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Περιγεννητικοί, κοινωνικοδημογραφικοί και παράγοντες του τρόπου ζωής που σχετίζονται με τον κίνδυνο εμφάνισης παιδικής παχυσαρκίας
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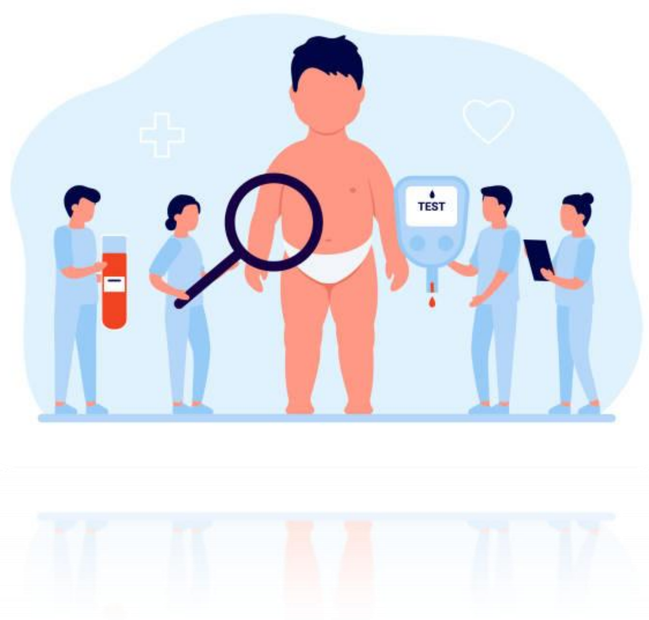

Αθήνα, 2022

Harokopio University

School of Health Sciences & Education Department of Nutrition and Dietetics

Postgraduate Program “Applied Nutrition and Dietetics”
Discipline: Nutrition and Exercise

Perinatal, sociodemographic and lifestyle correlates of childhood obesity
Master Thesis

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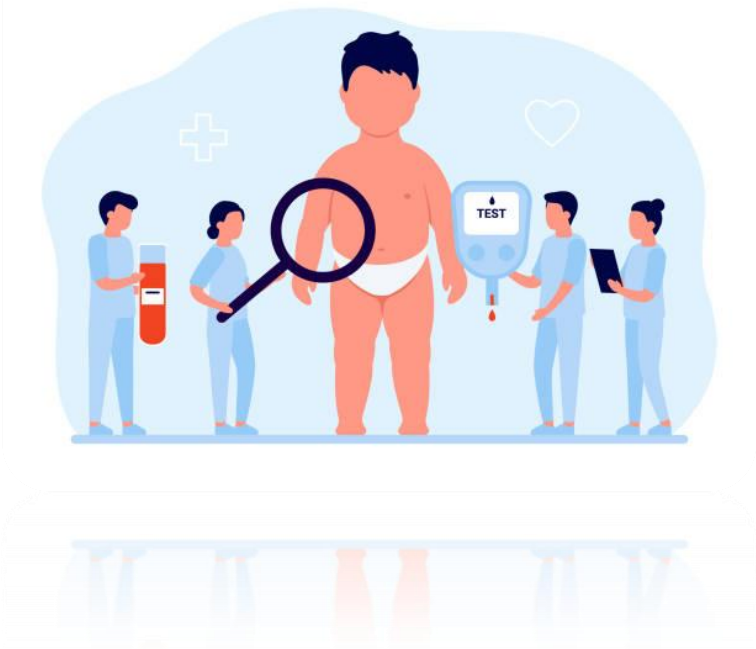

Athens, 2022

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Περίληψη

Εισαγωγή: Ο επιπολασμός της παιδικής υπερβαρότητας/παχυσαρκίας αποκτά επιδημικές διαστάσεις και θεωρείται ένα από τα σημαντικότερα προβλήματα δημόσιας υγείας. Η πρόληψή της είναι υψίστης σημασίας, της οποίας σημαντικό συστατικό είναι ο προσδιορισμός των πιο σημαντικών παραγόντων κινδύνου.

Σκοπός: Ο εντοπισμός των κυριότερων παραγόντων κινδύνου αυτής της νόσου, ανάμεσα σε πληθώρα περιγεννητικών, κοινωνικοδημογραφικών, παραγόντων του τρόπου ζωής και πρακτικών σίτισης των γονέων σε ένα μεγάλο δείγμα από έξι ευρωπαϊκές χώρες.

Μεθοδολογία: 12211 παιδιά (49,4% αγόρια) ηλικίας 4-12 ετών, από περιοχές χαμηλού κοινωνικοοικονομικού επιπέδου σε χώρες υψηλού εισοδήματος (Βέλγιο-Φινλανδία), από χώρες υψηλού εισοδήματος οι οποίες βρίσκονται σε οικονομική κρίση (Ελλάδα-Ισπανία) και από χώρες χαμηλού/ μεσαίου εισοδήματος (Βουλγαρία-Ουγγαρία) (συγχρονικά δεδομένα από τη μελέτη Feel4Diabetes).

Αποτελέσματα: Η υπερβαρότητα (OR, 95%CI 1,57(1,10-2,24)) και η παχυσαρκία (OR, 95%CI 3,14(1,89-5,22)) της μητέρας, η υπερβαρότητα (OR, 95% CI 1,79(1,28-2,52)) και η παχυσαρκία (OR, 95%CI 3,06(2,08-4,51)) του πατέρα καθώς και η διαμονή στην Ανατολική (OR, 95%CI 3,79(2,12-6,78)) και Νότια Ευρώπη (OR, 95%CI 6,14(3,39-11,14)) συσχετίστηκαν με μεγαλύτερο κίνδυνο παιδικής υπερβαρότητας/παχυσαρκίας. Παιδιά από μητέρες υπέρβαρες (OR, 95%CI 1,45(1,01-2,09)) ή παχύσαρκες (OR, 95%CI 2,16(1,56-3,00)) ή με διαβήτη πριν από την κύηση (OR, 95%CI 6,68(1,00-44,59)) είχαν επίσης μεγαλύτερο κίνδυνο. Ομοίως, τα παιδιά που γεννήθηκαν πρόωρα (<37 εβδομάδες)(OR, 95%CI 1,02(0,71 1,47)) και εκείνα με αυξημένο βάρος γέννησης (OR, 95%CI 1,43(1,00-2,04)) είχαν μεγαλύτερο κίνδυνο υπερβαρότητας/παχυσαρκίας. Αντίθετα, τα παιδιά που η αύξηση του βάρους κατά τους πρώτους 6 μήνες ζωής (WAZ) ήταν φτωχή (<-0,67 SD) (OR, 95%C.I. 0,52(0,36-0,75)) είχαν χαμηλότερο κίνδυνο υπερβαρότητας/παχυσαρκίας.

Συμπεράσματα: Η υπερβαρότητα/παχυσαρκία των γονέων, η διαμονή σε χώρες χαμηλού εισοδήματος και σε χώρες σε οικονομική κρίση, ο διαβήτης και η υπερβαρότητα/παχυσαρκία της μητέρας πριν την κύηση, η πρόωρη γέννηση και το αυξημένο βάρος γέννησης ήταν οι κυρίαρχοι παράγοντες κινδύνου της παιδικής υπερβαρότητας/παχυσαρκίας, ενώ, η φτωχή αύξηση του βάρους τους πρώτους 6 μήνες σχετίζεται με χαμηλότερο κίνδυνο. Για αυτό κρίνεται αναγκαίο οι στρατηγικές προώθησης της υγείας και τα προγράμματα παρέμβασης να απευθύνονται στην οικογένεια και να εστιάζουν στην κατάσταση βάρους των γονέων και στην υγεία της μητέρας πριν από την εγκυμοσύνη.

Λέξεις κλειδιά: παιδική υπερβαρότητα/ παχυσαρκία; παράγοντες κινδύνου; Feel4Diabetes; πρόληψη

Abstract

Background: The prevalence of childhood overweight and obesity has reached epidemic proportions and it is recognized as a major public health challenge. Therefore its prevention is of utmost importance, whose crucial component is the identification of the most dominant childhood overweight/ obesity risk factors.

Objectives: The aim of this study is to identify the predominant correlates of children overweight and obesity, among a variety of perinatal, socio-demographic, lifestyle factors and parental practices in a large sample from six European countries.

Methods: 12211 children (49.4% boys) 4-12 years old participated in the study from low-socioeconomic areas in high-income countries (HICs) (Belgium-Finland), HICs under economic crisis (Greece-Spain) and low/middle-income countries (LMICs) (Bulgaria-Hungary) (baseline data from the Feel4Diabetes study).

Results: Maternal overweight (OR, 95% C.I. 1.57 (1.10-2.24)) and obesity (OR, 95% C.I. 3.14 (1.89-5.22)) along with paternal overweight (OR, 95% C.I. 1.79 (1.28-2.52)) and obesity (OR, 95% C.I. 3.06 (2.08-4.51)) as well as living in Eastern (OR, 95% C.I. 3.79 (2.12-6.78)) and in Southern Europe (OR, 95% C.I. 6.14 (3.39-11.14)) were associated with higher risk of childhood overweight/ obesity. Children whose mothers were overweight (OR, 95% C.I. 1.45 (1.01-2.09)) or obese (OR, 95% C.I. 2.16 (1.56-3.00)) or had diabetes before pregnancy (OR, 95% C.I.6.68 (1.00-44.59)) were associated with a greater risk. Likewise pre-term children (<37 weeks) (OR, 95% C.I. 1.02 (0.71-1.47)) as well as those that were born large for gestational age (OR, 95% C.I. 1.43 (1.00-2.04)) had a higher overweight/ obesity risk. On the contrary, children whose weight gain during the first 6 months (WAZ) was poor (< -0,67 SD) (OR, 95% C.I. 0.52 (0.36-0.75)) had a lower overweight/ obesity risk.

Conclusions: Parental overweight/ obesity, living in low-income and countries under economic crisis, maternal diabetes and overweight/ obesity before pregnancy, premature birth and high birth weight were the predominant factors of increased childhood overweight and obesity risk, while, poor infant weight gain in the first six months is associated with lower risk. Thereby, it is essential that future health promotion strategies should be family oriented that will focus on parental weight status and maternal health before pregnancy.

Key words: childhood overweight/obesity; risk factors; Feel4Diabetes; prevention

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List of abbreviations

BMI	Body Mass Index
FINDRISC	Finnish Diabetes Risk Score
IOTF	International Obesity Task Force
POCS	Polycystic Ovarian Syndrome
SES	Socioeconomic status
SSBs	Sugar-Sweetened Beverages
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus
AGA	Appropriate for Gestational Age
LGA	Large for Gestational Age
SGA	Small for Gestational Age
WAZ	Weight-for-Age Z-scores
WHZ	Weight-for-Height Z-scores
WHO	World Health Organization

1. Introduction

1.1. Introduction to childhood overweight/ obesity and its definition

Childhood obesity is recognized as a new pandemic of the new millennium. Excess weight during childhood and adolescence remains one of the most crucial issues in global health, although it has emerged several decades ago (1). The increasing prevalence of childhood obesity has led to multiple serious obesity-related comorbidities that threaten human health and place a large strain on the health care system. Additionally, obesity in childhood tracks strongly into adulthood, especially in those with severe obesity and/or a family history of obesity (2,3).

Obesity is characterized by abnormal or excessive fat accumulation that presents a risk to health (4). It should be noted that there are two definitions of obesity in childhood: the IOTF definition that has developed an international standard growth chart which enables comparison of prevalence globally (5) and one based on the WHO growth reference (6). According to the latest clinical practice guidelines on pediatric obesity, children and adolescents between 2-20 years with a BMI over the 85^{th} but less than the 95^{th} percentile for age and gender are considered overweight and those with a BMI greater than the 95^{th} percentile are considered obese. Children and adolescents with a BMI greater than the 99^{th} percentile are considered severely obese (6-8).

1.2. Epidemiology of childhood overweight/ obesity worldwide

Childhood overweight/ obesity are considered as a public health crisis. The prevalence has doubled in more than 70 countries since 1980 and has approximately tripled in some developing countries (9). Although obesity rates vary among countries, its prevalence has continuously increased regardless of socio-demographic strata over the past 40 years (10). The prevalence of overweight and obesity has escalated in developed countries at 23.8% for boys and 22.6% for girls, in 2013 compared with 16.9% for boys and 16.2% for girls, in 1980 (10). In 2015, 107.7 million children were considered obese worldwide (3,11) while this prevalence was more than 10% in developing countries and even more than 20% in developed countries (3).

The most recent evaluations of trends in overweight and obesity revealed that 38.3 million of children under 5 years old around the world were overweight in 2020 (4,12) and over 340 million children and adolescents aged 5-19 were overweight or obese. Overall, the prevalence of overweight and obesity among children and adolescents aged 5-19 has risen dramatically from 4% in 1975 to over 18% in 2016. More specifically, in 2016, 18% and 6% of girls were overweight and obese, respectively and 19% and 8% of boys were overweight and obese, respectively (4).

1.3. Epidemiology of childhood overweight/ obesity in Europe

In the WHO European Region one child out of three, is overweight or obese. Children and adolescents, 5-19 years old have shown rising obesity rates in almost all nations, including those where the rates were far from alarming 40 years ago (13). The prevalence of overweight/obesity in 1975 in the majority of European countries was less than 10% and obesity less than 5%, while no European country had overweight prevalence higher than 30% and obesity higher than 10%. In 2016 the trend reversed, showing an alarming increase of overweight (over 30%) and obesity (over 10%) (1,14).

A recent review of Garrido-Miguel et al. in 2019 on children aged 2-7 years during a 10-year period (2006-2016) showed that about 17.9% of children were overweight or obese and 5.3% were obese according to the IOTF definition criteria (5). Southern European countries showed the highest prevalence of overweight and obesity especially those surrounding the Mediterranean Sea. More specifically, the highest prevalence was observed in Italy (32.4%), Greece (29.6%) and Portugal (26.4%). On the contrary, the lowest prevalence was found in Estonia (8.3%), France (11.0%) and Netherlands (13.4%). The observed prevalence in Eastern Europe was 21-24% (15).

The most accurate comparable data on the prevalence of childhood obesity are provided by the WHO European Childhood Obesity Surveillance Initiative (COSI) (13). Data were collected from 41 countries on 2015-2016 from children 6-9 years old. The prevalence of both overweight and obesity ranged from 17.6% to 41.9% for boys and from 20.1% to 38.5% for girls while the prevalence of obesity alone was 4.9-21% among boys and 5.1-14.9% among girls, while the highest prevalence of overweight and obesity were in Southern Europe (13). This very high prevalence in some European countries could be somehow explained by the gradual changes from the healthy traditional diets to a more westernized diet rich in animal proteins, fats and sugars and poor in complex carbohydrates and fiber (16,17) along with an increase in sedentary behaviors and a decrease in physical activity (18).

1.4. Complications of childhood overweight/ obesity

Childhood obesity is associated with comorbidities affecting almost every system in the body including, the endocrine, gastrointestinal, pulmonary, cardiovascular, and musculoskeletal system and has serious consequences, such as hypertension, dyslipidemia, insulin resistance, prediabetes, type 2 diabetes mellitus, fatty liver disease and steatohepatitis, obstructive sleep apnea and psychosocial complications including low self-esteem and depression (2,19). Furthermore, it can cause not only neurological (idiopathic intracranial hypertension) and dermatological disorders (acanthosis nigricans, intertrigo, furunculosis) but also growth and puberty related issues including PCOS and early menarche, in girls and reduced circulating androgens and later pubertal onset, in boys (20-22).

1.5. Risk factors of childhood overweight/ obesity

Obesity is a complex, multifactorial condition affected by genetic and non-genetic factors. Several parameters that have a major influence of children’s eating behavior and weight status and can increase childhood obesity risk have been separately identified (19).

1.5.1 Genetic factors

Several genome-wide association studies have identified genetic markers that increase predisposition to weight gain (1). The most relevant epigenetic mechanisms involved in gene activity control are histone modifications, non-coding RNAs (ncRNA) and DNA methylation (23). Obesity has been associated with the epigenetic modulation of several genes such as HIF3A, RXRA, micro RNA (miR)-122 and miR-519d (24-27). Moreover, the FTO gene is recognised as an important factor to the regulation of energy intake, with variants predisposing individuals to greater caloric intake and reduced feelings of satiety (28). Mutations in the melanocortin 4 receptor are the most common single gene defects in children with severe obesity (29,30). Other genetic associations with obesity include defects in leptin, leptin receptor, proopiomelanocortin, and proprotein convertase (3).

1.5.2 Perinatal factors

Among the risk factors of childhood obesity in the first 1000 days of life, maternal overweight and obesity before pregnancy as well as gestational weight gain are the strongest perinatal predictors of offspring obesity (31-33). Obese women have increased insulin resistance, which may lead to glucose intolerance and gestational diabetes during pregnancy and consequently to fetal overgrowth (34). Gestational diabetes and maternal type 1 and type 2 diabetes may also serve as risk factors for higher body fat accumulation and for childhood overweight/obesity (35, 36). Birth weight is also associated with increased body fat mass and childhood obesity (37, 38). A systematic review and meta-analysis showed that high birth weight (>4,000g) is correlated with an increased risk of obesity (39), while low birth weight (<2,500g) leads to abnormal fetal development and in a rapid catch-up growth in early infancy, which results in higher fat mass later in life (40-42). Moreover, there is robust evidence on the association between maternal smoking during pregnancy and childhood obesity. One meta-analysis of 16 observational studies found that maternal smoking during pregnancy was related to an increased risk of offspring overweight at age >3 years old (43). Other similar studies have examined maternal age at gestation and breastfeed in relation with childhood overweight and obesity. In two large European cohort studies (44, 45) maternal age did not consist a risk factor for childhood overweight, while Risvas et al in a cross-sectional study in Greece has shown that high maternal age at gestation was inversely associated with children's overweight and obesity (46). Also, a recent meta-analysis demonstrated that breastfeeding is associated with a 13% reduction of overweight and obesity (47) and Harder et al in a meta-analysis of 17 cohort studies conducted in children 4 months to 14 years old showed that each additional month of breastfeeding was associated with a 4% reduction in the prevalence of overweight as infants that breastfeed exclusively during the first 6 months of life are less likely to have excess weight during late infancy (>6 months) (48). Another important perinatal risk factor is the introduction of solid foods at weaning. The effect of the timing of introduction of solid foods is a much contested area as some studies claim that those having solid food introduced to their diet after 5 months were significantly more likely to be obese compared with children that had an early introduction of solid foods (≤4 months) (32), while other studies support that introduction before 4 months is a risk factor for obesity, and this may be particularly true for children who are formula-fed (49).

1.5.3 Sociodemographic characteristics

Over the last few years a variety of sociodemographic variables linked to childhood obesity have been detected, especially among population groups with lower income or educational attainment. People of low SES live in environments where the described determinants of obesity are present to a larger extent and they are less equipped to counteract obesogenic influences. Indeed, low SES seems to be correlated with poor dietary choices (lower consumption of fruits, vegetables, fish and whole grain products, skipping breakfast and higher intake of energy dense foods and beverages, rich in sugars and saturated fats) (50). Moreover, the sharp price increase for the low-energy-density foods (fruits, vegetables, whole grains, lean meats, low-fat dairy products) suggests that economic factors may pose a barrier to the adoption of a more healthful diet and so restrict the impact of dietary guidance (4). This phenomenon has shown an outburst in Southern/Eastern Europe (especially in countries surrounding the Mediterranean) and particularly in children from low SES families which are at greater risk of being overweight/obese than children from Northern Europe and from high SES families (33,51-53).

“Low SES” families have been characterized those whose at least one parent has less years of education (<14 years), is unemployed or works part time and those families whose annual income is low (54,55). Previous studies in children and adolescents, revealed a positive association between parental and children’s weight status, with the risk of overweight/obesity being higher in children with overweight/obese parents compared to their peers whose parents have normal weight (53,56). Furthermore, a variety of studies has shown that the prevalence of obesity until the age of 11 years old is approximately the same between boys and girls, but after that age the prevalence is much higher for boys than for girls mainly because in that period, girls tend to be more concerned about their body image and start to follow weight-loss diets. This could explain the reduction in overweight and obesity in girls after 11 years of age (57). Furthermore, ethnicity is associated with differences in food-related beliefs, preferences, behaviours, and cultural influences, which may contribute to the higher risk of obesity among children and adolescents in minority populations (56).

1.5.4 Lifestyle factors

Obesity generally results from adopting an unhealthy lifestyle. Diet and physical activity are the cornerstones of obesity prevention and weight management (58). Dietary factors and their contribution to obesity rates have been extensively studied and it was found that are strongly associated with obesity among school children (59,60). Children tend to refuse nutritious foods such as, whole grains, milk products, vegetables and fruits and as a result they decrease their daily consumption (61). On the other hand, they increase consumption of SSBs, calorie dense snacks and meals out of home (62). Regarding the SSBs, their high energy density, frequency of consumption, at the expense of water consumption, and large portions lead to obesity development (63). In addition, the calories provided by free sugars, especially in liquid form, do not provide a sense of satiety therefore do not reduce the intake of food. A prospective study which enrolled 548 ethnically diverse school children, has shown that for each additional serving of SSBs, BMI increased by an average of 0.18 kg/m^2 (64). Many studies found that junk food consumption, that has a high content of calories, salt, saturated fat and low content of iron, calcium and fiber, is linked with obesity (65,66). Another factor that has been identified as a possible contributor to childhood overweight/obesity is skipping breakfast (66). Children who skip breakfast have double risk of becoming obese than children who consume breakfast every day (67), as this omission is often associated with a decrease in diet quality during the day, since they replace breakfast with frequent snacking and they tend to choose sweet, salty and fatty foods rather than healthier options (68).

Moreover, a range of environmental factors including less active transport (69) and the changing nature of school-ground facilities (70) have resulted in the reduction of many physical activities from a child's contemporary lifestyle and therefore contributed to the childhood obesity epidemic. Physical inactivity can lead to energy imbalance and can increase the risk of becoming overweight or obese (71,72). A cohort study that has been carried out for 32 years on twins in order to investigate the role of physical activity on body weight while controlling for genetic cofactors, revealed that a twin on regular physical activity has significantly lower body weight than the inactive co-twin (73).

A sedentary lifestyle which is characterized by increased duration of watching television, playing video games and using the internet can augment the prevalence of obesity (66). Increased daily screen time can promote obesity among children in several ways: reducing time for physical activity, increasing the intake of more calories (especially sugar sweetened beverages, chocolates, sweets, potato chips and nuts) and even interfering with adequate sleep time (74). Several trials indicated that reducing screen time could improve BMI, body fat and other obesity-related measures among children (72,75).

Furthermore, insufficient sleep is associated with overweight and obesity among children and adolescents (66,76). Sleep deprivation may influence ghrelin and leptin levels, which consequently can cause disturbances on food intake, including rise of appetite and increase of calories consumption (76). Moreover, Tambalis et al. investigated the association between sleep duration and lifestyle profile on 177,091 children aged 8-17 years and showed that children with inadequate sleeping hours (≈7h/day) had a poorer physical activity, dietary habits and increased risk of overweight/obesity (77).

1.5.5 Parental practices

Children learn what, when, and how much to eat from their direct experience with food as well as by observing their parents, that influence them through a variety of mechanisms including role modeling, availability and accessibility of nutritious foods at home and development of attitudes, values and preferences (78,79). Parenting style is characterized by the degree of parental demandingness and responsiveness (80). The four parenting styles most commonly studied are: authoritative, authoritarian, permissive, and neglectful (81). Cross-sectional studies conducted in children aged 3-10 and adolescents 10-17 year old from diverse ethnic groups have consistently found that authoritative parenting style was associated with children's and adolescents' lower BMI, availability of fruit and vegetables at home, child consumption of fruit, vegetables and dairy products, lower consumption of SSBs and higher levels of physical activity (80, 82-85). On the contrary, authoritarian and neglectful parenting styles were positively associated with child and adolescent BMI, availability of sweets and unhealthy foods at home and negatively associated with vegetable consumption and physical activity (80,86). Parental practices such as feeding styles (restriction, pressure to eat, monitoring/control of dietary intake), instrumental behaviours (use food as a reward), availability, role modeling and nutritional knowledge are associated with child eating, physical activity habits and weight status (87,88). Pressure to eat has been associated with lower child BMI whereas restriction of foods has been related to increased child weight and emotional eating (89). The intention of controlling child's feeding has been associated with both underweight and overweight during childhood. Additionally, children are more likely to consume a healthy diet and accept new foods when parents model healthy eating themselves and provide children with healthy food options (54). In a comprehensive review of physical activity correlates, one of the strongest and most consistent correlates of physical activity in children was the time spent outdoors, a factor mostly determined by parents (90). Parental encouragement, support and involvement as well as modeling of physical activity have been shown to positively predict activity in children (91).

1.6. Research gap

As already mentioned, the prevalence of childhood and adolescence obesity is escalating and has reached epidemic proportions. Obesity-related complications are being diagnosed with increasing frequency in children and in certain cases can persist in adulthood and lead to life-threatening diseases. Consequently, prevention of obesity is a critical topic whose vital component is the identification of childhood and adolescence obesity risk factors.

To our knowledge, nationally representative European wide studies collecting data on behaviours related to sociodemographic, perinatal, lifestyle factors and parental practices, as well as using a common data collection protocol, are scarce and do not allow generalizability since most of those were conducted in single countries. Moreover, a variety of risk factors of childhood and adolescence obesity has not yet been investigated.

1.7. Research question

Aiming to counteract childhood overweight/ obesity as well as develop appropriate prevention programs, risk factors that provoke this health disease need to be better investigated. Therefore, the purpose of this study is to identify the predominant correlates of children overweight and obesity, among a variety of perinatal, socio-demographic, lifestyle factors and parental practices, in a large sample of six European countries (Greece, Spain, Bulgaria, Hungary, Belgium and Finland).

2. Methods

2.1. Study design and sampling procedure

The Feel4Diabetes study (National Clinical Trial number, NCT 02393872) was a large school and community-based intervention. The purpose was to promote a healthy lifestyle including healthy eating and enhancing physical activities intending to alleviate the negative outcomes of obesity and obesity-related metabolic risk factors in vulnerable families in Europe.

Recruitment was conducted within the provinces of six European countries, including low/middle income countries (Bulgaria, Hungary), countries under austerity measures (Greece, Spain) and high income countries (Belgium, Finland). In aim to target “vulnerable” population groups at high risk of developing T2DM a standardized multi-stage sampling procedure was applied. In Bulgaria and Hungary all the municipalities were considered eligible to participate in the study, while in Belgium, Finland, Greece and Spain families only from low SES municipalities were recruited. The categorization was made according to official resources and local authorities, within each country and “vulnerable” areas were randomly selected only from the tertile with the lowest education level or the highest unemployment rate (33, 92).

After the necessary approvals were obtained from the local authorities, in the “vulnerable” areas of all countries, lists of all primary schools were created in order to randomly select and recruit children attending the first three grades of compulsory education and their families. In the screening procedure, for the identification of the “high-risk families” based on the risk possibility of developing T2DM they were invited to fill in the FINDRISC questionnaire (93). The final sample after a 20% exit rate was 11,511 families ("all families"), of which 2,230 were "high risk families", in which at least one parent had a high FINDRISC score. The design of the study started in 2015, the recruitment began in January 2016 and the initial measurements were carried out between April-June while in three countries (Finland, Hungary, Bulgaria) the measurements were carried out during August-September 2016 (92).

2.2. Ethical approvals and consent forms

The Feel4Diabetes study adhered to all the conditions set out in the Helsinki Declaration and the Council of Europe conventions on human rights and biomedicine. In all participating countries ethical clearances were obtained, before initiating the intervention, from the relevant ethical committees and local authorities. More specifically, in Belgium the study was approved by the Medical Ethics Committee of the Ghent University Hospital; in Bulgaria the study was approved by the Ethics Committee of the Medical University of Varna and the Municipalities of Sofia and Varna, as well as the Ministry of Education and Science local representatives; in Finland the study was approved by the hospital district of Southwest Finland ethical committee; in Greece the study was approved by the Bioethics Committee of Harokopio University and the Greek Ministry of Education; in Hungary the study was approved by the National Committee for Scientific Research in Medicine); and in Spain the study was approved by the Clinical Research Ethics Committee and the Department of Consumers' Health of the Government of Aragón. All parents and caregivers gave signed consent before enrolling in the study. Prior to entering the study, all parents/guardians independently completed and signed a specific consent form (92).

2.3. Measurements

Trained research assistants have transacted all the measurements using standardized procedures and calibrated portable equipment.

2.3.1 Perinatal characteristics

A structured questionnaire to collect information on children's perinatal data was developed and administered to parents via the schools. The collected data included information on maternal age at child's birth, maternal pre-pregnancy BMI, which was calculated based on the mother's self-reported weight before pregnancy and current height and was categorized as underweight, normal-weight, overweight or obese according to the WHO cut-offs (94). Also self-reported gestational weight gain, which was categorized as less, within or above the weight gain recommended by the Institute of Medicine (95), maternal smoking during pregnancy that was classified as smoking during any trimester or non-smoking throughout pregnancy, maternal diabetes during pregnancy, according to which mothers were ranked as those with pre-existing or gestational diabetes and those with a normal glycemic profile, birth weight and gestational age in order to classify infants as small for gestational age (SGA<10th percentile), appropriate for gestational age (AGA 10–89th percentile), or large for gestational age (LGA≥90th percentile) (96). Finally, children's growth from birth to 6 months, based on the change in weight-for-length z-scores (Δ z-score), which were used to classify growth velocity as slow (Δ z-score<-0.67), gradual/ normal (Δ z-score =−0.67 to +0.67), or rapid (Δ z-score>0.67) (97), breastfeeding that was used to categorize infants as those exclusively or non-exclusively breastfed during the first 6 months and time of introduction of solids that classified children as those to whom solid food was introduced before 4 months, at 4–6 months, or after 6 months.

2.3.2. Anthropometry

Height measurement was conducted without the shoes or any other clothing/object that could obstruct the procedure. The nearest tenth of a centimetre (i.e. 0.1 cm) was recorded using telescopic stadiometers: SECA 213, SECA 214, SECA 217 and SECA 225. Weight measurement was conducted with light clothing and without the shoes. The nearest 0.1 kg was recorded using electronic weight scales: SECA 813 and SECA 877. All volunteers were categorised by the BMI cut off points according to their body weight. The waist circumference measurement was conducted without any heavy or tight clothing that could change the shape of the waist. The nearest tenth of centimetre (i.e. 0.1 cm) was recorded using a non-elastic measuring tape (SECA 201) and the WHO cut-off points were used for their classification (94).

2.3.3. Socio-demographic and behavioural characteristics

Standardized questionnaires were used for collecting information about basic socio-demographic characteristics (date of birth, tribe, education level, occupation, income insecurity) along with information about the person's eating habits. Moreover, information concerning parents’ and children’s drinking, eating, physical activity, sedentary behaviors, smoking, sleep duration as well as their determinants, were self-reported using standardized questionnaires. All questionnaires were developed, validated and standardized between the participating countries before the study.

2.3.4. Diet

The usual dietary intake of the participants was evaluated via standardized questionnaires in which were included questions about the main meals, snacking habits, the frequency of consumption of particular food items (i.e., dairy, bread, fruits, vegetables, pulses, meat, fish, salty snacks, nuts/seeds, tea, coffee, soft drinks with or without sugar and alcoholic beverages) using a semi-quantitative food frequency questionnaire.

2.3.5. Physical activity

Physical activity was assessed by the parents via standardized questionnaires and physical activity monitors (pedometers or accelerometers). The questionnaires included questions regarding the frequency, intensity and type of exercise of the participant during the previous 7 days, the contribution of other people in the decision of physical activity as well as the time and the reason for adopting a sedentary life as a habit.

2.3.6. Parenting Practices

The questionnaire on parenting practices contained a variety of parenting practices, derived from previously validated questionnaires including the Parental Support for Physical Activity Scale (test-retest reliability: ICC = 0.81) (98), the Parenting Strategies for Eating and Activity Scale (99) and the Parental Feeding Style Questionnaire (test-retest reliability: ICC = 0.76–0.83) (100). In the questionnaire applied for the present study, parenting practices were specifically related to fruit consumption, physical activity, screen-time and were therefore used in the analyses. All items were assessed on a five-point Likert scale: (1) Never, (2) Mostly Not, (3) Sometimes/Sometimes Not, (4) Mostly, (5) Always. For some questions, 'Not Applicable' was an alternative answer category, for which the results were set as missing values. For all variables, a higher mean value represents a higher form of the variable.

2.4. Statistical analysis

A descriptive statistical analysis was performed by using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA), version 21.0. Continuous variables are presented as mean ± standard deviations and categorical values as proportions (%). Differences in continuous variables were assessed by parametric (One-Way Analysis of Variance) or nonparametric tests (Kruskall-Wallis), according to the distribution of the variables (Kolmogorov-Smirnoff test), while Pearson's Chi-square test was used to evaluate the differences in proportions. Univariate regression analyses were employed to examine associations between several perinatal, socio-demographic and lifestyle indices (independent variables) with childhood obesity (dependent variables). In addition, multivariate regression analyses were performed of those risk factors that were found to have a significant association with childhood obesity at the univariate level. All statistical tests were two-tailed and the level of statistical significance was set at $p \leq 0.05$.

3. Results

Table 1 displays the main characteristics of the 12211 participants enrolled in the study, of which 50.6% were girls and the 64.6% were 7-9 years old. In total, the 18.0% of all children were overweight and the 7.5% were obese.

Table 1: Characteristics of the study sample.

Variables		(%) Total sample N=12211
Sex	Boy	49.4
	Girl	50.6
Age	4-7 years	12.7
	7-9 years	64.6
	9-12 years	22.6
Region	High-income countries	26.9
	Under economic crisis countries	32.5
	Low-income countries	40.6
Weight status	Underweight/Normal weight	74.5
	Overweight	18.0
	Obese	7.5
Maternal education	< 14 years	43.7
	≥14 years	56.3
Maternal occupation	Unemployed	28.1
	Employed	71.9
Maternal weight status	Normal weight	66.8
	Overweight	22.3
	Obese	11.0
Paternal education	≤ 14 years	54.0
	> 14 years	46.0
Paternal occupation	Unemployed	13.0
	Employed	87.0
Paternal weight status	Normal weight	31.5
	Overweight	47.5
	Obese	21.0
Income insecurity	Very difficult	8.7
	Difficult	16.0
	Fairly difficult	24.8
	Fairly easy	28.7
	Easy	17.4
	Very easy	4.4

Table 2 presents the univariate associations of socio-demographic, perinatal, parental practices and lifestyle correlates with the risk of overweight/ obesity in childhood. The analysis showed that children whose mother (OR, 95% C.I. 0.85 (0.75-0.97)) or father (OR, 95% C.I.0.77 (0.68-0.88)) had ≥14 years of education had lower risk of being overweight or obese. On the contrary, maternal overweight (OR, 95% C.I.1.85 (1.64-2.09)) and obesity (OR, 95% C.I.2.53 (2.17-2.95)) as well as paternal overweight (OR, 95% C.I. 1.68 (1.47-1.92)) and obesity (OR, 95% C.I. 2.85 (2.46-3.31)) were strongly associated with offspring overweight/ obesity. Moreover, children living in Southern (OR, 95% C.I. 2.47 (2.11-2.89)) and Eastern Europe (OR, 95% C.I. 1.60 (1.38-1.86)) had higher risk of being overweight/ obesity compared to those living in Northern Europe. Concerning the perinatal factors, maternal pre-pregnancy overweight and obesity, pre-pregnancy diabetes, gestational weight gain above the IOM guidelines along with smoking during any trimester of pregnancy had a positive association with offspring overweight/ obesity. Rapid infant weight gain during the first six months according to WAZ (OR, 95% C.I. 1.37 (1.08-1.74)) and WHZ (OR, 95% C.I. 1.30 (1.04-1.63)) recommendations was strongly associated with higher overweight/ obesity risk in childhood, while poor infant weight gain (WAZ) (OR, 95% C.I. 0.57 (0.43-0.75)) was found to be protective regarding overweight/ obesity in comparison with normal weight gain. In addition, children that were born small for gestational age had lower overweight/ obesity risk while those that were born large for gestational age had a higher risk. Regarding children's lifestyle behaviours, higher fresh fruit juices consumption, breakfast omission some days during the week and the adoption of a sedentary lifestyle (lower levels of physical activity and increased screen time) were positive associated with higher overweight/ obesity risk. Surprisingly, children who consume ≥3 portions of sweets per week had a negative association with overweight/ obesity risk compared to those consuming 1/or less portions per week. Last but not least, parental practices such as limited permission of computer, mobile or tablet was negatively associated with offspring overweight/ obesity risk while rare engagement to physical activity with the child is strongly associated with higher overweight/ obesity risk compared to very often/ often.

Table 2 Univariate associations of several perinatal, socio-demographic, parental practices and lifestyle correlates (independent variables) with children's overweight/ obesity (dependent variables). Total sample N=12211

Independent variables	% of total	Odds ratio (95% confidence interval) Overweight/Obesity
Socio-demographic factors		
Maternal education		
< 14 years	43.7	1.00
≥14 years	56.3	**0.85 (0.75-0.97)**
Maternal occupation		
Unemployed	28.1	1.00
Employed	71.9	1.05 (0.93-1.18)
Maternal weight status		
Normal weight	66.8	1.00
Overweight	22.3	**1.85 (1.64-2.09)**
Obese	11.0	**2.53 (2.17-2.95)**
Paternal education		
≤ 14 years	54.0	1.00
> 14 years	46.0	**0.77 (0.68-0.88)**
Paternal occupation		
Unemployed	13.0	1.00
Employed	87.0	1.05 (0.90-1.23)
Paternal weight status		
Normal weight	31,5	1.00
Overweight	47.5	**1.68 (1.47-1.92)**
Obese	21.0	**2.85 (2.46-3.31)**
Income insecurity		
Very difficult	8.7	1.00
Difficult	16.0	0.89 (0.72-1.11)
Fairly difficult	24.8	0.98 (0.79-1.20)
Fairly easy	28.7	0.95 (0.76-1.18)
Easy	17.4	0.83 (0.65-1.06)
Very easy	4.4	0.69 (0.48-1.00)
Region		
Northern Europe (High-income countries)	26.9	1.00
Southern Europe (Under economic crisis countries)	32.5	**2.47 (2.11-2.89)**
Eastern Europe (Low-income countries)	40.6	**1.60 (1.38-1.86)**
Perinatal factors		
Maternal age at birth		
25-30 years	34.0	1.00
< 25 years	36.0	1.01 (0.72-1.44)
> 30 years	50.0	1.15 (0.93-1.42)

Maternal pre-pregnancy weight status		
Underweight/Normal weight	82.2	1.00
Overweight	13.7	**1.54 (1.19-1.99)**
Obese	4.1	**2.51 (1.57-4.00)**
Gestational weight gain		
Within IOM recommendations	33.1	1,00
Below IOM recommendations	33.9	1.09 (0.85-1.40)
Above IOM recommendations	33.0	**2.00 (2.59-2.53)**
Gestational age		
Full-term (≥ 37 weeks)	79.4	1.00
Pre-term (< 37 weeks)	20.6	1.23 (0.94-1.60)
Maternal smoking during pregnancy		
No smoking	87.6	1.00
Smoking at any trimester	12.4	**1.59 (1.20-2.10)**
Maternal diabetes		
No	94.9	1.00
Before pregnancy	0.5	**4.92 (1.31-18.38)**
Gestational diabetes	4.6	1.48 (0.97-2.24)
Infant weight gain in the first 6 months (WAZ)		
Normal	43.7	1.00
Poor (< -0,67 SD)	26.9	**0.57 (0.43-0.75)**
Rapid (> 0,67 SD)	29.4	**1.37 (1.08-1.74)**
Infant weight gain in the first 6 months (WHZ)		
Normal	45.0	1.00
Poor (< -0,67 SD)	15.8	1.01 (0.74-1.38)
Rapid (> 0,67 SD)	39.2	**1.30 (1.04-1.63)**
Birth weight for gestational age		
AGA	72.3	1.00
SGA	6.5	**0.57 (0.36-0.89)**
LGA	21.2	**1.49 (1.15-1.92)**
Breastfeeding		
Exclusive	26.3	1.00
Non-exclusive	59.6	1.26 (0.99-1.61)
Never	14.1	1.01 (0.71-1.44)
Introduction of solids		
4-6 months	62.3	1.00
< 4 months	9.4	0.90 (0.62-1.30)
> 6 months	28.4	1.17 (0.92-1.47)
Children's Lifestyle		
Fruit juices fresh consumption		
≤ 1 cups/week	36.2	1.00
> 1-3 cups/week	22.1	0.97 (0.83-1.13)
> 3 cups/week	41.7	**1.28 (1.13-1.45)**
Soft drinks diet consumption		
≤ 1 cups/week	84.6	1.00
> 1-3 cups/week	7.6	1.16 (0.94-1.42)
> 3 cups/week	7.8	1.03 (0.83-1.27)
Sweets consumption		
≤ 1 portion[1]/week	7.6	1.00
> 1-3 portions[1]/week	22.9	0.93 (0.74-1.18)
> 3 portions[1]/week	69.5	**0.75 (0.60-0.93)**

Salty snacks consumption		
≤ 1 portion[2]/week	41.1	1.00
> 1-3 portions[2]/week	33.3	0.96 (0.84-1.09)
> 3 portions[2]/week	25.7	1.12 (0.96-1.30)
Breakfast consumption		
Everyday	88.6	1.00
Not everyday	11.4	**1.37 (1.17-1.61)**
Physical activity for 1hr		
Everyday	34.9	1.00
Not everyday	65.1	**1.40 (1.24-1.58)**
Screen-time activities		
< 2 hours/day	63.9	1.00
≥ 2 hours/day	36.1	**1.23 (1.09-1.39)**
Parental practices		
Consumption of fruit with child		
Very often/Often	60.6	1.00
Sometimes	28.4	0.97 (0.86-1.10)
Rarely/Never	11.0	1.04 (0.87-1.24)
Physically active with child		
Very often/Often	41.6	1.00
Sometimes	39.5	**1.26 (1.10-1.43)**
Rarely/Never	19.0	**1.43 (1.21-1.69)**
TV watching with child		
Very often/Often	39.5	1.00
Sometimes	42.1	0.91 (0.80-1.03)
Rarely/Never	18.4	0.93 (0.80-1.09)
Allow TV or DVD watching		
Very often/Often	29.6	1.00
Sometimes	39.5	1.00 (0.86-1.18)
Rarely/Never	30.9	1.15 (0.95-1.40)
Allow use of computer, mobile or tablet		
Very often/Often	26.3	1.00
Sometimes	34.9	0.94 (0.80-1.11)
Rarely/Never	38.9	**0.81 (0.67-0.98)**
Reward with TV watching		
Very often/Often	11.8	1.00
Sometimes	25.2	0.82 (0.67-1.00)
Rarely/Never	63.0	1.00 (0.83-1.20)
Reward with physical activity		
Very often/Often	37.8	1.00
Sometimes	39.8	**0.77 (0.68-0.88)**
Rarely/Never	22.4	**0.77 (0.66-0.91)**

*Adjusted for all statistically significant lifestyle factors and parental practices, and also for maternal education, child's sex and age.
IOM: Institute of Medicine, AGA: Appropriate for Gestational Age, SGA: Small for Gestational Age, LGA: Large for Gestational Age, WAZ: weight-for-age z-scores, WHZ: Weight-for-height z-scores, SD: Standard Deviation
[1] ½ cup
[2] 1 small hamburger, 1 small bag of chips, 1 slice of pizza
Bold font indicates statistically significant OR (P < 0.05).

Table 3 displays the multivariate associations of those socio-demographic, perinatal, parental practices and lifestyle factors found to be associated with children's overweight/ obesity at the univariate level. Maternal and paternal weight status, region, maternal pre-pregnancy weight status, gestational age, maternal diabetes, birth weight and infant weight gain in the first 6 months were found to have the strongest association with offspring overweight/ obesity. More specifically, maternal overweight (OR, 95% C.I. 1.57 (1.10-2.24)) and obesity (OR, 95% C.I. 3.14 (1.89-5.22)) along with paternal overweight (OR, 95% C.I. 1.79 (1.28-2.52)) and obesity (OR, 95% C.I. 3.06 (2.08-4.51)) were associated with higher risk of overweight/ obesity in childhood in comparison with children whose parents had normal weight status. Moreover, children living in Eastern Europe (low-income countries) had a 3-fold higher risk (OR, 95% C.I. 3.79 (2.12-6.78)) of being overweight or obese, while those living in Southern Europe (under economic crisis countries) had a 6-fold higher risk (OR, 95% C.I. 6.14 (3.39-11.14)) compared to children living in Northern Europe (high-income countries). Children whose mothers before pregnancy were overweight (OR, 95% C.I. 1.45 (1.01-2.09)) or obese (OR, 95% C.I. 2.16 (1.56-3.00)) had a higher overweight/ obesity risk compared to children whose mothers were underweight/normal weight before pregnancy. Furthermore, maternal diabetes before pregnancy increased almost 7 times the risk of children's overweight/ obesity (OR, 95% C.I.6.68 (1.00-44.59)) compared to no maternal diabetes. Pre-term children who were born before the 37 weeks of pregnancy (OR, 95% C.I. 1.02 (0.71-1.47)) as well as those that were born large for gestational age (OR, 95% C.I. 1.43 (1.00-2.04)) had a higher overweight/ obesity risk compared to those that were born full-term and those that had a normal birth weight, respectively. On the contrary, children whose weight gain during the first 6 months (WAZ) was poor (< -0,67 SD) (OR, 95% C.I. 0.52 (0.36-0.75)) had a lower overweight/ obesity risk compared to those with a normal weight gain during the first 6 months.

Table 3 Multivariate associations of several perinatal, socio-demographic, parental practices and lifestyle correlates (independent variables) with children's overweight/ obesity (dependent variables). Total sample N=12211

Independent variables	% of total	Odds ratio (95% confidence interval) Overweight/Obesity
Socio-demographic factors		
Gender		
Boy	49.4	1.00
Girl	50.6	1.01 (0.77-1.33)
Age		
4-7 years	12.7	1.00
7-9 years	64.6	1.25 (0.85-1.83)
9-12 years	22.6	1.38 (0.83-2.29)
Maternal education		
≤ 14 years	43.7	1.00
> 14 years	56.3	0.96 (0.69-1.34)
Maternal occupation		
Unemployed	28.1	1.00
Employed	71.9	1.26 (0.91-1.74)
Maternal weight status		
Normal weight	66.8	1.00
Overweight	22.3	**1.57 (1.10-2.24)**
Obese	11.0	**3.14 (1.89-5.22)**
Paternal education		
≤ 14 years	54.0	1.00
> 14 years	46.0	0.95 (0.69-1.29)
Paternal occupation		
Unemployed	13.0	1.00
Employed	87.0	0.93 (0.61-1.41)
Paternal weight status		
Normal weight	31,5	1.00
Overweight	47.5	**1.79 (1.28-2.52)**
Obese	21.0	**3.06 (2.08-4.51)**
Income insecurity		
Very difficult	8.7	1.00
Difficult	16.0	0.78 (0.43-1.41)
Fairly difficult	24.8	0.91 (0.52-1.59)
Fairly easy	28.7	0.89 (0.50-1.59)
Easy	17.4	1.10 (0.57-2.12)
Very easy	4.4	1.16 (0.40-3.30)
Region		
Northern Europe (High-income countries)	26.9	1.00
Southern Europe (Under economic	32.5	**6.14 (3.39-11.14)**

crisis countries)		
Eastern Europe (Low-income countries)	40.6	**3.79 (2.12-6.78)**
Perinatal factors		
Maternal age at birth		
25-30 years	34.0	1.00
< 25 years	36.0	1.32 (0.80-2.17)
> 30 years	50.0	0.87 (0.64-1.17)
Maternal pre-pregnancy weight status		
Underweight/Normal weight	82.2	1.00
Overweight	13.7	**1.45 (1.01-2.09)**
Obese	4.1	**2.16 (1.56-3.00)**
Gestational age		
Full-term (≥ 37 weeks)	79.4	1.00
Pre-term (< 37 weeks)	20.6	**1.02 (0.71-1.47)**
Maternal smoking during pregnancy		
No smoking	87.6	1.00
Smoking at any trimester	12.4	1.02 (0.67-1.57)
Maternal diabetes		
No	94.9	1.00
Before pregnancy	0.5	**6.68 (1.00-44.59)**
Gestational diabetes	4.6	1.28 (0.74-2.19)
Infant weight gain in the first 6 months (WAZ)		
Normal	43.7	1.00
Poor (< -0,67 SD)	26.9	**0.52 (0.36-0.75)**
Rapid (> 0,67 SD)	29.4	1.24 (0.90-1.71)
Birth weight for gestational age		
AGA	72.3	1.00
SGA	6.5	0.87 (0.45-1.59)
LGA	21.2	**1.43 (1.00-2.04)**
Breastfeeding		
Exclusive	26.3	1.00
Non-exclusive	59.6	1.14 (0.79-1.63)
Never	14.1	1.08 (0.76-1.55)
Introduction of solids		
4-6 months	62.3	1.00
< 4 months	9.4	0.29 (0.77-1.33)
> 6 months	28.4	1,17 (0,92-1,47)
Children's Lifestyle		
Fruit juices fresh consumption		
≤ 1 cups/week	36.2	1.00
> 1-3 cups/week	22.1	1.30 (0.87-1.95)
> 3 cups/week	41.7	1.27 (0.88-1.82)
Soft drinks diet consumption		
≤ 1 cups/week	84.6	1.00
> 1-3 cups/week	7.6	1.20 (0.59-2.42)
> 3 cups/week	7.8	1.28 (0.69-2.35)
Sweets consumption		
≤ 1 portion[1]/week	7.6	1.00
> 1-3 portions[1]/week	22.9	1.79 (0.98-3.29)
> 3 portions[1]/week	69.5	1.26 (0.72-2.17)

Salty snacks consumption		
≤ 1 portion[2]/week	41.1	1.00
> 1-3 portions[2]/week	33.3	1.26 (0.93-1.72)
> 3 portions[2]/week	25.7	1.01 (0.68-1.50)
Breakfast consumption		
Everyday	88.6	1.00
Not everyday	11.4	1.22 (0.80-1.88)
Physical activity for 1hr		
Everyday	34.9	1.00
Not everyday	65.1	1.29 (0.94-1.78)
Screen-time activities		
< 2 hrs/day	63.9	1.00
≥ 2 hrs/day	36.1	1.06 (0.78-1.44)
Parental practices		
Consumption of fruit with child		
Very often/Often	60.6	1.00
Sometimes	28.4	1.18 (0.86-1.62)
Rarely/Never	11.0	1.10 (0.71-1.72)
Physically active with child		
Very often/Often	41.6	1.00
Sometimes	39.5	1.03 (0.74-1.43)
Rarely/Never	19.0	1.19 (0.79-1.78)
TV watching with child		
Very often/Often	39.5	1.00
Sometimes	42.1	1.00 (0.73-1.36)
Rarely/Never	18.4	1.08 (0.73-1.60)
Allow TV or DVD watching		
Very often/Often	29.6	1.00
Sometimes	39.5	0.82 (0.53-1.28)
Rarely/Never	30.9	0.75 (0.45-1.24)
Allow use of computer, mobile or tablet		
Very often/Often	26.3	1.00
Sometimes	34.9	1.10 (0.70-1.75)
Rarely/Never	38.9	1.22 (0.73-2.03)
Reward with TV watching		
Very often/Often	11.8	1.00
Sometimes	25.2	1.09 (0.64-1.85)
Rarely/Never	63.0	1.16 (0.72-1.87)
Reward with physical activity		
Very often/Often	37.8	1.00
Sometimes	39.8	0.96 (0.70-1.32)
Rarely/Never	22.4	1.14 (0.77-1.69)

*Adjusted for all statistically significant lifestyle factors and parental practices, and also for maternal education, child's sex and age.
IOM: Institute of Medicine, AGA: Appropriate for Gestational Age, SGA: Small for Gestational Age, LGA: Large for Gestational Age, WAZ: weight-for-age z-scores, SD: Standard Deviation
[1] ½ cup
[2] 1 small hamburger, 1 small bag of chips, 1 slice of pizza
Bold font indicates statistically significant OR (P < 0.05).

4. Discussion

The present study aimed to identify the predominant correlates of children overweight and obesity, among a variety of perinatal, socio-demographic, lifestyle factors and parental practices in a large sample of six European countries. It was evidenced that children from Southern and Eastern Europe and those whose parents are overweight or obese have an increased overweight/ obesity risk. Additionally, maternal overweight/ obesity and maternal diabetes before pregnancy, pre-term children and those with elevated birth weight for gestational age have a greater childhood overweight/ obesity risk. On the contrary, children that had a poor infant weight gain in the first 6 months according to WAZ have a lower childhood overweight/ obesity risk. These findings further enlighten the knowledge and can facilitate the design of cost-effective future intervention programs, appropriate to their needs aiming to impede and counteract childhood overweight/ obesity.

As already previously reported (53,56,101-103), children with at least one overweight or obese parent have greater odds of being overweight or obese. Which could be explained by genetic as well as environmental and behavioural factors since parents play a direct role in shaping children's eating and activity habits (56, 104). In a previous study performed in Greece it was also shown that parental BMI status had the greatest effect on children's BMI classification, as children with two obese parents had 11.6 times higher likelihood of being overweight or obese than their peers with normal-weight parents (105). Moreover, in another study that was conducted in 2294 schoolchildren aged 9-13 years from four Greek counties it was disclosed that maternal overweight/ obesity was associated with 25% higher childhood obesity risk while the risk was 14% higher for paternal overweight/ obesity (32). A cross-sectional study of 2274 girls and 2237 boys 7.0-9.5 years old in Portugal showed that children with an obese father had a 7-fold increase of overweight/ obesity risk while children with an obese mother had a 18-fold increase of overweight/ obesity risk (106). Many neurological and hormonal factors are implicated in weight regulation. The number of genes, factors and chromosomal markers associated with obesity has been more than 250 (107). However, besides inheritance of genes that confer susceptibility to obesity, parental overweight is also a proxy for shaping children's eating and activity environment, as they learn eating behaviours not only through their own experiences but also by their parents, who act as role models (32,101). A growing body of evidence demonstrates similarities between parents' and children's food acceptance, preferences and intake. In most cases, overweight parents create and sustain an "obesogenic" environment (high energy diets and physical inactivity) not only for themselves but also for their children (106). Finally, another possible explanation is the fact that overweight mothers misperceive their children's excess weight problems compared to normal weight mothers (108). Due to this mistaken maternal perception of offspring weight status they do not acknowledge the need to change and adopt a healthier lifestyle as the attempts to combat childhood obesity might be successful if mothers could recognize their "at risk of being overweight" children (109,110).

Regarding SES in the present study it was disclosed that children from Southern (under economic crisis countries) and Eastern Europe (low-income countries) have a greater risk of being overweight or obese in comparison with children from Northern Europe (high-income countries). More specifically, children from countries under economic crisis with austerity measurements have a two-fold risk compared to children from low-income countries. Our results come to an agreement with numerous previous studies that have investigated the association between SES and childhood overweight/ obesity (33,111,112). In a multi-centre population-based intervention study on childhood obesity that was carried out in selected regions of eight European countries comprising Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden, it was shown that SES, characterized by parents education, occupation and income had an inverse association with the prevalence of childhood overweight (113). In the Toy-box study, that was conducted in 7554 preschool children 3.5-5.5 years old and their parents in six European countries (Belgium, Bulgaria, Germany, Greece, Poland and Spain), it was revealed that the prevalence of overweight/obesity was higher in Southern/Eastern European countries compared to Central/North European countries and higher prevalence was recorded among "low-SES" families (53). Finally, in another cross-sectional study in which 18745 children from eight European countries participated revealed that the combined prevalence of overweight/ obesity ranges from more than 40% in Southern Europe to less than 10% in Northern Europe (51). Low SES may be associated with poorer diet quality as a recent review showed that the consumption of refined grains and added fats has been associated with lower SES, whereas the consumption of lean meats, fish, whole grains, low-fat dairy products and fresh vegetables and fruit has been associated higher SES (114). Another review revealed that children from low SES families eat fewer family meals, are more likely to skip breakfast and to be food-insecure, have parents with less authoritative feeding practices or parents that are less concerned about their weight, have less available healthy foods at home and less healthy food habits. Moreover, they are more likely to eat fast food and SSBs more often during the week and finally they have excess screen time and are less physically active (115).

With regard to maternal weight status before pregnancy in the current study we revealed that children with overweight or obese mothers before pregnancy have an increased overweight/ obesity risk compared to children with underweight or normal weight mothers before pregnancy. Previous studies, reviews and meta-analyses have confirmed that higher maternal pre-pregnancy BMI increases the risk of childhood overweight/ obesity (31,44,46,116). The Avon Longitudinal Study of Parents and Children in the United Kingdom conducted in 8234 children, with a mean age of 7 years old, disclosed that maternal pre-pregnancy obesity was associated with offspring obesity (117). A meta-analysis of 45 studies found that, compared to women with normal BMI, pre-pregnancy maternal overweight/ obesity increased the risk of overweight and obesity in offspring from infancy to adolescence (118). Another meta-analysis of 20 studies indicated that, compared to infants of women with normal pre-pregnancy BMI, infants born to overweight and obese women had higher fat mass and percent of body fat (119). The relationship of maternal overweight/ obesity with greater offspring adiposity may be mediated by increased DNA methylation (36). Earlier studies have shown a positive association between mother's pre-pregnancy abdominal obesity and child's subcutaneous and visceral fat (32,33,120). Overweight and obese pregnant women are more likely to have insulin resistance, even those with normal glucose tolerance, compared to their normal weight counterparts (33). Subsequently, that intrauterine exposure to an excess of fuels such as glucose and lipids and their disturbed regulation causes permanent fetal changes and creates an adverse metabolic status (121).

Furthermore, maternal pre-pregnancy diabetes was associated with a greater offspring overweight/ obesity risk. Previous studies verify the present outcome as in a systematic review and meta-analysis of twenty observational studies it was shown that the offspring of T1DM mothers had significantly higher BMI z-scores from pre-pubertal to adolescence than offspring of non-diabetic mothers independently of maternal obesity. It was also revealed that BMI z-scores of the offspring of T1DM mothers were significantly higher than those of controls and this means the intrauterine exposure to hyperglycemia can affect directly offspring higher BMI z-scores despite hereditary determinants (122). Moreover, there is evidence that the long-term consequences of exposure to diabetes in utero on future obesity are independent of mother's diabetes type (123,124). The underlying mechanisms that increase the risk of offspring overweight/ obesity are not fully understood. Firstly, exposure to maternal diabetes is associated with excess fetal growth in utero, that may be due to an elevation in fetal fat mass and alterations of fetal hormones (125-127). Moreover, the fetal hyperinsulinemia, caused by high maternal glucose levels may not only be transported excessively to the fetus, but also can impact the fetal pancreas, causing β-cell hyperplasia and hypersensitivity. Fetal insulin that acts as a growth hormone, leads to LGA and subsequently to later childhood obesity development (128).

Regarding other perinatal factors, in the current study it was shown that pre-term (<37 weeks) children and those that had an increased birth weight, have a greater overweight/ obesity risk in comparison with children that were full-term (≥37 weeks) and had a normal birth weight, respectively. Our results are consistent with those of previous cohort studies which indicated that premature birth and high birth weight are associated with overweight/ obesity during childhood (31, 40, 129, 130). The WHO European COSI study that was conducted in 22 European countries in children 6-9 years old revealed that a high birth weight was also associated with a higher risk of being overweight and higher odds of being obese were also observed in cases of pre-term birth (42). However, there are several studies reporting a 'U'-shaped relationship between birth weight and childhood overweight, thereby proposing a more composite association between fetal size at birth and obesity later in life. Population-based studies and systematic reviews have identified that high birth weight (>4,000g) is associated with a greater risk of obesity while low birth weight (<2,500g) leads to abnormal fetal development and in a rapid catch-up growth in early infancy, that results in higher fat mass later in life (131, 132). The relationship between these perinatal factors and later obesity may be attributed to disturbances during critical periods of development (such as intrauterine growth and infancy), which may provoke permanent metabolic, physiological and structural adaptations (42,44,133). Moreover, regarding pre-term birth, a study that was conducted in 38 infants born ≤32 weeks and 29 full-term infants disclosed that the pre-term infants had a highly significant decrease in subcutaneous adipose tissue and significantly increased intra-abdominal adipose tissue that may lead to future overweight/ obesity (134).

Last but not least, in the present study a lower risk of childhood overweight/obesity was reported for children with poor infant weight gain in the first 6 months in comparison with children that had a normal infant weight gain. To the best of our knowledge, there is a lack of relevant studies investigating the association of poor infant weight gain. On the contrary, rapid weight gain in the first year of life has consistently been associated with an increased risk of obesity in childhood (135-137). In a meta-analysis and systematic review of 19 retrospective and prospective studies it was found that accelerated weight gain was a critical risk factor for childhood obesity and more specifically, in preterm infants, accelerated weight gain significantly increased the risk of obesity in middle childhood (8-11 years old). Although the mechanism by which rapid weight gain leads to childhood obesity is yet unclear, several hypotheses have been proposed, including perinatal programming, genetic factors, nutritional factors, parental feeding practices, and others (138). In addition, Baird et al. in a systematic review observed that the relative risks of obesity in infants growing more rapidly in the first year compared to those who had a more slowly growth ranged from 1.06-5.70 (135). The effect of early growth on later body composition has also been investigated. Particularly, studies that have focused on the first six months of life as is the period that body mass gain is primarily gain in fat mass, while fat free mass increases after this age, have shown that rapid weight gain from birth to 5 months is associated with higher fat mass, but not fat free mass (139). It should be noted that in certain population groups, such as SGA, intrauterine growth restriction or pre-term infants, rapid weight gain or catch-up growth is considered beneficial in terms of morbidity and mortality in the short term, but increases the risk of chronic diseases later in life. After the first year of life when the adipose tissue is growing, there is a slimming of the child until 6 years of age. Then the adipose tissue starts to increase relatively again and this is named as the adiposity rebound (140). A very early adiposity rebound is considered a determinant of obesity at later ages (141).

To the best of our knowledge, this is the first study that examines childhood overweight/ obesity in the viewpoint of several perinatal, socio-demographic, lifestyle factors and parental practices, in a very large sample of six European countries. This study has certain strengths and weaknesses. The large study sample, the standardized protocols and procedures followed across all centers and the objectively collected data (i.e. anthropometric indices) ensure more objective and reliable assessment and improve the generalizability of the findings. Inversely, most of the collected data is self-reported thus prone to recall and social desirability bias. Additionally, due to the cross-sectional design of the present analysis, no temporal relationship and hence causal inferences can be established. Despite the limitations mentioned above, the reported findings deserve further attention for the development of effective strategies to fight childhood overweight/ obesity.

5. Conclusion

After assessing various perinatal, socio-demographic, lifestyle factors and parental practices, parental overweight/ obesity, living in low-income and countries under crisis, maternal diabetes and maternal overweight/ obesity before pregnancy, premature birth and high birth weight remained the main significant predictors of childhood overweight and obesity. On the contrary, poor infant weight gain in the first six months seems to have a protective effect on that risk.

Subsequently, childhood overweight and obesity is an alarming public health problem worldwide, to which a variety of different factors may have a pivotal role like the perinatal and socio-demographic characteristics. Therefore it is recommended that health promotion strategies and intervention programs should be family oriented, to increase awareness of the cardinal role of parental behavior regarding childhood overweight/obesity and to highlight the importance of its prevention before gestation.

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