis and obstructive sleep apnea (OSA) used to be considered “adult” diseases (39). The severity of these comorbidities typically increases with the severity of obesity (39).

Children with obesity are at an increased risk of hyperinsulinemia, insulin resistance, prediabetes, and subsequently T2DM (40). A recent review and meta-analysis of 63 studies in children 5 to 15 years old in developed countries showed that overweight and obese children have higher systolic and diastolic blood pressure, higher total cholesterol and triglycerides, increased insulin resistance and a significant increase in left ventricular mass (41).

As far as endocrinological disorders are concerned, obesity may be associated with early onset of sexual maturation in girls and with accelerated linear growth and advanced skeletal maturation (42).

Moreover, obese children have a considerably higher prevalence of OSA than do healthy weight children (43). Childhood obesity has also been shown to be associated with asthma (44).

Nonalcoholic fatty liver disease (NAFLD) in children is strongly associated with obesity (45). The spectrum of NAFLD can range from simple steatosis to progressive steatohepatitis and cirrhosis (45).

In addition, childhood obesity increases the risk of various musculoskeletal problems including impairment in mobility and increased prevalence of fractures (46).

Psychosocial consequences of childhood obesity are common and include poor self-esteem, anxiety, depression, and decreased health-related quality of life (47). Additionally, children with obesity are more likely to become victims of bullying and discrimination (48). Poor school performance, including difficulty concentrating, homework completion and missed school days, are significantly more often in an adolescent obese population when compared with a healthy control sample (36). Furthermore, clinical populations of overweight/obese adolescents also show higher lifetime rates of eating disorders, especially bulimia nervosa, than population-based samples (49).

1.4 Long term risks of childhood obesity

The ages between 0 and 5 years have been shown to be a critical period in the development of overweight and obesity, and that childhood overweight and obesity is highly predictive of adult obesity (50). The majority of adiposity-related comorbidities are not evident until adulthood but still reflect the accrual of the systemic effects of excess fat over time (50).

Children whose obesity persists into adulthood have an increased risk of T2DM, dyslipidemia, hypertension, and carotid-artery atherosclerosis than do adults who were never afflicted with obesity (51). Increased BMI during childhood has also been associated with a significantly increased risk of fatal and nonfatal cardiovascular events during adulthood in both men and women, though this may be partially mediated by the association between childhood obesity and adult obesity (52).

The harmful effects of childhood obesity are depicted clearly on a recent systematic review and meta-analysis containing 37 longitudinal cohort studies, where higher childhood BMI was associated with an increased incidence of adult diabetes, coronary heart disease and the odds of cancer (53).

As far as death from coronary heart disease is concerned, data from a large cohort study which observed 2.3 million Israeli adolescents into adulthood from 1967 through 2010 showed that BMI between 50 and 74th percentiles during adolescence (which is regarded as normal) was associated with significantly increased risk for cardiovascular disease and death from coronary heart disease compared to people with BMI values between the 5th and 24th percentile during the 40-year follow up period (54).

On the other hand, an older review with data from four prospective cohort studies which measured childhood and adult BMI with a follow-up period of up to 20 years showed that reduction of body weight towards normal weight range, i.e., decreasing severity of obesity, between childhood and adulthood, is associated with significant reduction of features of the metabolic syndrome such as arterial hypertension, type 2 diabetes or dyslipidemia (55).

Finally, obesity in childhood has important economic and social costs, with increase burdens on health systems as well as later reduced economic productivity (33).

1.5 Research gap

As stated above, the problem of childhood obesity has reached epidemic levels globally (56). It has proven to be one of the most serious public health challenges of the 21st century and the prevalence keeps on increasing at an alarming rate (56). As childhood obesity has been linked to numerous medical conditions that could persist into adulthood and is proven to have a significant impact on children's social and emotional health, it is of outmost importance to develop effective preventive strategies. In order to accomplish that, obesity risk factors should be promptly identified.

Although the etiology of childhood obesity seems to be multifactorial, socioeconomic and specific demographic characteristics of the family seem to play a pivotal role in in defining the children's weight status. Many different variables of family's socioeconomic status are used across the literature, but only a number of them seem to be of special interest, namely parental education, income, occupation and parental BMI. Yet there seems to be an inconsistency in the associations noted between various risk factors and childhood obesity, mostly due to the wide variety of risk factors taken into consideration in various studies in order to define socioeconomic status, the small sample size or the cross-sectional design of the studies. Thus, further research is necessary in order to effectively recognize the risk factors that can eventually affect the offspring's weight status and provide early intervention and treatment in high-risk families.

1.6 Research question

Since the problem of childhood obesity is affecting families globally, it is of great importance to better understand the specific socio-demographic characteristics of the family that lead to increased risk for obese and overweight to the offspring and explore how parental obesity can affect children, in order to develop appropriate prevention strategies. Because of the above-mentioned facts, the aim of the present study is to

evaluate the prevalence of childhood obesity in a large, multi-country sample of families in Europe and examine the association between family's socio-demographic characteristics and parental obesity.

2.Methodology

2.1 Study design

The Feel4Diabetes Study was a school- and community-based intervention with cluster-randomized design, aiming to promote a healthier lifestyle and prevent type-2 diabetes among families from vulnerable population groups. This intervention took place in 2016–2018 and included families (primary-school children, their parents and grandparents) from the overall population in two low/middle-income countries (Bulgaria, Hungary), from low socio-economic areas in two high-income countries (Belgium, Finland) and from two countries under austerity measures (Greece, Spain).

This intervention included two components, the 'all-families' component, provided to all children and their families via a school- and community-based intervention, and an additional component, the 'high-risk families' component, provided to high-risk families for diabetes as identified with the FINDRISC questionnaire, a validated tool to assess future diabetes risk which has been used in several studies in this field. The Feel4Diabetes-intervention reached to 30.309 families from 236 primary schools in the above-mentioned countries.

2.2 Ethics and consent

The Feel4Diabetes-study adhered to the Declaration of Helsinki and the conventions of the Council of Europe on human rights and biomedicine. Prior to initiating the intervention, all participating countries obtained ethical clearance from the relevant ethical committees and local authorities. More specifically, in Greece the study was approved by the Bioethics Committee of Harokopio University and the Greek Ministry of Education. All parents/caregivers provided a signed consent form before their enrollment in the study.

2.3 Study sample

The sample of the study consisted of families from “vulnerable” social groups from six European countries. In Bulgaria and Hungary, the two low/middle income countries, all areas within the selected provinces were considered “vulnerable” and thus eligible to participate in theFeel4Diabetes-study. On the contrary, in Spain, Belgium, Greece and Finland, the municipalities, school districts or other equivalent units were grouped in tertiles according to socio-economic indices and “vulnerable” areas were randomly selected only from the lowest tertile, which was defined by the lowest education level or the highest unemployment rate.

Children attending the first three grades of primary school, their parents and grandparents were recruited to participate to the study. The study sample at baseline included 12193 “all families” and 2230 “high-risk families”. High risk families were identified by using the FINDRISC questionnaire.

2.4 Measurements

A series of anthropometric indices, blood pressure measurements and blood tests were conducted by trained research assistants, using standardized protocols and equipment. To evaluate the impact of the Feel4Diabetes-intervention, children’s and adults’ drinking, eating, physical activity and sedentary behaviors were self-reported by the parents via standardized questionnaires and physical activity monitors. Data related to the socio-economic status of the families (e.g., paternal and maternal years of education and age) participating in the intervention were also collected.

2.5 Statistical analysis

In the present study categorical variables are presented as relative frequencies. To assess the possible associations between sociodemographic factors with childhood obesity, logistic regression was performed to extract crude odds ratios (Crude OR, 95% Cl). Moreover, multiple logistic regression was performed after adjusting for all

variables to extract adjusted odds ratios in order to identify all factors independently associated with childhood obesity (Adjusted OR, 95% Cl).

3.Results

3.1Prevalence of childhood overweight and obesity

Prevalence of childhood overweight and obesity in the total sample and by sex is shown on Figure 1.

The total sample size for which the “childhood obesity” variable was calculated/created is 9576 people from the “all families” group.

About 25% of the children in the total sample were overweight and obese. The obesity percentages were similar between boys and girls, namely 7.4-7.6% of them were obese. On the contrary, there is a statistically significant difference ($p<0.05$) between boys and girls overweight status with 19.7% of the girls being overweight in comparison to 16.4% of the boys. Furthermore, there was also a statistically significant difference as far as under- and normal- weight children are concerned, with more boys having normal or lower BMI values than girls.

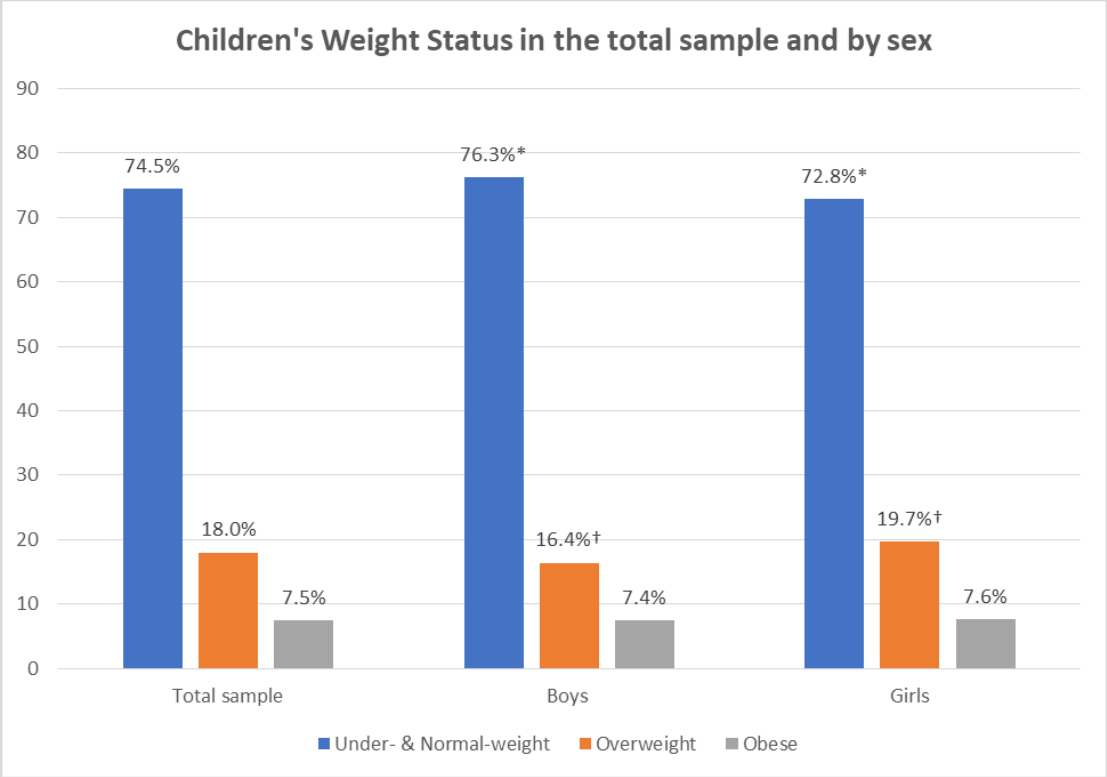

Figure 1 Children's weight status in the total sample and by sex

*,†: Statistical significant difference ($p<0.05$) between boys and girls, in the pairwise comparison of percentages that share the same superscript symbol based on the χ^2 test.

3.2 Children's weight status by parental obesity status

Children's weight status by parental obesity status is shown on Figure 2. It is depicted clearly that even one obese parent in the family increased the prevalence of childhood obesity and overweight greatly, whereas when obesity affects both parents the effect on childhood obesity and overweight is even stronger. Specifically, when both parents were obese approximately half of the children were overweight or obese as well. All of the above stated effects were of statistical significance.

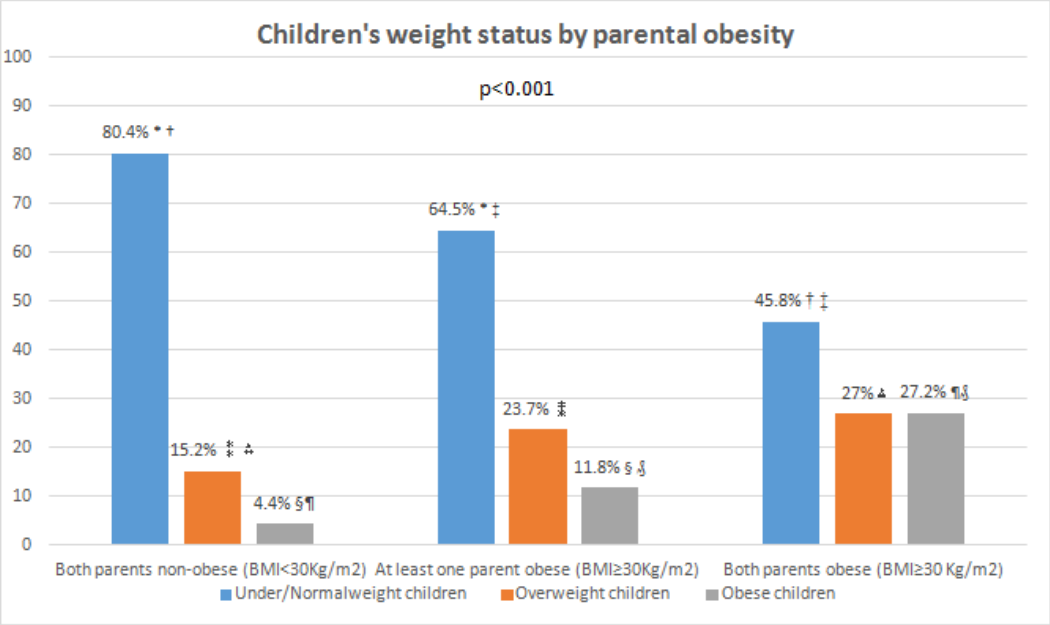

Figure 2 Children's weight status by parental obesity status

*,†,‡,⁂,♣,§,¶,ß: Statistical significant difference among parental weight status groups, in the comparison of percentages that share the same superscript symbol based on the χ^2 test (p<0.001).

3.3 Parental socio-demographic characteristics and obesity status by country's economic classification

Parental socio-demographic characteristics and obesity status in the total sample and by country's economic classification is shown on table 1. All differences in examined variables by country's socioeconomic status were of statistical significance.

		Total sample	By economic classification *			
			Low Income	Under economic crisis	High income	*p*-value
Child sex (%)	boy	49.4	48.5	50.0	50.0	0.260
	girl	50.6	51.5	50.0	50.0	
Age of Mother (%)	< 45 years old	90.4	93.1[a]	85.6[a,c]	91.9[c]	< 0.001
	≥ 45 years old	9.6	6.9[a]	14.4[a,c]	8.1[c]	
Age of Father (%)	< 45 years old	77.7	81.3[a]	68.6[a,c]	83.3[c]	< 0.001
	≥ 45 years old	22.3	18.7[a]	31.4[a,c]	16.7[c]	
Education of Mother (%) **	< 9 years	8.4	11.9[a,b]	7.7[a,c]	4.1[b,c]	
	9 - 14 years	35.3	34.3[a]	39.2[a,c]	32.6[c]	< 0.001
	> 14 years	51.9	53.8[a]	53.1[b]	63.3[a,b]	
Education of Father (%) **	< 9 years	9.7	10.9[b]	11.3[c]	6.2[b,c]	
	9 - 14 years	44.4	48.3[a]	37.9[a,c]	45.5[c]	< 0.001
	> 14 years	46.0	40.8[a,b]	50.8[a]	48.3[b]	
Occupation of Mother (%)	unemployed/other #	29.5	32.1[a,b]	35.5[a,c]	19.3[b,c]	
	employed full-time	57.5	62.0[a]	48.2[a,c]	60.9[c]	< 0.001
	employed part-time	13.1	6.0[a,b]	16.5[a,c]	19.8[b,c]	
Occupation of Father (%)	unemployed/other #	14.1	19.2[a,b]	11.9[a,c]	9.4[b,c]	
	employed full-time	81.5	75.4[a,b]	83.1[a,c]	88.6[b,c]	< 0.001
	employed part-time	4.3	5.4[b]	5.0[c]	2.0[b,c]	
BMI of Mother (%)	< 25 kg/m^2	66.8	70.0[a,b]	65.4[a]	63.5[b]	<0.001
	25-29.9 kg/m^2	22.3	20.1[b]	23.0[c]	24.5[b,c]	
	≥ 30 kg/m^2	11.0	9.8[b]	11.6[c]	11.9[b,c]	<0.001
BMI of Father (%)	< 25 kg/m^2	31.5	27.5[b]	30.3[c]	39.0[b,c]	
	25-29.9 kg/m^2	47.5	47.0	49.5[c]	45.8[c]	
	≥ 30 kg/m^2	21.0	25.5[a,b]	20.1[a,c]	15.2[b,c]	
Parental BMI classification (%)	Both parents without obesity (BMI< 30 kg/m^2)	72.1	68.2[a,b]	72.9[a,c]	77.0[b,c]	<0.001

Table 1 Parental socio-demographic characteristics and obesity status in the total sample and by country's economic classification*

p-value derived from χ^2 test.

BMI=body mass index.

* Countries classified in three economic brackets as "low income" (Bulgaria and Hungary), "under economic crisis" (at the time the data were collected - Greece and Spain), "high income" (Belgium and Finland).

** Having completed less than 9, 9 to 14, or more than 9, years of education.

Never employed, or previously employed, or retired, etc.

3.4 Children's weight status by country's economic classification and parental socio-demographic characteristics

Weight status of participating children by economic classification of country and parental socio-demographic characteristics is shown on Table 2.

Differences on children's weight status according to country's economic classification, maternal age, parental education and parental occupation were of statistical significance.

Overweight and obesity were more prevalent in counties of low economic status or under economic crisis, as compared to countries of high income. Of note, overweight was more prevalent in countries under economic crisis, as compared to countries of low income. Compulsory education only (<9 years) was more prevalent to the mother and the father of obese children, but not overweight children.

	Children's with weight status		
	Under- & normal weight	**overweight**	**obesity**
Country economic classification*	%	%	%
Low Income	74.5[a,b]	17.4[a,b]	8.2[a]
Under economic crisis	68.0[a,c]	22.7[a,c]	9.3[c]
High income	82.4[b,c]	13.4[b,c]	4.2[a,c]
p-value		< 0.001	
Age of mother			
< 45 years old	75.0[a]	17.8	7.2[a]
≥ 45 years old	72.1[a]	18.8	9.1[a]
p-value		0.037	
Age of father			
< 45 years old	75.3	17.7	7.0
≥ 45 years old	73.7	19.2	7.1
p-value		0.231	
Education of mother **			
< 9 years	71.4[b]	17.9	10.7[b]
9-14 years	69.9[c]	20.0[c]	10.0[c]
> 14 years	78.6[b,c]	16.3[c]	5.1[b,c]
p-value		< 0.001	
Education of father **			
< 9 years	69.5[b]	18.5	11[a,b]
9-14 years	72.1[c]	19.4[c]	8.4[a,c]
> 14 years	79.6[b,c]	15.9[c]	4.5[b,c]
p-value		< 0.001	
Occupation of mother			
unemployed/other #	71.6[a,b]	19.4[b]	9.1[a,b]
employed full-time	75.7[a]	17.4	6.8[a]
employed part-time	78[b]	16.2[b]	5.8[b]
p-value		< 0.001	
Occupation of father			
unemployed/other #	73.4	18.5	8.1
employed full-time	75.8	17.6	6.6[c]
employed part-time	70.9	18.7	10.4[c]
p-value		0.007	

Table 2 Weight status of participating children by economic classification of country and parental socio-demographic characteristics

p-value derived from χ^2 test.

[a,b,c]: Statistical significant difference (p<0.05) in the pairwise comparison of percentages that share the same superscript symbol within the same column (under-, normal, or overweight) and factor of analysis (e.g. age of mother), based on the χ^2 test.

* Countries classified in three economic brackets as "low income" (Bulgaria and Hungary), "under economic crisis" (at the time the data were collected - Greece and Spain), "high income" (Belgium and Finland).

** Having completed less than 9, 9 to 14, or more than 9, years of education.

Never employed, or previously employed, or retired, etc.

3.5 Multivariate associations between childhood obesity and country's economic classification, parental socio-demographic characteristics and parental obesity

Multivariate logistic regression analysis for the associations between childhood obesity with country's economic classification, parental socio-demographic characteristics and parental obesity is shown on Table 3.

When adjusting for all other variables, only country's economic classification, paternal education and parental weight status remained of statistical significance. In more detail, in high income countries there seems to be an approximately 50% less chance for obesity in children. Furthermore, children whose fathers have had education longer than 14 years have approximately half the odds of being obese. On the contrary, when parental weight status is taken into consideration, children from families with at least one obese parent are 2.5 times more likely to be obese, whereas children whose both parents are affected by obesity are approximately 7 times more likely to be obese.

	Dependent variable: childhood obesity	
Independent variables	**OR**	**95% CI**
Sex		
boys	1.00	
girls	0.99	0.83, 1.17
Country economic classification*		
Low Income	1.00	
Under economic crisis	1.17	0.97, 1.42
High income	**0.48**	**0.37, 0.62**
Age of mother		
< 45 years old	1.00	
≥ 45 years old	1.17	0.88, 1.55
Education of mother **		
< 9 years	1.00	
9-14 years	1.22	0.88, 1.71
> 14 years	0.78	0.54, 1.14
Education of father **		
< 9 years	1.00	
9-14 years	0.75	0.56, 1.01
> 14 years	**0.46**	**0.33, 0.65**
Occupation of mother		
unemployed/other #	1.00	
employed full-time	1.07	0.88, 1.31
employed part-time	0.88	0.64, 1.20
Occupation of father		
unemployed/other #	1.00	
employed full-time	1.09	0.85, 1.40
employed part-time	1.25	0.83, 1.89
Parental weight status		
Both parents without obesity (BMI < 30kg/m^2)	1.00	
At least one parent with obesity (BMI ≥ 30 kg/m^2)	**2.49**	**2.07, 2.99**
Both parents with obesity (BMI ≥ 30 kg/m^2)	**6.83**	**5.15, 9.05**

Table 3 Multivariate logistic regression analysis for the associations between childhood obesity with country's economic classification, parental socio-demographic characteristics, and parental obesity

95% CI=95% confidence interval; BMI=body mass index; OR=odds ratio; ref=reference category.

* Countries classified in three economic brackets as "low income" (Bulgaria and Hungary), "under economic crisis" (at the time the data were collected - Greece and Spain), "high income" (Belgium and Finland).

** Having completed less than 9, 9 to 14, or more than 9, years of education.

Never employed, or previously employed, or retired, etc.

Values in bold indicate statistically significant OR.

4.Discussion

The present study aimed to examine the prevalence of childhood obesity by children's sex, parental obesity and socio-economic characteristics, as well as by country's economic classification. The results of this study highlighted some principal findings. First, more girls seem to be overweight compared to boys, whereas more boys are under- or normal weight. Second, when negative associations with childhood obesity are taken into consideration, children from high-income countries and from families with longer paternal education are half as likely to suffer from childhood obesity. Third, when positive associations with childhood obesity are considered, children with at least one obese parent are 2.5 times as likely to be obese, whereas children whose both parents are affected by obesity are approximately 7 times more likely to be obese. All of the above stated facts remained of statistical significance when adjusted for all other variables.

In more detail, the present study highlighted differences in the prevalence of overweight between boys and girls, with more girls being overweight than boys. The above stated effect has been studied in the literature with mixed results. The World Obesity Federation released the first Atlas of Childhood Obesity in 2019, presenting the country-specific obesity prevalence by sex and age groups, as well as the calculated risk scores for future obesity (57). A notable difference in the prevalence of obesity by sex was reported across all age groups. Among children 5–9 years of age, 123 of 188 (65%) countries reported a greater prevalence of obesity for boys than girls (57). For children aged 10–19, this same trend was observed for 112 (60%) countries (57). This trend existed in the vast majority of high income and upper middle-income countries, but was not observed among lower middle and low-income countries (57). There has been limited discussion on the possible reasons and implications of this difference. At first, difference in the prevalence of childhood obesity may be driven in part by biological influences. Females generally have greater fat mass and less fat-free mass, which is in turn associated with less energy intake and lower calorie needs for females than males, whereas sex steroid hormones are associated with differences in body composition in children and youth (58, 59). Furthermore, females exhibit higher circulating concentrations of leptin, a hormone that suppresses appetite and

promotes energy utilization (60). Differences in obesity prevalence between boys and girls may also be driven in part by socio-cultural influences. Evidence suggests that girls, particularly those in higher income countries, may prefer foods that are lower in energy and nutrient-dense, such as fruits and vegetables, whereas boys tend to consume more meat and calorie-dense foods (61). Girls may also frequently report higher levels of weight-related concerns compared with boys, including desire to lose weight, feelings of guilt over eating too much and lower self-esteem (62). These differences are likely a result of gender-based stereotypes as feminine identity is typically characterized by eating smaller portions and preferring healthier options to maintain appearance, while a masculine eating identity is characterized by feeling full, with a focus on optimizing physical performance (63). The greater emphasis on 'thinness' as a cultural ideal in girls may also lead to differences in parental feeding practices and attitudes (63). Studies have shown that parents tend to be more concerned about weight status in their daughters than sons, while sons are usually encouraged to eat more (63).

On the contrary, as far as obesity prevalence in adult women and men is concerned, there seems to be an inverse correlation than the one stated before. In a recent study, internationally comparable obesity prevalence estimates for adult men and women for 192 countries were retrieved from the 2010 WHO Global Infobase and it was clearly depicted that in the majority of the countries, female obesity prevalence greatly exceeded that of males (64). The above stated difference in obesity rates between men and women that is primarily observed in developed countries has not been studied extensively, but is hypothesized to be related to numerous reasons. At first, although women are more likely to report eating or wanting to eat "healthier" foods, they seem to prefer more foods high in added sugars than men, including energy-dense processed foods (65). Furthermore, men consume a greater percentage of their energy intake from protein which primarily affects fat-free mass (66). Moreover, since women are often more sedentary than men, they are more vulnerable to excess weight gain due to the increased consumption of energy-dense foods high in refined carbohydrates (67).

Moreover, the present study highlighted that children from high-income countries are half as likely to suffer from obesity. This relationship has been studied in the literature with mixed results. As stated above and shown by a literature review of the past decade, there is a negative association between adiposity and SES in high-income countries, as well as a positive association in middle to low-income countries (28). A recent systematic review which included 158 observational studies and explored the association between socioeconomic position and childhood weight status in rich countries also concluded that the majority of the included papers observed an inverse relationship between weight status and family SEP, i.e. the measure of weight status registered the highest and lowest magnitudes in participants of low and high SEP, respectively (68). These effects could be explained by the facts that individuals from lower socioeconomic groups tend to be less likely to have a healthy diet than those from higher socioeconomic groups, because affordable healthy foods are less accessible, whereas unhealthy convenience foods are readily available in more deprived communities (69). Moreover, data from a pooled analysis of 2416 population-based studied in 128.9 million children, adolescents and adults from 1975 to 2016 showed that the rising trends in children's and adolescents' BMI have plateaued in many high-income countries, albeit at high levels, but have accelerated in many low-income countries (70). This plateauing of children's and adolescents' BMI in high-income countries although adult BMI continues to increase might be due to specific initiatives by governments, community groups, schools etc. that have increased public awareness about overweight and obesity in children, leading to changes in nutrition and activity that are sufficient to curb the rise in mean BMI (70).

The impact of economic crisis on children's obesity prevalence has also been studied in the literature with mixed results. Socio-economic changes in countries under austerity measures modify body mass index values and dietary patterns in the affected population. In more detail, a cross-sectional analysis with data from the Spanish National Health Survey of 2006/07 and from the last Spanish National Health Survey of 2011/12 showed that economic crisis in Spain increased the probability of obesity and poor dietary habits, with unemployed people and population in the lower educational levels having a higher obesity prevalence (71). These results could be

attributed to the diet modification which is a result of economic crisis, as diets high in fats and sweets represent a low-cost option to the consumer, whereas the recommended food diversity based on healthy food consumption costs more (72, 73). Similar results have been found in two cohort studies in Ireland and Japan. Results in Ireland showed that obesity rates increased during economic crisis and similar effects have also been observed in Japan, where children from low-income households were at increased risk for obesity after the onset of economic crisis (74, 75). On the contrary, results from a Greek longitudinal study that followed Greek schoolchildren before and during the early years of the Greek economic crisis demonstrated a statistically significant decrease in the prevalence of overweight and obesity, as well as a slight increase in the prevalence of underweight children, although not significant (76). These outcomes could be attributed to food price increases that have been associated with reductions in the number of meals and consuming cheap food (77, 78).

The present study also indicates that in families where paternal education was longer than 14 years children were half as likely of suffer from family obesity. The effect of parental education on children's obesity has also been studied previously but is not yet completely understood. Results from the Italian HBSC 2010 cross-sectional study (Health Behavior in School-Aged Children) which included a nationally representative sample of 11–15 year old students from 20 Italian regions showed that students with both parents in the lower educational level were more likely to be overweight than those with at least one parent with the highest educational level (79). This relationship was significant and consistent across gender and age groups (79). On the other hand, results from a multinational cross-sectional study which included data from children in 12 countries around the world showed positive relationships between parental education and child overweight in lower economic status countries as well as negative correlation in higher economic status countries (80). These findings may be explained by a higher level of awareness among the more educated parents in higher economic status countries in regard to the positive effects of maintaining a healthy body weight (80). On the contrary, as far as low-income countries are concerned, higher parental education is associated with a higher likelihood of their children being overweight and this may be a consequence of social norms, namely in some developing countries, a

more overweight child may be perceived as a "healthy child", with adequate food aspired to (80).

Moreover, the present study highlighted that the prevalence of even one obese parent in a family increases the offspring's chances for obesity, whereas when both parents are obese the above stated effect is even greater. This finding is supported by the literature. One of the first studies that highlighted the present finding was published in 1997 and consisted of 854 children of whom 135 were obese. The conclusion of this study was that after adjustment for parental obesity, having even one obese parent more than doubles the risk of adult obesity among both obese and non-obese children under 10 years of age (81). A more recent meta-analysis which included 32 studies from 21 countries and examined the association between parental and childhood obesity depicted that children with both obese parents have a higher likelihood of childhood obesity (82). There are many possible explanations about this association. At first, common genetic predisposition puts both parents and their offspring at similar levels of obesity susceptibility (83). Furthermore, obesogenic lifestyle and behavioral traits can be easily passed down from parents to their children through the family socialization process (84). The living environment that parents and their offspring share also means that they both may be exposed to common obesogenic factors, such as unhealthy eating and a sedentary lifestyle (84). Last, from the gene-environment interaction perspective, the parental generation's chronic exposure to obesogenic environments commonly found in modern societies may lead to metabolic adaptations that produce epigenetic phenotypes more susceptible to obesity, such as insulin- and leptin resistance (85). The fact that obesity in both parents has an even greater effect on offspring's obesity than obesity in only one of them could be a consequence of the double genetic burden as a consequence from 2 overweight or obese parents (83).

The present study has certain strengths and weaknesses. As it is a large population study, in which a large number of children from six European countries participated, the findings of the study are reliable enough to draw significant conclusions. Moreover, the standardized protocols and procedures followed across all centers and

the objectively collected data ensure reliable assessment and improve the generalizability of the findings. An important advantage is also the large number of variables examined, and not only those used directly to derive the results, but also the variables that were used as confusing factors, thus contributing to a better understanding of the correlations.

On the contrary, part of the collected data is self-reported and thus prone to recall bias and social desirability. Furthermore, due to the cross-sectional design of the present analysis, no temporal relationship and hence causal inferences can be established. Despite the aforementioned limitations, the present study highlights some important findings on the difference in childhood obesity prevalence according to family's and country's socio-economic status, as well as the demographic and socio-economic factors that are associated with childhood obesity. Further research is needed in order to develop effective preventive strategies.

5.Conclusion

In conclusion, the present study highlighted the gender difference between obesity prevalence, with more girls being overweight than their male counterparts. As far as country's socio-economic status is concerned, children from high-income countries half as likely to suffer from childhood obesity. When family's socio-demographic characteristics are taken into consideration, children from families with longer paternal education are half as likely to suffer from childhood obesity, whereas children with at least one obese parent are 2.5 times as likely to be obese and children whose both parents are affected by obesity are approximately 7 times more likely to be obese. All of the above stated facts remained of statistical significance when adjusted for all other variables. As childhood obesity is one of the most pressing public health issues, affecting children and adolescents worldwide, interventions should be family-centered and targeted to specific in-risk populations in order to impact the pediatric obesity epidemic in a way that increases awareness on the importance of lifestyle changes.

References:

1. Kumar, S., & Kelly, A. S. (2017). Review of Childhood Obesity. Mayo Clinic Proceedings, 92(2), 251–265.
2. 2018 Global Nutrition Report: Shining a Light to Spur Action on Nutrition. Accessed December 1st 2021 at https://globalnutritionreport.org/reports/global-nutrition-report-2018/
3. Abarca-Gómez, L., Abdeen, Z. A., Hamid, Z. A., Abu-Rmeileh, N. M., Acosta-Cazares, B., Acuin, C., Aguilar-Salinas, C. A. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. The Lancet, 390(10113), 2627–2642.
4. Lobstein T, Brinsden H (2019). Atlas of childhood obesity. World Obesity Federation
5. Garrido-Miguel, Oliveira, Cavero-Redondo, Álvarez-Bueno, Pozuelo-Carrascosa, Soriano-Cano, & Martínez-Vizcaíno. (2019). Prevalence of Overweight and Obesity among European Preschool Children: A Systematic Review and Meta-Regression by Food Group Consumption. Nutrients, 11(7), 1698.
6. World Health Organization (WHO) (2021) Obesity and overweight. Accessed December 1st 2021 at https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
7. Mei, Z., Grummer-Strawn, L. M., Pietrobelli, A., Goulding, A., Goran, M. I., & Dietz, W. H. (2002). Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. The American Journal of Clinical Nutrition, 75(6), 978–985.
8. Centers for Disease Control and Prevention. About child & teen BMI. Mar 2021 [internet publication].
9. Kelly, A. S., Barlow, S. E., Rao, G., Inge, T. H., Hayman, L. L., … Steinberger, J. (2013). Severe Obesity in Children and Adolescents: Identification, Associated Health Risks, and Treatment Approaches: A Scientific Statement From the American Heart Association. Circulation, 128(15), 1689–1712.

10. Barlow, S. E. (2007). Expert Committee Recommendations Regarding the Prevention, Assessment, and Treatment of Child and Adolescent Overweight and Obesity: Summary Report. Pediatrics, 120 (Supplement 4), S164–S192.
11. Koyuncuoğlu Güngör, N. (2014). Overweight and Obesity in Children and Adolescents. Journal of Clinical Research in Pediatric Endocrinology, 129–143.
12. Han, J. C., Lawlor, D. A., & Kimm, S. Y. (2010). Childhood obesity. The Lancet, 375(9727), 1737–1748.
13. Kumar, S., & Kelly, A. S. (2017). Review of Childhood Obesity. Mayo Clinic Proceedings, 92(2), 251–265.
14. Gurnani, M., Birken, C., & Hamilton, J. (2015). Childhood Obesity. Pediatric Clinics of North America, 62(4), 821–840.
15. Han, J. C., Lawlor, D. A., & Kimm, S. Y. (2010). Childhood obesity. The Lancet, 375(9727), 1737–1748.
16. Gurnani, M., Birken, C., & Hamilton, J. (2015). Childhood Obesity. Pediatric Clinics of North America, 62(4), 821–840.
17. Yan, J., Liu, L., Zhu, Y., Huang, G., & Wang, P. P. (2014). The association between breastfeeding and childhood obesity: a meta-analysis. BMC Public Health, 14(1).
18. Han, J. C., Lawlor, D. A., & Kimm, S. Y. (2010). Childhood obesity. The Lancet, 375(9727), 1737–1748.
19. Chaput, J.-P., Willumsen, J., Bull, F., Chou, R., Ekelund, U., Firth, J., Katzmarzyk, P. T. (2020). 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: summary of the evidence. International Journal of Behavioral Nutrition and PhysicalActivity, 17(1).
20. Fang, K., Mu, M., Liu, K., & He, Y. (2019). Screen time and childhood overweight/obesity: a systematic review and meta-analysis. Child: Care, Health and Development.
21. Brown, T., Moore, T. H., Hooper, L., Gao, Y., Zayegh, A., Ijaz, S., Summerbell, C. D. (2019). Interventions for preventing obesity in children. Cochrane Database of Systematic Reviews.
22. Wang, Y., & Beydoun, M. A. (2007). The Obesity Epidemic in the United States Gender, Age, Socioeconomic, Racial/Ethnic, and Geographic Characteristics: A

Systematic Review and Meta-Regression Analysis. Epidemiologic Reviews, 29(1), 6–28.

23. Drewnowski, A. (2012). The Economics of Food Choice Behavior: Why Poverty and Obesity Are Linked. Nestlé Nutrition Institute Workshop Series, 95–112.
24. Luppino, F. S., de Wit, L. M., Bouvy, P. F., Stijnen, T., Cuijpers, P., Penninx, B. W. J. H., & Zitman, F. G. (2010). Overweight, Obesity, and Depression. Archives of General Psychiatry, 67(3), 220.
25. Chan, G., & Chen, C. T. (2009). Musculoskeletal effects of obesity. Current Opinion in Pediatrics, 21(1), 65–70.
26. Sawyer, M. G., Harchak, T., Wake, M., & Lynch, J. (2011). Four-Year Prospective Study of BMI and Mental Health Problems in Young Children. PEDIATRICS, 128(4), 677–684.
27. Lobstein, T., & Dibb, S. (2005). Evidence of a possible link between obesogenic food advertising and child overweight. Obesity Reviews, 6(3), 203–208.
28. Vazquez, C. E., & Cubbin, C. (2020). Socioeconomic Status and Childhood Obesity: a Review of Literature from the Past Decade to Inform Intervention Research. Current Obesity Reports.
29. Gebremariam, M. K., Lien, N., Nianogo, R. A., & Arah, O. A. (2017). Mediators of socioeconomic differences in adiposity among youth: a systematic review. Obesity Reviews, 18(8), 880–898.
30. Barriuso, L., Miqueleiz, E., Albaladejo, R., Villanueva, R., Santos, J. M., & Regidor, E. (2015). Socioeconomic position and childhood-adolescent weight status in rich countries: a systematic review, 1990–2013. BMC Pediatrics, 15(1).
31. Weaver, R. G., Brazendale, K., Hunt, E., Sarzynski, M. A., Beets, M. W., & White, K. (2019). Disparities in childhood overweight and obesity by income in the United States: an epidemiological examination using three nationally representative datasets. International Journal of Obesity.
32. Bouchard C (1997). Genetic determinants of regional fat distribution. HumReprod, 12(suppl 1):1-5

33. Di Cesare, M., Sorić, M., Bovet, P., Miranda, J. J., Bhutta, Z., Stevens, G. A., Bentham, J. (2019). The epidemiological burden of obesity in childhood: a worldwide epidemic requiring urgent action. BMC Medicine
34. Speiser, P. W., Rudolf, M. C. J., Anhalt, H., Camacho-Hubner, C., Chiarelli, F., Eliakim, A., Hochberg, Z. (2005). Childhood Obesity. The Journal of Clinical Endocrinology & Metabolism, 90(3), 1871–1887.
35. Vaisse, C., Clement, K., Durand, E., Hercberg, S., Guy-Grand, B., &Froguel, P. (2000). Melanocortin-4 receptor mutations are a frequent and heterogeneous cause of morbid obesity. Journal of Clinical Investigation, 106(2), 253–262.
36. Miller, J., Rosenbloom, A., & Silverstein, J. (2004). Childhood Obesity. The Journal of Clinical Endocrinology & Metabolism, 89(9), 4211–4218.
37. Weihrauch-Blüher, S., & Wiegand, S. (2018). Risk Factors and Implications of Childhood Obesity. Current Obesity Reports.
38. McClafferty, H. H. (2007). Integrative Approach to Obesity. Pediatric Clinics of North America, 54(6), 969–981.
39. Skinner, A. C., Perrin, E. M., Moss, L. A., & Skelton, J. A. (2015). Cardiometabolic Risks and Severity of Obesity in Children and Young Adults. New England Journal of Medicine, 373(14), 1307–1317.
40. HEALTHY Study Group; Kaufman FR, Hirst K, Linder B (2009). Risk factors for type 2 diabetes in a sixth- grade multiracial cohort: the HEALTHY study. Diabetes Care. 32(5): 953-955
41. Friedemann, C., Heneghan, C., Mahtani, K., Thompson, M., Perera, R., & Ward, A. M. (2012). Cardiovascular disease risk in healthy children and its association with body mass index: systematic review and meta-analysis. BMJ, 345, e4759–e4759.
42. Kaplowitz, P. B., Slora, E. J., Wasserman, R. C., Pedlow, S. E., & Herman-Giddens, M. E. (2001). Earlier Onset of Puberty in Girls: Relation to Increased Body Mass Index and Race. PEDIATRICS, 108(2), 347–353.
43. Spilsbury, J. C., Storfer-Isser, A., Rosen, C. L., & Redline, S. (2015). Remission and Incidence of Obstructive Sleep Apnea from Middle Childhood to Late Adolescence. Sleep, 38(1), 23–29.

44. Papoutsakis, C., Priftis, K. N., Drakouli, M., Prifti, S., Konstantaki, E., Chondronikola, M., Matziou, V. (2013). Childhood Overweight/Obesity and Asthma: Is There a Link? A Systematic Review of Recent Epidemiologic Evidence. Journal of the Academy of Nutrition and Dietetics, 113(1), 77–105.
45. Feldstein, A. E., Charatcharoenwitthaya, P., Treeprasertsuk, S., Benson, J. T., Enders, F. B., & Angulo, P. (2009). The natural history of non-alcoholic fatty liver disease in children: a follow-up study for up to 20 years. Gut, 58(11), 1538–1544.
46. Chan, G., & Chen, C. T. (2009). Musculoskeletal effects of obesity. Current Opinion in Pediatrics, 21(1), 65–70.
47. Sawyer, M. G., Harchak, T., Wake, M., & Lynch, J. (2011). Four-Year Prospective Study of BMI and Mental Health Problems in Young Children. PEDIATRICS, 128(4), 677–684.
48. Schwimmer, J. B. (2003). Health-Related Quality of Life of Severely Obese Children and Adolescents. JAMA, 289(14), 1813.
49. Schwimmer, J. B. (2003). Health-Related Quality of Life of Severely Obese Children and Adolescents. JAMA, 289(14), 1813.
50. Cunningham, S. A., Datar, A., Narayan, K. M. V., & Kramer, M. R. (2017). Entrenched obesity in childhood: findings from a national cohort study. Annals of Epidemiology, 27(7), 435–441.
51. Juonala, M., Magnussen, C. G., Berenson, G. S., Venn, A., Burns, T. L., Sabin, M. A, Raitakari, O. T. (2011). Childhood Adiposity, Adult Adiposity, and Cardiovascular Risk Factors. New England Journal of Medicine, 365(20), 1876–1885.
52. Baker, J. L., Olsen, L. W., & Sørensen, T. I. A. (2007). Childhood Body-Mass Index and the Risk of Coronary Heart Disease in Adulthood. New England Journal of Medicine, 357(23), 2329–2337.
53. Llewellyn, A.; Simmonds, M.; Owen, C. G.; Woolacott, N. (2016). Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta-analysis. Obesity Reviews, 17(1), 56–67.
54. Twig, Gilad; Yaniv, Gal; Levine, Hagai; Leiba, Adi; Goldberger, Nehama; Derazne, Estela; Ben-Ami Shor, Dana; Tzur, Dorit; Afek, Arnon; Shamiss, Ari;

Haklai, Ziona; Kark, Jeremy D. (2016). Body-Mass Index in 2.3 Million Adolescents and Cardiovascular Death in Adulthood. New England Journal of Medicine

55. Tirosh, Amir; Shai, Iris; Afek, Arnon; Dubnov-Raz, Gal; Ayalon, Nir; Gordon, Barak; Derazne, Estela; Tzur, Dorit; Shamis, Ari; Vinker, Shlomo; Rudich, Assaf (2011). Adolescent BMI Trajectory and Risk of Diabetes versus Coronary Disease. New England Journal of Medicine, 364(14), 1315–1325.
56. Krushnapriya Sahoo, Bishnupriya Sahoo, Ashok Kumar Choudhury & Ajeet Singh Bhadoria (2015). Childhood obesity: causes and consequences. Journal of Family Medicine and Primary Care, 4 (2), 187-192
57. Shah, Bindra; Tombeau Cost, Katherine; Fuller, Anne; Birken, Catherine S; Anderson, Laura N (2020). Sex and gender differences in childhood obesity: contributing to the research agenda. BMJ Nutrition, Prevention & Health
58. Campbell MK (2016). Biological, environmental, and social influences on childhood obesity. Pediatr Res, 79:205–11.
59. Wells JCK (2007). Sexual dimorphism of body composition. Best Pract Res Clin Endocrinol Metab, 21:415–30.
60. Blum WF, Englaro P, Hanitsch S (19997). Plasma leptin levels in healthy children and adolescents: dependence on body mass index, body fat mass, gender, pubertal stage, and testosterone. J Clin Endocrinol Metab, 82:2904–10.
61. Caine-Bish NL, Scheule B (2009). Gender differences in food preferences of school-aged children and adolescents. J Sch Health, 79:532–40.
62. Bauer KW, Larson NI, Nelson MC (2009). Socio-environmental, personal and behavioural predictors of fast-food intake among adolescents. Public Health Nutr, 12:1767–74.
63. Keller K, Kling S, Fuchs B, et al (2019). A biopsychosocial model of sex differences in children's eating behaviors. Nutrients, 11:682.
64. Garawi, F; Devries, K; Thorogood, N; Uauy, R (2014). Global differences between women and men in the prevalence of obesity: is there an association with gender inequality? European Journal of Clinical Nutrition, 68(10), 1101–1106.

65. Wardle J, Haase AM, Steptoe A, Nillapun M, Jonwutiwes K, Bellisle F (2004). Gender differences in food choice: the contribution of health beliefs and dieting. Ann Behav Me, 27(2):107-16.
66. Bray GA, Smith SR, de Jonge L, Xie H, Rood J, Martin CK, Most M, Brock C, Mancuso S, Redman LM (2012). Effect of dietary protein content on weight gain, energy expenditure, and body composition during overeating. JAMA, 307:47–55
67. Knopp RH, Paramsothy P, Retzlaff BM, Fish B, Walden C, Dowdy A, Tsunehara C, Aikawa K, Cheung MC (2005). Gender differences in lipoprotein metabolism and dietary response: basis in hormonal differences and implications for cardiovascular disease. Curr Atheroscler Rep, 7(6):472-9.
68. Barriuso, Laura; Miqueleiz, Estrella; Albaladejo, Romana; Villanueva, Rosa; Santos, Juana M.; Regidor, Enrique (2015). Socioeconomic position and childhood-adolescent weight status in rich countries: a systematic review, 1990–2013. BMC Pediatrics, 15(1), 129–144.
69. Black, C, Moon, G, Baird, J (2014). Dietary inequalities: what is the evidence for the effect of the neighbourhood food environment. Health Place, 27: 229–242.
70. Abarca-Gómez, L., Abdeen, Z. A., Hamid, Z. A., Abu-Rmeileh, N. M., Acosta-Cazares, B., Acuin, C., Aguilar-Salinas, C. A. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. The Lancet, 390(10113), 2627–2642.
71. Norte, A., Sospedra, I., & Ortíz-Moncada, R. (2018). Influence of economic crisis on dietary quality and obesity rates. International Journal of Food Sciences and Nutrition, 1–8.
72. Drewnowski A, Darmon N, Briend A (2004). Replacing fats and sweets with vegetables and fruits-a question of cost. Am J Public Health. 94, 1555–1559.
73. Drewnowski A, Specter SE (2004). Poverty and obesity: the role of energy density and energy costs. Am J Clin Nutr. 79, 6–16.
74. Jabakhanji, S. B., Pavlova, M., Groot, W., Boland, F., & Biesma, R. (2017). Social class variation, the effect of the economic recession and childhood obesity at 3 years of age in Ireland. The European Journal of Public Health

75. Ueda, P., Kondo, N., & Fujiwara, T. (2015). The global economic crisis, household income and pre-adolescent overweight and underweight: a nationwide birth cohort study in Japan. International Journal of Obesity, 39(9), 1414–1420.
76. Kleanthous, K., Dermitzaki, E., Papadimitriou, D. T., Papaevangelou, V., & Papadimitriou, A. (2015). Overweight and obesity decreased in Greek schoolchildren from 2009 to 2012 during the early phase of the economic crisis. Acta Paediatrica, 105(2), 200–205.
77. Rajmil L, Fernandez de Sanmamed MJ, Choonara I, Faresjo T, Hjern A & Kozyrskyj AL (2014) . International Network for Research in Inequalities in Child Health (INRICH). Impact of the 2008 economic and financial crisis on child health: a systematic review. Int J Environ Res Public Health ,11, 6528–46
78. Rajmil L, Fernandez de Sanmamed MJ, Choonara I, Faresjo T, Hjern A & Kozyrskyj AL (2014) . International Network for Research in Inequalities in Child Health (INRICH). Impact of the 2008 economic and financial crisis on child health: a systematic review. Int J Environ Res Public Health ,11, 6528–46
79. Lazzeri, G., Giacchi, M. V., Spinelli, A. (2014). Overweight among students aged 11–15 years and its relationship with breakfast, area of residence and parents' education: results from the Italian HBSC 2010 cross-sectional study. Nutrition Journal, 13(1).
80. Muthuri, S. K., Onywera, V. O., Tremblay (2016). Relationships between Parental Education and Overweight with Childhood Overweight and Physical Activity in 9–11 Year Old Children: Results from a 12-Country Study. PLOS ONE, 11(8)
81. Whitaker, Robert C.; Wright, Jeffrey A.; Pepe, Margaret S.; Seidel, Kristy D.; Dietz, William H. (1997). Predicting Obesity in Young Adulthood from Childhood and Parental Obesity. New England Journal of Medicine, 337(13), 869–873.
82. Wang, Youfa, Min, Jungwon, Khuri, Jacob, Li, Miao (2017). A Systematic Examination of the Association between Parental and Child Obesity across Countries. Advances in Nutrition: An International Review Journal, 8(3), 436–448

83. Bouchard, C. (2009). Childhood obesity: are genetic differences involved? American Journal of Clinical Nutrition, 89(5), 1494S–1501S.
84. Richard R Rosenkranz, David A Dzewaltowski (2008). Model of the home food environment pertaining to childhood obesity. , 66(3), 123–140.
85. Sebert, S.; Sharkey, D.; Budge, H.; Symonds, M. E. (2011). The early programming of metabolic health: is epigenetic setting the missing link? American Journal of Clinical Nutrition, 94(6_Suppl), 1953S–1958S.