

The temporal relationship between socioeconomic vulnerability, dietary intake and childhood obesity: longitudinal results from the Feel4Diabetes-study

Lubna Mahmood

University of Zaragoza

Guiomar Masip

University of Zaragoza

Luis A. Moreno

lmoreno@unizar.es

University of Zaragoza

Peter Schwarz

University of Dresden

Lena Roth

University of Dresden

Maxi Bretschneider

University of Dresden

Ruben Willems

Ghent University

Greet Cardon

Ghent University

Violeta Iotova

Medical University of Varna

Natalya Usheva

Medical University of Varna

Tsvetalina Tankova

Medical University of Sofia

Eva Karaglani

Harokopio University

Yannis Manios

Harokopio University

Esther M. Gonzalez-Gil

University of Zaragoza

The Feel4Diabetes -Study Group

Research Article

Keywords: Socioeconomic vulnerability, children, dietary intake, obesity, Europe

Posted Date: April 2nd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9159464/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at European Journal of Pediatrics on September 16th, 2026. See the published version at <https://doi.org/10.1007/s00431-026-07415-2>.

Abstract

Purpose

To examine the temporal relationship between socioeconomic vulnerability, dietary intake, and childhood obesity in European children using longitudinal data.

Methods

1,796 parent–child dyads from the control group of the Feel4Diabetes study in six European countries were assessed at baseline (2016) and two follow-ups (2017, 2018). Socioeconomic vulnerability was measured using a cumulative index of parental education, employment, and income security. Children's dietary intake was reported by parents via a food frequency questionnaire, and BMI z-scores were objectively measured. Cross-lagged panel models tested temporal relationships between socioeconomic vulnerability and dietary intake, while moderation analyses assessed if diet moderated the socioeconomic vulnerability–BMI relationship.

Results

Higher socioeconomic vulnerability predicted poorer dietary patterns over time, with lower intake of meat ($\beta = -0.100$) and fruits, vegetables, legumes ($\beta = -0.119$), and higher consumption of salty snacks ($\beta = 0.129$) and sweets/sweetened beverages ($\beta = 0.084$, all $p < 0.001$). Reverse diet-to- socioeconomic vulnerability associations were mostly non-significant. Meat intake also moderated the baseline socioeconomic vulnerability–BMI association (interaction $p < 0.05$).

Conclusions

Socioeconomic vulnerability influences children's dietary behaviors and contributes to obesity risk over time. These findings underscore the need for public health interventions targeting vulnerable populations to improve diet quality and reduce health disparities.

Trial registration:

The Feel4Diabetes-study is registered with the clinical trials registry (NCT02393872), <http://clinicaltrials.gov>

What is Known

1. Childhood obesity remains a major public health concern, with socioeconomic inequalities influencing both dietary behaviors and obesity risk.
2. Previous research has shown associations between socioeconomic status and diet or obesity, but limited evidence exists on their temporal and longitudinal interrelationships in children.

What is New:

1. This study provides longitudinal evidence that socioeconomic vulnerability precedes and predicts unfavourable dietary patterns in children over time.
2. It demonstrates that these diet-related inequalities contribute to the development of childhood obesity, highlighting a temporal pathway linking socioeconomic vulnerability, diet, and obesity risk.

Introduction

Childhood obesity remains a major public health issue with important implications for long-term health, including elevated risks of cardiometabolic disease, type 2 diabetes, and other comorbidities later in life [1]. Among the determinants of childhood obesity, the imbalance between energy intake and expenditure is a key driver. In particular, a significant contributing factor is nutrition, especially the excessive consumption of foods rich in calorie density, as well as environmental and hereditary variables, low levels of physical activity, and high levels of sedentary behavior [1].

In this regard, research on school-age children has repeatedly revealed suboptimal nutritional intake, which is typified by a high intake of processed foods, sugar-sweetened drinks, and snacks, and a low intake of fruits, vegetables, and legumes [1,2]. Nonetheless, recent research [3,4] has indicated that there are significant socioeconomic vulnerabilities that may affect weight status and nutrition. For instance, the Childhood Obesity Surveillance Initiative (COSI) in the European area discovered that children from homes with jobless parents or parents with lower levels of education were more likely to have overweight or obesity, albeit these correlations differed significantly between nations [3,4]. In line with these findings, an increasing amount of research [2,5,6] shows that a higher risk of childhood obesity is linked to less favourable dietary patterns, such as consuming more ultra-processed foods and fewer nutrient-rich foods, as well as greater socioeconomic vulnerability. Therefore, it is crucial to concentrate on the interactions between childhood weight trajectories, food consumption, and socioeconomic vulnerability.

Socioeconomic vulnerability is the reduced capacity of individuals, households, or communities to withstand, cope with, and recover from external stressors such as pandemics, natural disasters, or economic crises. This cross-cutting concept is used in geography, public health, sociology, and disaster studies. Even though it is often understood to indicate that one is at danger of harm or loss, vulnerability is mostly socially created and impacted by underlying differences in housing, employment, education, income, and access to resources. These structural components affect risk exposure as well as the ability to respond and recover [6–8]. Although prior research has shown some connections between food

quality, weight status, and socioeconomic risk, there are still a number of significant gaps [6–8]. First, the ability to infer temporal sequences is limited by the fact that many research use cross-sectional designs or short follow-up periods [7]. Second, despite the growing recognition of the importance of the concept of cumulative socioeconomic vulnerability, few longitudinal studies have specifically measured how these vulnerabilities work to affect dietary patterns over time and how those behavioral changes may affect weight trajectories. Third, much less research has jointly modelled the mediating or moderating role of dietary intake in the socioeconomic vulnerability–childhood obesity pathway in a longitudinal framework. This is because the majority of existing research has tended to treat diet and socioeconomic vulnerability as independent predictors of obesity. Fourth, the majority of extensive multi-country European research have focused on weight status or food consumption by nation, but less frequently on the interplay between diet, obesity, and socioeconomic susceptibility across time.

In light of the above, this study aims to examine the cumulative socioeconomic vulnerabilities and their association with dietary intake and obesity levels in European children, using longitudinal data from the Feel4Diabetes study. By exploring the temporal relationship between dietary intake and childhood obesity while considering socioeconomic vulnerability, this study addresses existing research gaps and contributes evidence to inform early prevention strategies for socioeconomically disadvantaged families.

Methods

Study Design

The Feel4Diabetes study is a large-scale European cluster randomized study designed to prevent obesity and its related comorbidities by promoting healthier lifestyles among 11,396 families across six countries. These countries were classified into three economic categories: high-income (Belgium and Finland), countries affected by austerity measures following the economic crisis (Greece and Spain), and low-income (Bulgaria and Hungary). The study targeted children in the first three grades of primary school and their parents, with data collected at baseline in 2016 and follow-up assessments conducted in 2017 (T1) and 2018 (T2). A detailed description of the study protocol has been published previously [9]. The project is registered in the <http://clinicaltrials.gov> database (NCT02393872).

All study procedures complied with the ethical standards outlined in the Declaration of Helsinki and the Council of Europe Convention on Human Rights and Biomedicine. Ethical approval was obtained from the appropriate committees and authorities in each participating country: Belgium (B670201524237), Finland (174/1801/2015), Greece (46/3-4-2015), Spain (CP03/2016), Hungary (20095/2016/EKU), and Bulgaria (52/10-3-2015). Written informed consent was secured from all participants prior to their inclusion in the study.

Study Sample

For this study, *parent-child dyads* were included. All dyads with full anthropometric measurements and completely filled-out questionnaires for both, the parent and the child, at baseline, T1, and T2 were considered eligible. Since some families participated with more than one child, we randomly selected one child per family in order not to duplicate parental information.

To avoid potential bias introduced by the intervention and to preserve the natural observational associations between exposure and outcome, analyses were restricted to participants in the control group. Only data from the same parent-child dyad that were available at baseline, T1, and T2 were included because of the longitudinal nature of the study. Out of the 2,748 families identified and measured at baseline from the control group, 1,796 *parent-child dyads* had complete data at both time points and were included in this study.

Socioeconomic vulnerability

In the Feel4Diabetes project, sociodemographic characteristics were obtained using standardized and validated questionnaires designed specifically for the study. Collected data included information on the child's age and sex, as well as details on parental education, employment status, and household income security. Parental education was initially recorded in six categories (<6, 7–9, 10–12, 13–14, 15–16, and >16 years of schooling) and subsequently recoded into two groups: ≤ 12 years (up to completion of secondary education) and >12 years. Employment status, originally classified into homemaker, full-time, part-time, unemployed, student, or retired, was later dichotomized into *unemployed* (including homemakers and unemployed) and *employed* (including all other categories).

Household income security was assessed through a qualitative question asking parents how easily they managed household expenses, rated on a six-point Likert scale from *very difficult* to *very easy*. For analysis, responses were grouped into *difficult* versus *easy*. Maternal and paternal education and employment were evaluated separately, whereas household income security was considered at the family level. Five dichotomized indicators—maternal education, paternal education, maternal occupation, paternal occupation, and household income security—were used to construct the socioeconomic vulnerability index. Each indicator was assigned a value of 1 if the condition of vulnerability was present and 0 otherwise. For instance, if either parent had ≤ 12 years of education, the child had 1 point for that indicator; if both parents exceeded 12 years, the point achieved was 0. The same procedure was applied for occupational status. The total number of vulnerabilities was then used to create SES vulnerability categories, ranging from 0 (no vulnerabilities) to 5 (highest vulnerability), reflecting the cumulative burden of socioeconomic disadvantages within each family.

Dietary Assessment

A semi-quantitative food frequency and eating behavior questionnaire was provided to families, that one parent completed at home. The questionnaire gathered information on the children's frequency of consuming breakfast, grains, fresh fruits, vegetables, legumes, red meat, poultry, fish and seafood, dairy products, savory snacks (e.g., croissants and cheese pie), sweets (e.g., pancakes, cookies, or

chocolates), and soft drinks. For the dietary intake of other food items, parents were asked: "How many servings of (item) does your child eat?" They could then choose from the following options: "One or less than one serving per week," "2 servings per week," "3-4 servings per week," "5-6 servings per week," "1-2 servings per day," "3-4 servings per day," or "5 or more servings per day." The portion size for each food item was defined using household units. For example, one serving of fresh fruit was equivalent to a medium-sized fruit (e.g., one apple = 90 grams), two small fruits (e.g., apricots), or half a cup of chopped fruit or berries. Responses ranged from "less than one serving per week" to "5 or more servings per day". In this study, the foods were regrouped for analysis purposes to 7 groups including "milk and milk products", "grains", "fruits, vegetables, and legumes", "red meat and poultry", "fish and seafood", "salty snacks", "sweets, and sugar sweetened-beverages".

Anthropometric Measurements

Anthropometric measurements were conducted according to standardized protocols [10]. In children, weight was measured by Seca 813 digital flat scale and recorded to the nearest 0.1 kg, and standing height was measured by Seca 217 stadiometer for mobile height measurement and recorded to the nearest 0.1 cm. Height and weight were measured while children were barefoot and with the head in the Frankfurt plane with light clothing. The BMI of parents and children was calculated by dividing body weight (kg) to height squared (m^2). Parental BMI was calculated based on their self-reported weight and height, while, children's BMI was calculated based on their objectively weight and height which were measured at schools by trained researchers. Two readings were obtained for each measurement and the mean was used for the analysis. BMI z-scores were calculated for children according to Cole et al. [11] to obtain an optimal measure for their weight in accordance with their sex and age, the International Obesity Task Force (IOTF) cut-off points were used to categorize children as having "normal weight", "overweight", or "obesity".

Statistical Analysis

Descriptive data on participants' characteristics are presented as percentages or means for categorical or continuous variables, respectively. Kolmogorov-Smirnov test was used to check the distribution of the included variables. We conducted cross-lagged path models (CLPM) within a structural equation modelling framework to examine the temporal associations between socioeconomic vulnerability and children's dietary intake across the three study waves. The food group variables included fruits, vegetables and legumes; sweets and sugar-sweetened beverages; salty snacks; red meat and poultry; fish and seafood; dairy; and grains. Prior to estimating the CLPM, socioeconomic vulnerability and each dietary intake variable were regressed on child age and sex (Model 1), and additionally on maternal age, maternal BMI, and country (Model 2). The standardized residuals obtained from these regressions were used in the CLPM analyses. The presence of related siblings within the dataset was accounted for by applying survey methods with robust standard errors using cluster variance estimators. Model fit was evaluated using established goodness-of-fit criteria, including a Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) ≥ 0.90 , and a Root Mean Square Error of Approximation (RMSEA) close to 0.06.

To examine whether food groups' consumption moderated the association between socioeconomic vulnerability at baseline and BMI at follow-up 2, moderation analyses were conducted using generalized linear regression models. An interaction term between baseline socioeconomic vulnerability and meat consumption at follow-up 1 was included in the models. Analyses were performed for the overall sample and stratified by child sex. Two models were fitted: Model 1 was adjusted for child age at baseline and sex (except in sex-stratified analyses), and Model 2 was additionally adjusted for mother's BMI, mother's age at baseline, and country of residence. The same covariate structure used in the cross-lagged analyses was applied. A statistically significant interaction term was interpreted as evidence of moderation.

The statistical analyses were carried out using IBM-SPSS (Version 26.0. Armonk, NY: IBM Corp, USA) and R-studio (v3.2), with a $p < 0.05$ representing statistical significance for all tests.

Results

Characteristics of the study participants

A total of 1,796 parent-child dyads were analyzed, as shown in **Table 1**. The average age of the children was 8.21 years (SD 0.9), while the average age of the parents was 38.6 years (SD 2.8). 49.2% of the children were female, while 87.7% of the parents were female. The majority of parents were married (62.7%), worked (89.7%), and had more than 12 years of schooling (76.7%). In terms of household economic security, 61.3% of households said it was simple to satisfy their demands. While smaller percentages were spread throughout higher vulnerability categories, with 3.5% falling into the highest group (group 5), more than half of the sample (51.4%) showed no socioeconomic vulnerability (Category 0). Belgium (24.1%) and Greece (21.4%) had the highest percentages of participants, followed by Spain (13.5%), Finland (13.3%), Hungary (13.3%), and Bulgaria (14.4%). Participants were recruited from six European nations. According to BMI categorization, 72.3% of children and 77.6% of parents were normal weight, but 22.4% of parents and 27.7% of children were having overweight or obesity. Children's mean BMI z-score was 0.72 (SD 1.1).

Prospective associations between socioeconomic vulnerability and dietary intake

For every food group, the cross-lagged panel models showed a satisfactory model fit (**Figure 1**). Excellent fit indices (CFI range: 0.996–0.998; TLI range: 0.995–0.997; RMSEA range: 0.033–0.045; SRMR range: 0.005–0.014; all $\chi^2 p < 0.001$) were found in the partially adjusted model (Model 1; adjusted for child age and sex) (**Table 2**). The completely adjusted model (Model 2; further adjusted for nation, maternal age, and maternal BMI) again demonstrated acceptable to good fit for all food categories (all $\chi^2 p < 0.001$), with CFI ranges of 0.982–0.996, TLI ranges of 0.969–0.994, RMSEA ranges of 0.032–0.073, and SRMR ranges of 0.013–0.034 (**Table 4**).

Socioeconomic vulnerability at Wave 2 and food consumption at Wave 3 were the main temporal relationships found in Model 1 (**Table 3**). Lower intake of meat ($\beta = -0.100$, SE = 0.023, 95% CI: -0.144 to

-0.051, $p < 0.001$) and fruits, vegetables, and legumes ($\beta = -0.119$, $SE = 0.026$, 95% CI: -0.181 to -0.076, $p < 0.001$) was linked to higher SEV. On the other hand, higher SEV was linked to increased consumption of salty snacks ($\beta = 0.129$, $SE = 0.023$, 95% CI: 0.060 to 0.153, $p < 0.001$) and sweets and sugar-sweetened drinks ($\beta = 0.084$, $SE = 0.024$, 95% CI: 0.035 to 0.130, $p < 0.001$).

Fish and seafood, dairy products, and cereals did not show any significant temporal relationships with SEV (all $p > 0.05$). Sweets ($\beta = 0.036$, $p = 0.027$) and salty snacks ($\beta = 0.071$, $p < 0.001$) showed minor impacts, while the reverse cross-lagged pathways (dietary intake linked to subsequent SEV) were generally not significant. Model 1 and the fully modified model's results were mainly in agreement (**Table 5**). Lower intake of meat ($\beta = -0.100$, $SE = 0.023$, 95% CI: -0.144 to -0.051, $p < 0.001$) and fruits, vegetables, and legumes ($\beta = -0.118$, $SE = 0.027$, 95% CI: -0.118 to -0.076, $p < 0.001$) was significantly correlated with higher SEV at Wave 2. Conversely, higher SEV was linked to increased consumption of salty snacks ($\beta = 0.129$, $SE = 0.023$, 95% CI: 0.061 to 0.154, $p < 0.001$) and sweets and sugar-sweetened drinks ($\beta = 0.084$, $SE = 0.024$, 95% CI: 0.035 to 0.130, $p < 0.001$).

Fish and seafood, dairy products, and cereals did not show any significant temporal relationships (all $p > 0.05$). Sweets ($\beta = 0.036$, $p = 0.027$) and salty snacks ($\beta = 0.071$, $p < 0.001$) showed minor but statistically significant relationships with subsequent SEV, but overall, the reverse directed routes from food consumption to subsequent SEV were non-significant. These correlations were not consistently seen across dietary groups, though, and their size was moderate. Overall, the results show that rather than the other way around, socioeconomic vulnerability occurs before later dietary consumption.

Moderation of the association between socioeconomic vulnerability and children's BMI by food groups' consumption

In the whole sample, the relationship between children's BMI at follow-up 2 and baseline socioeconomic vulnerability was significantly mitigated by meat intake at follow-up 1 (interaction $p < 0.05$). Over time, the correlation between BMI and socioeconomic vulnerability was reinforced by higher meat intake. No significant interactions were found, despite testing additional dietary categories as possible moderators. Girls but not boys showed this moderating impact when analyses were stratified by sex. The results were true for both fully and minimally adjusted models (**Figure 2**).

Discussion

In this longitudinal study involving 1,796 European children from the Feel4Diabetes control group-cohort, we discovered that increased socioeconomic vulnerability was consistently linked to less favorable dietary intake over time, characterized by higher consumption of sweets and salty snacks and reduced intake of FV, legumes, and meat. Furthermore, diet did not precede subsequent socioeconomic vulnerability. Moreover, meat consumption moderated the prospective relationship between socioeconomic vulnerability and children's BMI, particularly among girls, indicating that dietary context can affect obesity risk within socioeconomically vulnerable populations.

Our results corroborate the hypothesis that socioeconomic disadvantage affects children's dietary behaviors over time. Children classified in higher vulnerability categories exhibited a greater propensity to increase their consumption of energy-dense, low-nutrient-dense foods while simultaneously decreasing their intake of nutritious foods, such as fruits and vegetables, across successive waves, even after controlling for potential confounding variables. This is in line with earlier studies that found that children with low socioeconomic status (SES) tend to eat less fruit and vegetables and more energy-dense snacks and sweets [12,13,14].

Numerous European samples have shown socioeconomic disparities in dietary quality, with disadvantaged children consuming more ultra-processed and high-energy foods [15,16,17]. These patterns are thought to be caused by socioeconomic factors, such as limited access to nutritious foods and limitations in household resources [18,19]. Furthermore, these disparities may be exacerbated by lower parental educational attainment because poor health literacy and nutrition knowledge can affect meal planning, food choices, and the importance of dietary quality in households [15–19]. Importantly, our study provides longitudinal evidence that socioeconomic vulnerability prospectively shapes dietary intake rather than the other way around, despite some cross-sectional research suggesting concurrent associations between SES, diet, and weight [20,21]. This is consistent with social causation models of dietary risk, which postulate that long-term risk for obesogenic eating behaviors is increased by material and educational constraints that limit the selection of healthy foods [12,13,17]. Our cross-lagged models' strong stability paths align with research that demonstrates dietary patterns that persist throughout childhood [16,22]. High energy density diets started early in childhood tend to last and are linked to increases in adiposity through mid-childhood and adolescence, according to a prior cohort study [12]. By showing how early socioeconomic vulnerability affects later unhealthy dietary patterns over time, our results build on these findings.

Socioeconomic disadvantage has been associated with increased risks of childhood overweight and obesity, which is consistent with the evidence currently available [13,23,24]. Low SES is generally linked to higher adiposity in children living in high-income countries [24], and longitudinal analysis in US birth cohorts has demonstrated that lower SES is associated with higher odds of overweight/obesity throughout early childhood [13]. Although we did not directly estimate total energy intake, our findings indirectly support these associations: the observed socioeconomic gradients in diet, favoring lower-quality foods, probably contribute to cumulative energy imbalance and excessive weight gain over time.

Evidence that meat consumption moderated the prospective relationship between socioeconomic vulnerability and BMI, especially in girls, is a novel aspect of this study. This result is consistent with some epidemiologic data linking later adiposity outcomes to higher meat consumption. In particular, although based on a small body of research, meta-analytic evidence indicates that increased meat consumption may raise the risk of overweight/obesity in children and adolescents [17,25,26]. Higher poultry consumption may also be linked to increased body fat accumulation into adolescence, according to prospective data from European birth cohorts [26]. Our sample's sex-specific findings are consistent with other long-term dietary patterns that affect the development of adiposity in boys and girls in

different ways [27]. Higher early-life animal protein intakes have been biologically associated with faster growth and higher BMI trajectories in certain cohorts [28]. Higher meat consumption may be a reflection of diets high in energy and saturated fats in socioeconomically vulnerable contexts where overall dietary quality is low, which can exacerbate weight gain when paired with other unhealthy eating habits [28]. On the other hand, although controlling for significant confounders in our models probably reduces the likelihood, meat consumption may serve as a stand-in for other lifestyle factors that are not directly measured.

The need to take into account sex differences in the aetiology of obesity is highlighted by the stronger moderation effect of meat consumption in girls. Dietary patterns and adiposity have been linked to sex bias in previous longitudinal studies. For example, "refined grain snack" patterns have been shown to predict higher waist circumference z scores and obesity risk in girls but not in boys [27]. Future studies should look into the underlying mechanisms of these differential susceptibilities, which may be influenced by biological, behavioural, and social factors.

In order to improve dietary intake and prevent obesity, our findings highlight the significance of addressing socioeconomic disparities. Dietary interventions could change the course of unhealthy eating patterns before they become ingrained in families that are socioeconomically vulnerable. It is especially necessary to implement school-based and community-based nutrition programs that increase access to fruits, vegetables, and other foods high in nutrients [16, 29]. The link between socioeconomic vulnerability and obesogenic diets and unfavourable weight outcomes may be broken by policies that lower financial barriers to nutritious foods and provide nutrition education to carers [18,19].

There are many limitations to the current investigation. First, children's data were based on parental reports, which may introduce bias. Second, results that are socially acceptable may result from self-reported data. BMI was used to assess body composition, but it may not accurately reflect body fat compared to other methods like skinfold thickness or bioimpedance analysis. The frequency of particular meals was the main focus of the study; food preparation techniques were not taken into account. The results might not apply to all EU member states because the sample was taken from specific areas within each nation. Lastly, even after controlling for a number of variables, there is still a chance of residual confounding because our research did not account for certain important variables, including cultural norms, children's physical activity levels, sedentary habits, and other lifestyle or environmental factors. However, strengths include its longitudinal design across multiple European countries, standardized anthropometric measurements by trained researchers, a large sample from six European countries, and robust statistical modelling of bidirectional influences, and adjustment for relevant confounders. Future work should integrate objective measures of diet quality and energy balance markers, as well as explore mechanisms underlying sex differences in dietary moderation [21,30,31].

Conclusion

In conclusion, this longitudinal study show that socioeconomic vulnerability precedes and shapes children's dietary intake over time. Children from more vulnerable families were more likely to adopt unhealthy dietary patterns, characterized by higher consumption of sweets and salty snacks and lower intake of fruits, vegetables, legumes, and meat. Furthermore, meat consumption strengthened the association between socioeconomic vulnerability and BMI, particularly among girls, highlighting the complex interplay between social disadvantage, diet, and obesity risk. These findings emphasize the need for targeted public health strategies that address socioeconomic inequalities as a fundamental driver of unhealthy eating behaviors. School- and community-based interventions should prioritize vulnerable families to prevent the persistence of dietary disparities and reduce childhood obesity inequalities across Europe.

Abbreviations

BMI	
Body Mass Index	
CFI	
Comparative Fit Index	
CI	
Confidence interval	
CLPM	
Cross-lagged Path Models	
COSI	
Childhood Obesity Surveillance Initiative	
FV	
Fruit and Vegetables	
IOTF	
International Obesity Task Force	
RMSEA	
Root Mean Square Error of Approximation	
SD	
Standard deviation	
SE	
Standard error	
SES	
Socioeconomic Status	
SEV	
Socioeconomic Vulnerability	
zBMI	
BMI z-scores	

Declarations

Acknowledgments:

The Feel4Diabetes study was funded by the European Union's Horizon 2020 research and innovation programme under grant agreement n° 643708. We also thank the Feel4Diabetes study group members and all participating schools, parents, children, and those involved in data collection and processing.

Members of the Feel4Diabetes-study Group:

Coordinator: Yannis Manios; **Steering Committee:** Yannis Manios, Greet Cardon, Jaana Lindström, Peter Schwarz, Konstantinos Makrilakis, Lieven Annemans, Winne Ko.

Harokopio University (Greece): Yannis Manios, Kalliopi Karatzi, Odysseas Androutsos, George Moschonis, Spyridon Kanellakis, Christina Mavrogianni, Konstantina Tsoutsouloupoulou, Christina Katsarou, Eva Karaglani, Irini Qira, Efstathios Skoufas, Konstantina Maragkopoulou, Antigone Tsiafitsa, Irini Sotiropoulou, Michalis Tsolakos, Effie Argyri, Mary Nikolaou, Eleni-Anna Vampouli, Christina Filippou, Kyriaki Apergi, Amalia Filippou, Gatsiou Katerina, Efstratios Dimitriadis.

Finnish Institute for Health and Welfare (Finland): Jaana Lindström, Tiina Laatikainen, Katja Wikström, Jemina Kivelä, Päivi Valve, Esko Levälahti, Eeva Virtanen, Tiina Pennanen, Seija Olli, Karoliina Nelimarkka.

Ghent University (Belgium), Department of Movement and Sports Sciences: Greet Cardon, Vicky Van Stappen, Nele Huys, Department of Public Health: Lieven Annemans, Ruben Willems, Department of Endocrinology and Metabolic Diseases: Samyah Shadid.

Technische Universität Dresden (Germany): Peter Schwarz, Patrick Timpel.

University of Athens (Greece): Konstantinos Makrilakis, Stavros Liatis, George Dafoulas, Christina-Paulina Lambrinou, Angeliki Giannopoulou.

International Diabetes Federation European Region (Belgium): Winne Ko, Ernest Karuranga. **Universidad De Zaragoza (Spain):** Luis Moreno, Fernando Civeira, Gloria Bueno, Pilar De Miguel-Etayo, Esther M^a Gonzalez-Gil, María L. Miguel-Berges, Natalia Giménez-Legarre; Paloma Flores-Barrantes, Aleli M. Ayala-Marín, Miguel Seral-Cortés, Lucia Baila-Rueda, Ana Cenarro, Estíbaliz Jarauta, Rocío Mateo-Gallego.

Medical University of Varna (Bulgaria): Violeta Iotova, Tsvetalina Tankova, Natalia Usheva, Kaloyan Tsochev, Nevena Chakarova, Sonya Galcheva, Rumyana Dimova, Yana Bocheva, Zhaneta Radkova, Vanya Marinova, Yuliya Bazdarska, Tanya Stefanova.

University of Debrecen (Hungary): Imre Rurik, Timea Ungvari, Zoltán Jancsó, Anna Nánási, László Kolozsvári, Csilla Semánova, Éva Bíró, Emese Antal, Sándorné Radó.

Extensive Life Oy (Finland): Remberto Martinez, Marcos Tong.

Members of the Feel4Diabetes-study Group:

The group representative: Yannis Manios

Department of Nutrition and Dietetics, School of Health Science & Education, Harokopio University, Athens, Greece. (manios@hua.gr).

¹Universidad De Zaragoza (Spain): Luis Moreno, Fernando Civeira, Gloria Bueno, Pilar De Miguel-Etayo, Esther M^a Gonzalez-Gil, María L. Miguel-Berges, Natalia Giménez-Legarre; Paloma Flores-Barrantes, Aleli M. Ayala-Marín, Miguel Seral-Cortés, Lucia Baila-Rueda, Ana Cenarro, Estíbaliz Jarauta, Rocío Mateo-Gallego.

³Technische Universität Dresden (Germany): Peter Schwarz, Patrick Timpel.

⁶Ghent University (Belgium), Department of Movement and Sports Sciences: Greet Cardon, Vicky Van Stappen, Nele Huys, Department of Public Health: Lieven Annemans, Ruben Willems, Department of Endocrinology and Metabolic Diseases: Samyah Shadid.

⁸University of Debrecen (Hungary): Imre Rurik, Timea Ungvari, Zoltán Jancsó, Anna Nánási, László Kolozsvári, Csilla Semánova, Éva Bíró, Emese Antal, Sándorné Radó; **Extensive Life Oy (Finland):** Remberto Martinez, Marcos Tong.

¹⁰Medical University of Varna (Bulgaria): Violeta Iotova, Tsvetalina Tankova, Natalia Usheva, Kaloyan Tsochev, Nevena Chakarova, Sonya Galcheva, Rummyana Dimova, Yana Bachata, Zhaneta Radkova, Vanya Marinova, Yuliya Bazdarska, Tanya Stefanova.

¹²Harokopio University (Greece): Yannis Manios, Kalliopi Karatzi, Odysseas Androutsos, George Moschonis, Spyridon Kanellakis, Christina Mavrogianni, Konstantina Tsoutsouloupoulou, Christina Katsarou, Eva Karaglani, Irini Qira, Efsthios Skoufas, Konstantina Maragkopoulou, Antigone Tsiafitsa, Irini Sotiropoulou, Michalis Tsolakos, Effie Argyri, Mary Nikolaou, Eleni-Anna Vampouli, Christina Filippou, Kyriaki Apergi, Amalia Filippou, Gatsiou Katerina, Efstratios Dimitriadis.

¹⁶University of Athens (Greece): Konstantinos Makrilakis, Stavros Liatis, George Dafoulas, Christina-Paulina Lambrinou, Angeliki Giannopoulou;

¹⁷Finnish Institute for Health and Welfare (Finland): Jaana Lindström, Tiina Laatikainen, Katja Wikström, Jemina Kivelä, Päivi Valve, Esko Levälahti, Eeva Virtanen, Tiina Pennanen, Seija Olli, Karoliina Nelimarkka.

¹⁸International Diabetes Federation European Region (Belgium): Winne Ko, Ernest Karuranga.

Funding: The Feel4Diabetes study was funded by the European Union's Horizon 2020 research and innovation programme under grant agreement n° 643708. The funding body had no role in the study design, data collection, analysis,

interpretation, or manuscript writing. The views expressed are those of the authors, and the European Community is not liable for any use of the information.

Conflicts of Interest: The authors declare no conflicts of interest.

Availability of Data: Data are available for scientific analysis from the corresponding author upon reasonable request.

Statement of responsibility (authors' contributions): Guiomar Masip conducted statistical analyses. Lubna Mahmood cleaned the dataset and wrote the manuscript; Yannis Manios coordinated the study; Luis A Moreno, Yannis Manios, Peter Schwarz, Greet Cardon, Violeta Iotova, contributed to the study design; Esther M. Gonzalez-Gil¹ and Luis A Moreno critically revised and supervised the manuscript; Ruben Willems and Peter Schwarz, provided essential intellectual input; all authors read, revised, and approved the final manuscript.

Ethics Approval: The study followed the Declaration of Helsinki guidelines. Ethical approval was obtained from the Ethical Committees of Spain (code: CP03/2016), Greece (code: 46/3-4-2015), Finland (code: 174/1801/2015), Belgium (code: B670201524237), Bulgaria (code: 52/10-3-201r), and Hungary (code: 20095/2016/EKU).

Consent to Participate: Informed consent was obtained from all participants.

Consent for Publication: Not applicable.

References

1. Harakeh Z, Otten W, van Empelen P. Determinants Associated with Obesity in Children of Low Socioeconomic Status Families: A Narrative Review. *J Obes.* 2025:4992624.
2. Miguel-Berges ML, Masip G, Moreno LA. Sugars in children's diets: current sources, determinants and health impacts. *Curr Opin Clin Nutr Metab Care.* 2026 Jan 23.
3. Mahmood L, Moreno LA, Schwarz P, Annemans L, Cardon G, Hilal S, Rurik I, Iotova V, Usheva N, Tankova T, Anastasiou C, Manios Y, Gonzalez-Gil EM; Feel4Diabetes-Study Group. Socioeconomic Vulnerability and Its Associations with Dietary Patterns and Obesity Degree Among Children in Families Across Six European Countries: The Feel4Diabetes-Study. *Pediatr Obes.* 2026. 21(1): e70072.
4. Wijnhoven TM, van Raaij JM, Spinelli A, Rito AI, Hovengen R, Kunesova M, Starc G, Rutter H, Sjöberg A, Petrauskiene A, O'Dwyer U, Petrova S, Farrugia Sant'angelo V, Wauters M, Yngve A, Rubana IM, Breda J. WHO European Childhood Obesity Surveillance Initiative 2008: weight, height and body mass index in 6-9-year-old children. *Pediatr Obes.* 2013. 8(2):79–97
5. Iguacel I, Fernández-Alvira JM, Bammann K, De Clercq B, Eiben G, Gwozdz W, Molnar D, Pala V, Papoutsou S, Russo P, Veidebaum T, Wolters M, Börnhorst C, Moreno LA. Associations between social vulnerabilities and dietary patterns in European children: the Identification and prevention of

- Dietary- and lifestyle-induced health Effects in Children and infants (IDEFICS) study. *Br J Nutr.* 2016. 116(7):1288–1297
6. Pala V, Lissner L, Hebestreit A, Lanfer A, Sieri S, Siani A, Huybrechts I, Kambek L, Molnar D, Tornaritis M, Moreno L, Ahrens W, Krogh V. Dietary patterns and longitudinal change in body mass in European children: a follow-up study on the IDEFICS multicenter cohort. *Eur J Clin Nutr.* 2013. 67(10):1042-9
 7. Camara S, de Lauzon-Guillain B, Heude B, Charles MA, Botton J, Plancoulaine S, Forhan A, Saurel-Cubizolles MJ, Dargent-Molina P, Lioret S; on behalf the EDEN mother-child cohort study group. Multidimensionality of the relationship between social status and dietary patterns in early childhood: longitudinal results from the French EDEN mother-child cohort. *Int J Behav Nutr Phys Act.* 2015. 24; 12:122.
 8. Iguacel I, Fernández-Alvira JM, Ahrens W, Bammann K, Gwozdz W, Lissner L, Michels N, Reisch L, Russo P, Szommer A, Tornaritis M, Veidebaum T, Börnhorst C, Moreno LA; IDEFICS consortium. Prospective associations between social vulnerabilities and children's weight status. Results from the IDEFICS study. *Int J Obes (Lond).* 2018. 42(10):1691–1703
 9. Manios Y, Androutsos O, Lambrinou CP, Cardon G, Lindstrom J, Annemans L, et al. A school- and community-based intervention to promote healthy lifestyle and prevent type 2 diabetes in vulnerable families across Europe: design and implementation of the Feel4Diabetes-study. *Public Health Nutr.* 2018, 21(17):3281–3290.
 10. Androutsos O, Anastasiou C, Lambrinou C, Mavrogianni C, Cardon G, Van Stappen V, Kivelä J, Wikström K, Moreno L, Iotova V, Tsochev K, Chakarova N, Ungvári T, Jancso Z, Makrilakis K, Manios Y. Intra- and inter- observer reliability of anthropometric measurements and blood pressure in primary schoolchildren and adults: the Feel4Diabetes-study. *BMC endocrine disorders.* 2020, 20, 27
 11. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatric obesity.* 2012, 7(4):284–94.
 12. Emmett PM, Jones LR. Diet, growth, and obesity development throughout childhood in the Avon Longitudinal Study of Parents and Children. *Nutr Rev.* 2015.73(3):175–206.
 13. Jones-Smith JC, Dieckmann MG, Gottlieb L, Chow J, Fernald LC. Socioeconomic status and trajectory of overweight from birth to mid-childhood: the Early Childhood Longitudinal Study-Birth Cohort. *PLoS One.* 2014. 9(6): e10018.
 14. Hähnel E, Sobek C, Ober P, Kiess W, Vogel M. Age, socioeconomic status, and weight status as determinants of dietary patterns among German youth: findings from the LIFE child study. *Front Nutr.* 2025. 12:1578176.
 15. Fernández-Alvira JM, Börnhorst C, Bammann K, Gwozdz W, Krogh V, Hebestreit A, Barba G, Reisch L, Eiben G, Iglesia I, Veidebaum T, Kourides YA, Kovacs E, Huybrechts I, Pigeot I, Moreno LA. Prospective associations between socio-economic status and dietary patterns in European children: the Identification and Prevention of Dietary- and Lifestyle-induced Health Effects in Children and Infants (IDEFICS) Study. *Br J Nutr.* 2015;113(3):517 – 25.

16. Williamson VG, Dilip A, Dillard JR, Morgan-Daniel J, Lee AM, Cardel MI. The Influence of Socioeconomic Status on Snacking and Weight among Adolescents: A Scoping Review. *Nutrients*. 2020; 12(1):167.
17. Jakobsen DD, Brader L, Bruun JM. Association between Food, Beverages and Overweight/Obesity in Children and Adolescents—A Systematic Review and Meta-Analysis of Observational Studies. *Nutrients*. 2023; 15(3):764
18. Trapp G, Hooper P, Thornton LE, et al. Exposure to unhealthy food and beverage advertising during the school commute in Australia *J Epidemiol Community Health* 2021; 75:1232–1235.
19. Liang, R., Goto, R., Okubo, Y. et al. Poverty and Childhood Obesity: Current Evidence and Methodologies for Future Research. *Curr Obes Rep*.2025, 14, 33.
20. Papamichael MM, Karatzi K, Mavrogianni C, Cardon G, De Vylder F, Iotova V, Usheva N, Tankova T, González-Gil EM, Kivelä J, Wikström K, Moreno L, Liatis S, Makrilakis K, Manios Y; Feel4Diabetes-Study Group. Socioeconomic vulnerabilities and food intake in European children: The Feel4Diabetes Study. *Nutrition*. 2022.103-104:111744.
21. Raychaudhuri M, Sanyal D. Childhood obesity: Determinants, evaluation, and prevention. *Indian J Endocrinol Metab*. 2012.16(2):S192-4. doi: 10.4103/2230-8210.
22. Watts AW, Mason SM, Loth K, Larson N, Neumark-Sztainer D. Socioeconomic differences in overweight and weight-related behaviors across adolescence and young adulthood: 10-year longitudinal findings from Project EAT. *Prev Med*. 2016. 87:194–199.
23. Chaquila, J.A., Pereyra-Elías, R. Early life socioeconomic status and risk of overweight and obesity across childhood and adolescence in four low- and middle-income countries. *Sci Rep*.2026. 16, 3819.
24. Shrewsbury V, Wardle J. Socioeconomic status and adiposity in childhood: a systematic review of cross-sectional studies 1990–2005. *Obesity (Silver Spring)*. 2008. 16(2):275 – 84.
25. Arnesen EK, Thorisdottir B, Lamberg-Allardt C, Bärebring L, Nwaru B, Dierkes J, Ramel A, Åkesson A. Protein intake in children and growth and risk of overweight or obesity: A systematic review and meta-analysis. *Food Nutr Res*. 2022. 66.
26. You J, Choo J. Adolescent Overweight and Obesity: Links to Socioeconomic Status and Fruit and Vegetable Intakes. *Int J Environ Res Public Health*. 2016;13(3):307.
27. Gingras, V., Rifas-Shiman, S.L., Taveras, E.M. et al. Dietary behaviors throughout childhood are associated with adiposity and estimated insulin resistance in early adolescence: a longitudinal study. *Int J Behav Nutr Phys Act*. 2018. 15, 129.
28. Jen V, Braun KVE, Karagounis LG, Nguyen AN, Jaddoe VWV, Schoufour JD, Franco OH, Voortman T. Longitudinal association of dietary protein intake in infancy and adiposity throughout childhood. *Clin Nutr*. 2019. 38(3):1296–1302. doi: 10.1016/j.clnu.2018.05.013
29. Biadgilign S, Mgutshini T, Gebremichael B, Berhanu L, Cook C, Deribew A, Gebre B, Memiah P. Association between dietary Intake, eating behavior, and childhood obesity among children and adolescents in Ethiopia. *BMJ Nutr Prev Health*. 2023;6(2):203–211.

30. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry*. 2012;24(3):176–188.
31. Costa CS, Del-Pontes L, Assunção MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutr*. 2018;21(1):148–159.

Tables

Table 1
Descriptive statistics

Characteristics	Parents	Children
Age (in years)	38.6 (2.8)	8.21 (0.9)
Sex (% women)	87.7%	49.2%
Education level (> 12 years of education)	76.7%	-
Employment status (employed)	89.7%	-
Marital status (married)	62.7%	-
Household income security (easy)	61.3%	-
Socioeconomic vulnerability		
Category 0	51.4%	-
Category 1	19.8%	-
Category 2	9.4%	-
Category 3	15.2%	-
Category 4	0.7%	-
Category 5	3.5%	-
Country of residence		
Belgium	24.1%	-
Finland	13.3%	-
Spain	13.5%	-
Greece	21.4%	-
Hungary	13.3%	-
Bulgaria	14.4%	-
BMI ¹ (kg/m ²)		
Normal	77.6%	72.3%
Overweight/Obesity	22.4%	27.7%
BMI z-score	-	0.72 (1.1)
N = 1796 parents and children. This table provides mean (SD) for the continuous variables and frequency (%) for the categorical variables. Category 0 = no SES vulnerability, Category 5 = highest SES vulnerability. 1 BMI: Body Mass Index. BMI z-scores were calculated according to Cole et al.		

Table 2

Model fit indices for the cross-lagged panel model adjusted for demographic covariates (Model 1).

Food Group	χ^2	p-value	CFI	TLI	RMSEA	(90% CI)	SRMR
Fruits, vegetables & legumes	55.58	< 0.001	0.997	0.995	0.045	(0.033, 0.057)	0.014
Sweets & Sugar-sweetened beverages	44.50	< 0.001	0.998	0.996	0.038	(0.027, 0.051)	0.007
Salty snacks	43.47	< 0.001	0.998	0.996	0.038	(0.026, 0.050)	0.008
Meat (red meat and poultry)	40.31	< 0.001	0.998	0.997	0.036	(0.024, 0.048)	0.005
Fish and Seafood	46.81	< 0.001	0.998	0.996	0.040	(0.028, 0.052)	0.011
Dairy products	36.75	< 0.001	0.998	0.997	0.033	(0.021, 0.046)	0.007
Grains	47.74	< 0.001	0.996	0.996	0.041	(0.029, 0.053)	0.012
Model fit indices refer to the cross-lagged panel model examining reciprocal associations between socioeconomic vulnerability and food intake over time. p < 0.05 indicates significance. CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation (90% CI = 90% confidence interval); SRMR = Standardized Root Mean Square Residual.							

Table 3

Cross-lagged path estimates for Model 1 examining associations between socioeconomic vulnerability and dietary intake across three waves.

Food Group	Path	B (standardized)	SE	(95% CI)	p-value
Fruits, vegetables & legumes	SEV ₁ → Diet ₂	0.002	0.001	(-0.001, 0.005)	0.338
	Diet ₁ → SEV ₂	0.002	0.002	(0.004, 0.001)	0.676
	SEV ₂ → Diet ₃	-0.119	0.026	(-0.181, -0.076)	< 0.001
	Diet ₂ → SEV ₃	-0.009	0.014	(0.019, -0.009)	0.543
Sweets & Sugar-sweetened beverages	SEV ₁ → Diet ₂	-0.002	0.002	(-0.005, 0.001)	0.322
	Diet ₁ → SEV ₂	0.001	0.001	(-0.001, 0.004)	0.365
	SEV ₂ → Diet ₃	0.084	0.024	(0.035, 0.130)	< 0.001
	Diet ₂ → SEV ₃	0.036	0.014	(0.003, 0.059)	0.027
Salty snacks	SEV ₁ → Diet ₂	0.001	0.001	(-0.001, 0.003)	0.421
	Diet ₁ → SEV ₂	-0.000	0.001	(-0.002, 0.002)	0.782
	SEV ₂ → Diet ₃	0.129	0.023	(0.060, 0.153)	< 0.001
	Diet ₂ → SEV ₃	0.071	0.021	(0.037, 0.121)	< 0.001
Meat (red meat and poultry)	SEV ₁ → Diet ₂	0.003	0.001	(0.000, 0.006)	0.042
	Diet ₁ → SEV ₂	0.001	0.001	(-0.001, 0.005)	0.277
	SEV ₂ → Diet ₃	-0.100	0.023	(-0.144, -0.051)	< 0.001

Cross-lagged model 1 was used to assess temporal association between socioeconomic vulnerability (SEV) and food groups. The model was adjusted for child age and gender. Number 1 refers to wave 1, 2 = wave 2, 3 = wave 3. SE = Standard Error. 95% CI = 95% Confidence Interval. p < 0.05 indicates significance.

Food Group	Path	B (standardized)	SE	(95% CI)	p-value
	Diet ₂ → SEV ₃	-0.022	0.014	(-0.050, 0.007)	0.146
Fish and Seafood	SEV ₁ → Diet ₂	0.001	0.001	(-0.002, 0.003)	0.674
	Diet ₁ → SEV ₂	-0.001	0.001	(-0.003, 0.000)	0.108
	SEV ₂ → Diet ₃	-0.021	0.017	(-0.049, 0.019)	0.390
	Diet ₂ → SEV ₃	0.005	0.017	(-0.028, 0.039)	0.764
Dairy products	SEV ₁ → Diet ₂	-0.000	0.0017	(-0.003, 0.003)	0.937
	Diet ₁ → SEV ₂	0.000	0.0016	(-0.002, 0.003)	0.595
	SEV ₂ → Diet ₃	0.035	0.0216	(-0.005, 0.079)	0.089
	Diet ₂ → SEV ₃	-0.012	0.3246	(-0.031, 0.010)	0.324
Grains	SEV ₁ → Diet ₂	-0.001	0.001	(-0.003, 0.001)	0.200
	Diet ₁ → SEV ₂	-0.001	0.002	(-0.004, 0.002)	0.529
	SEV ₂ → Diet ₃	0.026	0.021	(-0.018, 0.064)	0.267
	Diet ₂ → SEV ₃	0.025	0.013	(-0.001, 0.049)	0.055

Cross-lagged model 1 was used to assess temporal association between socioeconomic vulnerability (SEV) and food groups. The model was adjusted for child age and gender. Number 1 refers to wave 1, 2 = wave 2, 3 = wave 3. SE = Standard Error. 95% CI = 95% Confidence Interval. p < 0.05 indicates significance.

Table 4
Model fit indices for the fully adjusted cross-lagged panel model (Model 2).

Food Group	χ^2	p-value	CFI	TLI	RMSEA	(90% CI)	SRMR
Fruits, vegetables & legumes	422.42	< 0.001	0.982	0.969	0.073	(0.066, 0.079)	0.034
Sweets & Sugar-sweetened beverages	292.88	< 0.001	0.988	0.979	0.059	(0.053, 0.065)	0.028
Salty snacks	179.58	< 0.001	0.993	0.989	0.044	(0.037, 0.051)	0.020
Meat (red meat and poultry)	207.23	< 0.001	0.992	0.987	0.048	(0.041, 0.054)	0.016
Fish and Seafood	220.61	< 0.001	0.991	0.985	0.050	(0.043, 0.056)	0.025
Dairy products	243.61	< 0.001	0.991	0.985	0.053	(0.046, 0.059)	0.024
Grains	115.49	< 0.001	0.996	0.994	0.032	(0.025, 0.039)	0.013
Model fit indices refer to the cross-lagged panel model examining reciprocal associations between socioeconomic vulnerability and food intake over time. p < 0.05 indicates significance. CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation (90% CI = 90% confidence interval); SRMR= Standardized Root Mean Square Residual.							

Table 5

Cross-lagged path estimates for Model 2 examining associations between socioeconomic vulnerability and dietary intake across three waves

Food Group	Path	B (standardized)	SE	(95% CI)	p-value
Fruits, vegetables & legumes	SEV ₁ → Diet ₂	0.001	0.002	(-0.001, 0.005)	0.338
	Diet ₁ → SEV ₂	0.001	0.002	(0.676, 0.004)	0.676
	SEV ₂ → Diet ₃	-0.118	0.0266	(-0.118, -0.076)	< 0.001
	Diet ₂ → SEV ₃	-0.009	0.0142	(-0.009, 0.019)	0.543
Sweets & Sugar-sweetened beverages	SEV ₁ → Diet ₂	-0.001	0.001	(-0.005, 0.001)	0.322
	Diet ₁ → SEV ₂	0.0012	0.001	(-0.002, 0.004)	0.365
	SEV ₂ → Diet ₃	0.0843	0.0241	(0.035, 0.130)	< 0.001
	Diet ₂ → SEV ₃	0.036	0.014	(0.004, 0.05)	0.027
Salty snacks	SEV ₁ → Diet ₂	0.001	0.001	(-0.001, 0.003)	0.421
	Diet ₁ → SEV ₂	-0.000	0.001	(-0.003, 0.002)	0.783
	SEV ₂ → Diet ₃	0.129	0.023	(0.061, 0.154)	< 0.001
	Diet ₂ → SEV ₃	0.071	0.021	(0.037, 0.121)	< 0.001
Meat (red meat and poultry)	SEV ₁ → Diet ₂	0.003	0.002	(0.000, 0.006)	0.042
	Diet ₁ → SEV ₂	0.002	0.001	(-0.001, 0.005)	0.277
	SEV ₂ → Diet ₃	-0.100	0.023	(-0.144, -0.051)	< 0.001

Cross-lagged model 2 was used to assess temporal association between Socioeconomic vulnerability (SEV) and food groups. The model was adjusted for child age and gender, maternal age, maternal BMI, and country. Number 1 refers to wave 1, 2 = wave 2, 3 = wave 3. SE = Standard Error. 95% CI = 95% Confidence Interval. $p < 0.05$ indicates significance.

Food Group	Path	B (standardized)	SE	(95% CI)	p-value
	Diet ₂ → SEV ₃	-0.022	0.014	(-0.050, 0.007)	0.146
Fish and Seafood	SEV ₁ → Diet ₂	0.001	0.0015	(-0.002, 0.003)	0.674
	Diet ₁ → SEV ₂	-0.001	0.001	(-0.003, 0.000)	0.108
	SEV ₂ → Diet ₃	-0.021	0.017	(-0.049, 0.019)	0.390
	Diet ₂ → SEV ₃	0.004	0.017	(-0.028, 0.039)	0.764
Dairy products	SEV ₁ → Diet ₂	-0.000	0.001	(-0.003, 0.003)	0.937
	Diet ₁ → SEV ₂	0.001	0.002	(-0.002, 0.0039)	0.595
	SEV ₂ → Diet ₃	0.035	0.021	(-0.005, 0.079)	0.089
	Diet ₂ → SEV ₃	-0.013	0.011	(-0.031, 0.010)	0.324
Grains	SEV ₁ → Diet ₂	-0.001	0.001	(-0.002, 0.001)	0.200
	Diet ₁ → SEV ₂	-0.001	0.002	(-0.004, 0.002)	0.529
	SEV ₂ → Diet ₃	0.025	0.021	(-0.017, 0.063)	0.267
	Diet ₂ → SEV ₃	0.025	0.012	(-0.001, 0.049)	0.055
Cross-lagged model 2 was used to assess temporal association between Socioeconomic vulnerability (SEV) and food groups. The model was adjusted for child age and gender, maternal age, maternal BMI, and country. Number 1 refers to wave 1, 2 = wave 2, 3 = wave 3. SE = Standard Error. 95% CI = 95% Confidence Interval. p < 0.05 indicates significance.					

Figures

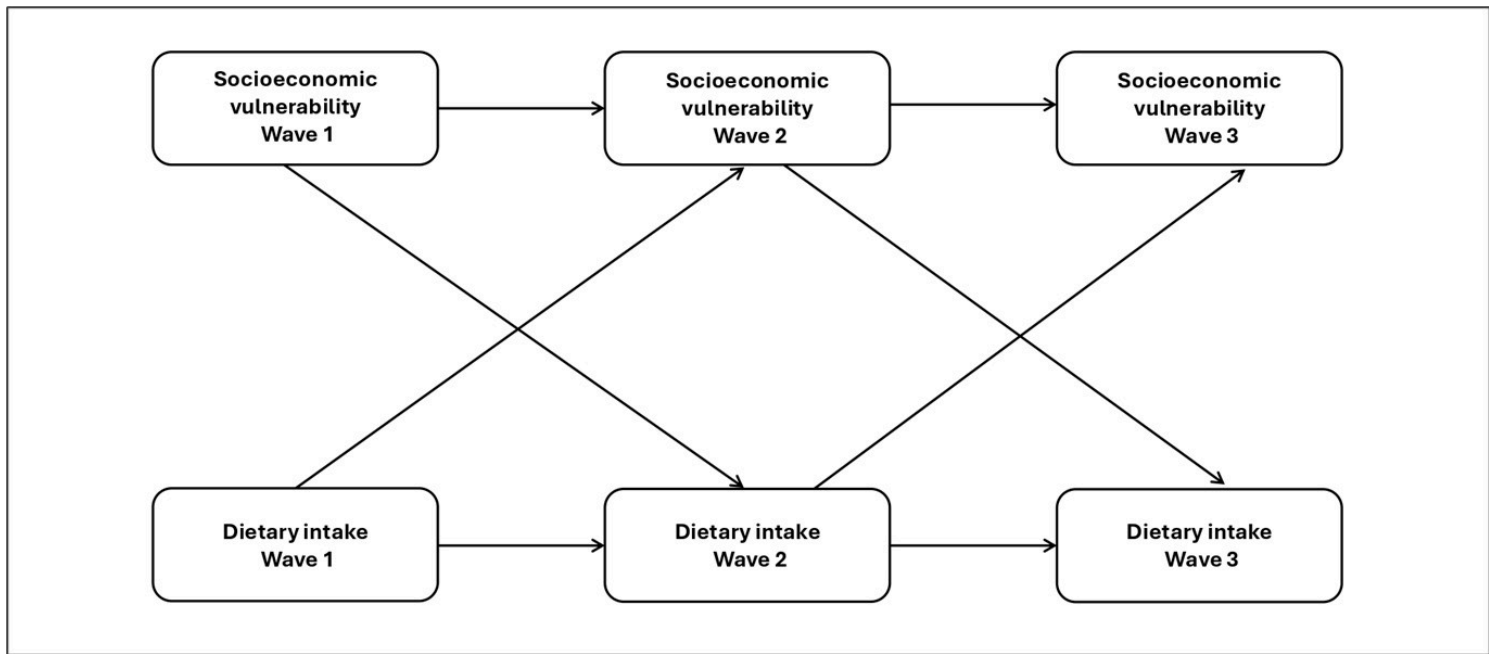


Figure 1

Cross-lagged path model for socioeconomic vulnerability and children's dietary intake.

The model was adjusted for child age and gender, maternal age, maternal BMI, and country

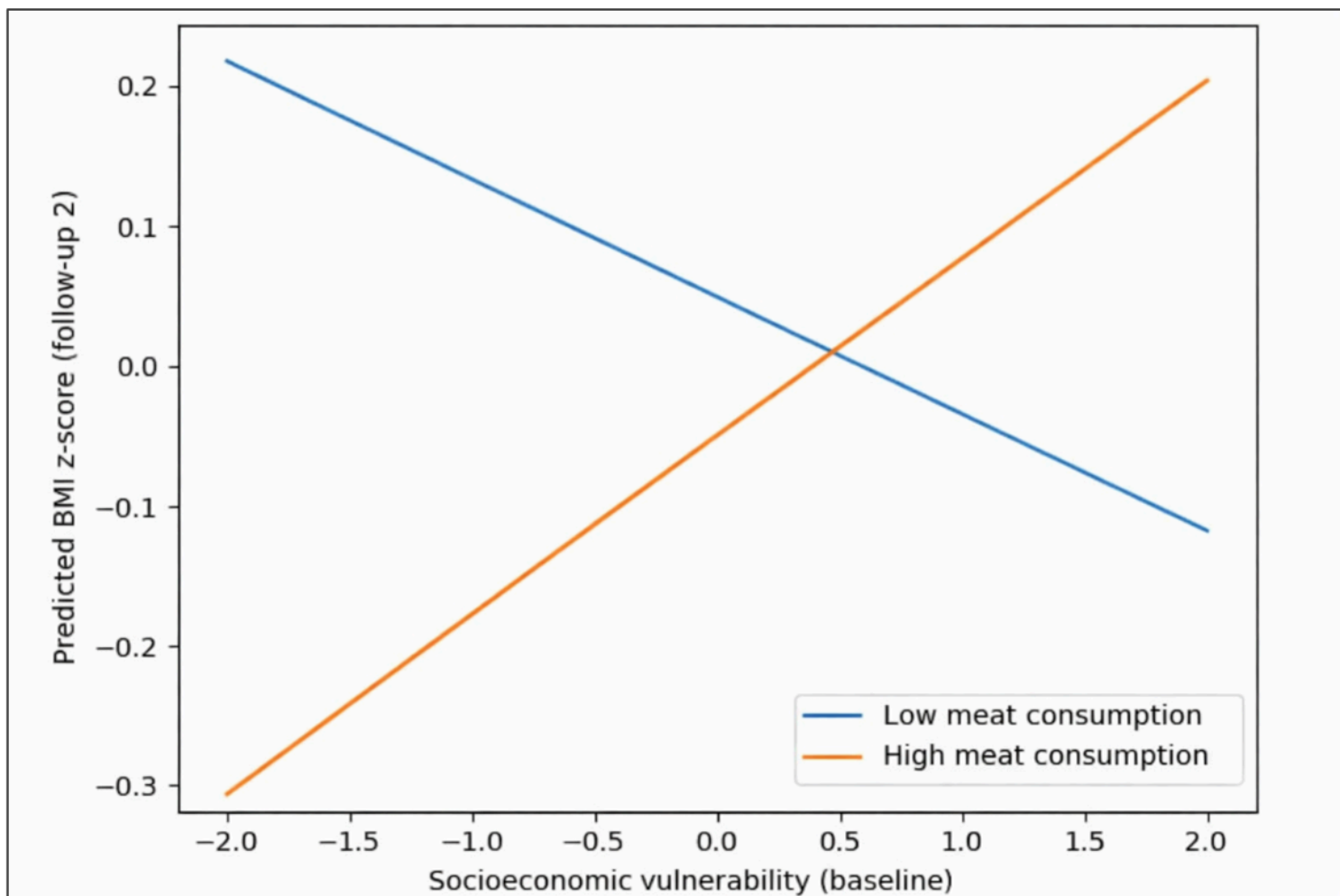


Figure 2

Moderation of the association between socioeconomic vulnerability and children’s BMI by meat consumption

Predicted BMI z-score at follow-up 2 according to baseline socioeconomic vulnerability, stratified by levels of meat consumption at follow-up 1 among girls.