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Long-Term Effectiveness of a School- and Community-Based Intervention for the Prevention of Childhood Obesity in High-Risk Families Across Europe: The Feel4Diabetes Study

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ABSTRACT

Introduction: Obesity disproportionately affects children from socioeconomically disadvantaged backgrounds. This study assessed the effectiveness of the Feel4Diabetes intervention on weight outcomes among children from low socioeconomic settings.

Methods: Feel4Diabetes was a randomised pragmatic trial implemented in real-world school and community settings across Europe. Using a two-stage screening procedure, families were recruited and categorised as either 'all families' or 'high-risk families'. The intervention included a 2-year school-based health promotion for all families and additional counselling for high-risk families. Weight improvement was defined as a reduction of ≥0.2 BMI z-score units among children with overweight/obesity. Multiple logistic regressions identified predictors of improvement.

Results: Data from 2710 children from high-risk families and 7625 children from all families were analysed. After 2 years, a higher proportion of children from high-risk families in the intervention group reduced their BMI z-score compared to the control group ($p = 0.002$). Children from non–high-risk families showed only a marginal improvement. Multivariate analyses identified predictors of improvement: randomisation in the intervention group (OR = 1.46; 95% CI: 1.14–1.87), baseline obesity (OR = 1.55; 95% CI: 1.16–2.08), residence in LMICs (OR = 2.33; 95% CI: 1.65–3.30) or HICs facing economic crisis (OR = 2.12; 95% CI: 1.54–2.91), and reported financial difficulties (OR = 1.36; 95% CI: 1.06–1.74). Interestingly, maternal obesity was positively associated with BMI z-score improvement (OR = 1.31; 95% CI: 1.03–1.68), while higher maternal education was inversely related (OR = 0.64; 95% CI: 0.41–0.99).

Conclusion: These findings underscore the importance of equity-oriented, long-term interventions addressing both behavioural and structural determinants of obesity.

1 | Introduction

Childhood obesity has become one of the most urgent public health challenges of the 21st century [1]. According to recent epidemiological data from the World Health Organization (WHO), an estimated 35 millions of children under the age of five were living with excess body weight in 2024, while over 390 million children 5–19 years were affected by the same condition in 2022 [2]. In Europe, approximately 30% of children are living with overweight or obesity [3]. Children with obesity commonly face many short- and long-term health consequences, including cardiometabolic (e.g., insulin resistance, hyperlipidemia), mechanical (e.g., obstructive sleep apnea, musculoskeletal problems), mental health (e.g., anxiety, depression), and social (e.g., bullying) complications [4–6].

Although childhood obesity was once more common in high-income countries, currently it is increasingly affecting children in low- and middle-income countries, as well as those from lower socioeconomic backgrounds [7, 8]. Family income, parental employment, and education have been identified as key risk factors, highlighting that the disease affects disproportionately children from more deprived socio-economic backgrounds [9]. The social determinants of health defined by the WHO as the conditions in which people are born, grow, live, and age, as well as their access to services and resources, play a central role in shaping these disparities [10, 11]. Thus, the social determinants of health could also contribute to the limited effectiveness of prevention efforts among the most vulnerable parts of the population, as children from lower socio-economic strata often face greater structural barriers to adopting healthy lifestyles [12, 13]. The aforementioned barriers include limited access to healthcare services, nutritious food, and safe environments for physical activity. As a result, children who mostly need those programs and initiatives are often the least likely to be reached or positively impacted by them.

The aim of the present study was to evaluate the effectiveness of a pragmatic school- and community-based intervention, implemented in six European countries, for the prevention of obesity among children from high-risk families from lower socioeconomic backgrounds. The study also sought to identify children's and families' characteristics that could predict a positive weight-related outcome, by leveraging data from a multinational 2-year intervention delivered under real-life conditions.

2 | Methods

2.1 | Study Design

The Feeld4Diabetes study was a large school and community-based intervention, implemented between 2015 and 2019, across six countries in Europe. The aim of the study was to tackle overweight and obesity for the prevention of type 2 diabetes among families from lower socio-economic backgrounds. Feel4Diabetes was implemented in both low- and medium- income countries (LMICs), as well as in high income countries (HICs). In Bulgaria and Hungary (LMICs) all families were eligible to participate, while in Belgium and Finland (HICs), Greece and Spain (HICs under austerity measures) only families from municipalities with high rates of unemployment and low educational levels were considered vulnerable and thus eligible to participate.

The study followed a standardised, two-stage screening procedure for the recruitment of the participants. The first stage screening, using schools as entry points to the community, targeted all children enrolled in the three first grades of elementary school as well as their parents, caregivers and/or grandparents ('all-families'). During the first stage screening, 'high-risk families' were identified using the Finnish Diabetes Risk Score (FINDRISC) questionnaire, which was completed by an adult family member. Families were classified as 'high-risk' if at least one adult member scored ≥ 9 on the questionnaire, indicating an elevated risk for developing type 2 diabetes. High-risk families identified through the FINDRISC were then invited to a second-stage assessment. This included a medical evaluation for all participating family members. So, the intervention comprised two components: the 'all families' and the 'high-risk families' component. This screening procedure provided an opportunity for families from diverse backgrounds—including those with low health literacy who typically do not undergo annual check-ups—to be screened for non-communicable diseases such as diabetes and obesity.

The randomisation to the arms of the study (i.e., intervention and control group) was done at municipality level on a 1:1 allocation ratio. In the LMICs (i.e., Bulgaria and Hungary), all municipalities from the participating regions were considered eligible to participate. In the HICs (Belgium, Finland, Greece and Spain) the municipalities from the participating regions were grouped into tertiles according to the socio-economic indicators retrieved from official resources and statistical authorities. As a result, 'vulnerable' municipalities where randomly selected from the tertile with the lowest education level and highest unemployment rate. Following this eligibility procedure, 18 municipalities were included in the study, equally distributed across intervention and control arms. Consequently, participating families (both for the 'all families' and the 'high-risk families' component) were assigned to either intervention or control group based on their municipality of residence.

Regarding the 'all families' component, in the intervention municipalities, it was implemented through schools during the school years 2016–2018, focusing on promoting healthy eating and active living for all children. The school-based intervention was delivered by teachers, trained at the beginning of each school year. The schools randomised to the control group continued to follow the existing curriculum.

Regarding the 'high-risk families' component, it was delivered additionally, only to those families identified as being at elevated risk for type 2 diabetes. To prevent potential stigmatisation of children, the intervention was delivered outside the school setting in local community centers. The intervention aimed to promote healthy eating and active living through tailor-made, face-to-face counselling sessions conducted in healthcare and community settings within each area, ensuring easy access and participation for all parents from high-risk families. In more detail, in the intervention municipalities, during the first year, seven face-to-face counselling sessions were provided to the participants, comprising two sessions delivered separately to

each family and five group sessions. In each of the sessions, the 'high-risk families' received counselling based on behavioural change techniques as well as relevant informational material (e.g., newsletters). During the second year, participants from high-risk families received automated motivational text messages (SMS) to support them in adopting and maintaining the targeted lifestyle behaviours. In the control municipalities, 'high-risk families' received a single annual counselling session, offering general advice on healthy diet and physical activity.

The methodology of the Feel4Diabetes study has been published previously [14]. The study was registered at ClinicalTrials.gov (NCT02393872).

Building on the overarching aim of the Feel4Diabetes-study (i.e., to promote healthy lifestyle and tackle obesity and obesity-related metabolic risk factors for the prevention of T2D among families from vulnerable groups in Europe), the present secondary analyses focus children from 'high-risk' families in order to assess the effectiveness of the intervention in this sub-group.

2.2 | Anthropometric and Socio-Demographic Data Collection

Trained researchers collected anthropometric data using standardised protocols [15]. Children's body weight was measured to the nearest 0.1 kg using electronic scales, with participants wearing light clothing and no shoes. Height was measured to the nearest 0.1 cm using a portable stadiometer, also without shoes. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Age- and sex-specific BMI z-scores (zBMI) were computed, and weight status was categorised as normal weight, overweight, or obesity based on the International Obesity Task Force (IOTF) criteria [16]. Children classified as underweight were excluded from the present analysis that focused on weight-related outcomes and specifically BMI z-score reduction for children living with overweight or obesity.

At baseline, anthropometric and socio-demographic data—including parental age, weight, height, education level, occupation, and region of residence—were collected via self-administered questionnaires. Adult BMI was calculated based on self-reported weight and height, and overweight and obesity were defined according to the World Health Organization (WHO) cut-off points of 25 and 30 kg/m^2, respectively [17]. It has been found that BMI computed from self-reported weight and height is a valid measure in men and women across different socio-demographic groups [18].

2.3 | Ethics

The Feel4Diabetes study was conducted in accordance with the principles of the Declaration of Helsinki and the Council of Europe's Convention on Human Rights and Biomedicine. Prior to the initiation of the study, ethical approval was obtained from the relevant Ethics Committees and local authorities in each participating country. In more detail, approval was granted in Belgium by the Medical Ethics Committee of Ghent University Hospital (B670201524437); in Bulgaria by the Ethics Committee of the Medical University of Varna (52/10-3-2016r), as well as by the Municipalities of Sofia and Varna and local representatives of the Ministry of Education and Science; in Finland by the Ethical Committee of the Hospital District of Southwest Finland (174/1801/2015); in Greece by the Bioethics Committee of Harokopio University (46/3-4-2015) and the Greek Ministry of Education; in Hungary by the National Committee for Scientific Research in Medicine (20095/2016/EKU); and in Spain by the Clinical Research Ethics Committee and the Department of Consumers' Health of the Government of Aragón (CP03/2016). All participating families received detailed written information about the study procedures and requirements. Informed consent was obtained in writing from parents, caregivers, and/or grandparents before their enrollment in the study.

Given the nature of the Feel4Diabetes intervention, no adverse events were anticipated, and no intervention-related adverse effects were reported neither by participants nor by implementers during the study period.

2.4 | Statistical Analysis

Categorical variables are presented as frequencies (*n*) and percentages (%), while continuous variables are summarised using means and standard deviations (SD). Several baseline characteristics reflecting the families' socio-economic background were investigated as potential predictors of children's BMI z-score improvement. These included parental education (categorised as: ≤9 years and >9 years), employment status (dichotomized into unemployed/other, full-/part-time), age (<45 years vs. ≥45 years) and BMI classification (normal weight <25 kg/m^2, overweight/obesity >25 kg/m^2). Additionally, country's economic classification, grouped into three categories: low-income (Bulgaria and Hungary), high-income under economic austerity (Greece and Spain), and high-income without austerity (Belgium and Finland), as defined in Moschonis et al. Other covariates included group assignment (intervention vs. control) and child's sex (boy or girl), BMI z-score classification (normal weight <1SD, overweight 1-2SD, obesity ≥2SD) treated as categorical variables, while child's age was used as a continuous variable.

Improvement in children's BMI z-score was defined as a decrease in the BMI z-score of ≥0.2 units from baseline among those who were living with overweight or obesity, evaluated at one and 2 years. This threshold is considered significant for achieving clinically important change, while it is comparable with a weight loss of 5% in adults [19]. Thus, the outcome was a 2-level categorical variable (0: no improvement; 1: improvement). The chi-square test and independent samples *t*-test were used to examine differences in characteristics of children and parents from high-risk families, between the intervention and control groups. Multiple logistic regression models were applied to identify factors associated with positive weight improvement, accounting for group, economic classification of countries, anthropometric and socio-demographic variables. Results are presented as Odds Ratios (OR) and corresponding 95% Confidence Intervals (95% CI). A *p*-value less than 0.05 was considered statistically significant. All analyses were performed in STATA (StataCorp. 2015. Stata: Release 15. Statistical Software).

3 | Results

3.1 | Baseline Characteristics of Children and Parents From High-Risk Families

For the purpose of the present study, data from 2710 parent–child pairs from high-risk families and 7625 children from all families were analysed. Table 1 summarises the baseline anthropometric and socio-demographic characteristics of the participating children and their families. The mean age of the children was 8.2 ± 1.0 years, with girls representing 50.8% of the sample. No significant differences were observed between groups (i.e., intervention and control group) in terms of age, sex, or BMI z-scores (mean: 0.706 ± 1.088). Overall, 31.2% of the children were classified as having overweight or obesity. Regarding countries' economic status, approximately one-third of the children lived in high-income countries, another third in low-income countries, while 39.7% resided in high-income countries under austerity measures.

Concerning parental characteristics, most of both mothers and fathers were under the age of 45 and had completed more than 9 years of education. While 28.5% of mothers were unemployed, the corresponding proportion among fathers was notably lower, at 13.3%. Interestingly, the percentage of mothers with normal weight was more than twice that of fathers (48.1% vs. 19.1%), whereas the prevalence of overweight and obesity was significantly higher among fathers, reaching 80.9%. Lastly, nearly half of all families (49.3%) reported financial difficulty in meeting basic needs, with no statistically significant variation between the intervention and control groups.

3.2 | Weight Status Outcome in Children From High-Risk Families

To evaluate the effectiveness of the intervention on weight outcomes among children with overweight and obesity from high-risk families, changes in BMI z-score were analysed prospectively. Following the two-year school and community-based intervention, a greater proportion of children from high-risk families randomised in the intervention group achieved a beneficial weight outcome—defined as a reduction of at least 0.2 standard deviations in BMI z-score—compared to those in the control group. Specifically, from baseline to the first follow-up, 12.5% of children in the intervention group showed improvement compared to 9.9% in the control group ($p = 0.046$). This difference became more pronounced over the two-year period, with 15.5% of children in the intervention group achieving a beneficial outcome compared to 11.2% in the control group ($p = 0.002$) (Figure 1). Although the proportion of children achieving a clinically meaningful reduction differed between groups, the distribution of BMI z-score (mean ± SD) did not differ significantly between the intervention and control groups at baseline or follow-up (Table 2).

Given the intervention's effectiveness among children from high-risk families, additional analyses were conducted to examine whether similar outcomes were observed among children from non–high-risk families. As shown in Table 3, after the two-year intervention, children from non–high-risk families in the intervention group demonstrated a slightly greater improvement in weight status compared to those in the control group (11.7% vs. 10.5%), although the difference was not statistically significant. Notably, a greater proportion of children from high-risk families benefited from the intervention compared to their counterparts from the control group ($p = 0.002$).

3.3 | Predictors of Weight Status Amelioration in Children From High-Risk Families

The logistic regression unveiled several child and family characteristics that were significantly associated with a beneficial weight outcome among children living with overweight or obesity from high-risk families. As presented in Table 4, children in the intervention group had significantly higher odds of achieving a beneficial weight outcome compared to the control group over the 2-year period (OR = 1.46; 95% CI: 1.14–1.87; $p = 0.003$). Furthermore, children with obesity compared to children with overweight (at baseline) were 55% more likely to achieve a beneficial weight outcome after the completion of the intervention (OR = 1.55; 95% CI: 1.16–2.08; $p = 0.003$).

Geographic context appeared to play a significant role; compared to children living in high-income countries, those from countries under economic crisis (i.e., Greece and Spain) and low-income countries (i.e., Bulgaria and Hungary) had greater odds of improvement after the 2-year intervention (both $p < 0.001$). Similarly, children from families reporting financial difficulty in covering household expenses had greater odds of a beneficial outcome over 2 years (OR = 1.36; 95% CI: 1.06–1.74; $p = 0.014$).

Regarding parents' characteristics, parental age was not recognised as an important predictor for children' weight status outcome. Nevertheless, maternal obesity was associated with 31% greater odds of achieving a reduction in children's BMI z-score ($p = 0.030$), while maternal education of more than 9 years was associated inversely with the prospective amelioration of children's weight status ($p = 0.045$).

4 | Discussion

The present study examined the effectiveness of a 2-year school and community-based intervention in improving weight outcomes among children from high-risk families. Moreover, the study provided insights on the determinants related to children's and families' characteristics that could predict the amelioration of children's weight status. The findings highlight that targeted interventions, tailored to the needs of children from diverse backgrounds, can lead to meaningful improvements in weight status.

A key finding of the study was that a higher proportion of children from high-risk families in the intervention group achieved a clinically significant reduction in their BMI z-score, compared to their counterparts in the control group, highlighting the effectiveness of the school and community-based intervention. When examining changes in mean BMI z-score

TABLE 1 | Baseline anthropometric and socio-demographic characteristics of children and parents in high-risk families.

	Total population ($N=2710$)	Intervention group ($N=1501$)	Control group ($N=1209$)	p
Children				
Age, years	8.2 ± 1.0	8.2 ± 1.0	8.1 ± 1.0	0.571[a]
Sex				
% Girls	50.8%	50.3%	52.3%	0.171[b]
BMI z-score	0.706 ± 1.088	0.709 ± 1.105	0.702 ± 1.068	0.869[a]
Weight category				
Normal weight, %	68.8%	67.4%	70.6%	0.198[b]
Overweight, %	21.0%	22.2%	19.5%	
Obesity, %	10.2%	10.4%	9.9%	
Country by income status[d]				
High income countries (Belgium, Finland), %	31.6%	29.9%	33.8%	0.082[b]
High income countries under economic crisis (Greece, Spain), %	39.7%	40.3%	39.0%	
Low income (Bulgaria, Hungary), %	28.7%	39.8%	27.3%	
Mother				
Age				
% < 45 years	84.6%	84.0%	85.2%	0.401[b]
Weight category				
Normal weight, %	48.1%	47.7%	48.5%	0.353[b]
Overweight, %	30.0%	31.2%	28.5%	
Obesity, %	21.9%	21.1%	23.0%	
Education				
% ≤ 9 years	6.5%	6.4%	6.5%	0.916[b]
Occupation				
Unemployed/other%	28.5%	27.9%	29.3%	0.022[b,c]
Full time, %	56.7%	58.7%	54.0%	
Part time, %	14.5%	13.4%	16.7%	
Father				
Age				
% < 45 years	67.5%	66.8%	68.3%	0.418[b]
Weight category				
Normal weight, %	19.1%	18.8%	19.6%	0.100[b]
Overweight, %	47.3%	49.2%	44.9%	
Obesity, %	33.6%	32.0%	35.4%	
Education				
% ≤ 9 years	8.6%	8.2%	9.2%	0.360[b]

(Continues)

TABLE 1 | (Continued)

	Total population ($N=2710$)	Intervention group ($N=1501$)	Control group ($N=1209$)	p
Occupation				
Unemployed/other, %	13.3%	13.2%	13.4%	0.140[b]
Full time, %	82.6%	83.3%	81.6%	
Part time, %	4.2%	3.4%	5.0%	
Family income status				
% Difficult	49.3%	47.9%	50.9%	0.128[b]

Note: values are means ± SD or percentages (%).
[a]*t*-test.
[b]Pearson's Chi Square test for the comparison between intervention and control groups.
[c]Statistically significant result at $\alpha=5\%$.
[d]Country income status according to Word Bank. High income: Belgium and Finland; Under economic crisis: Greece and Spain; Low income: Bulgaria and Hungary.

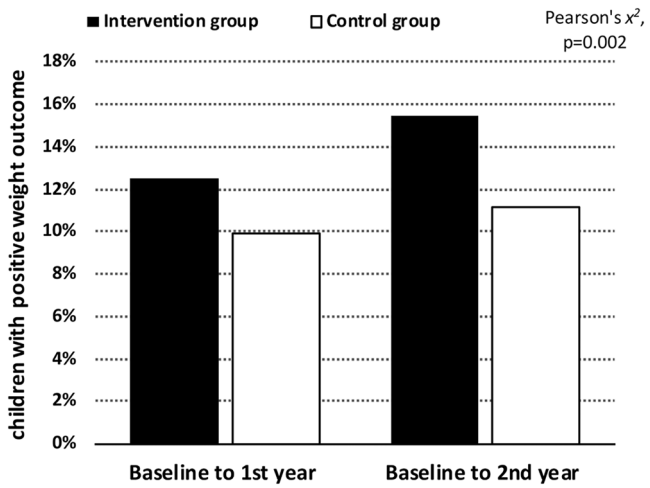

FIGURE 1 | Percentage of children with excess weight from high-risk families who achieved a beneficial weight outcome (≥0.2 SD reduction in BMI z-score) in the intervention versus control groups, from baseline to 1st and 2nd follow-up.

TABLE 2 | Mean (±SD) BMI z-score at baseline and 2-year follow-up, and change over time, between intervention and control groups among children with overweight or obesity.

	Intervention group ($N=1230$)	Control group ($N=1039$)	p
Baseline	1.870 ± 0.623	1.848 ± 0.646	0.584
2nd follow-up	1.731 ± 0.686	1.721 ± 0.754	0.846
Change (Δ)	−0.139 ± 0.394	−0.127 ± 0.451	0.504

over the two-year period, both children in the intervention and control groups demonstrated modest reductions, with no statistically significant differences between the two groups. This finding suggests that while the overall shift in mean BMI z-score was comparable between groups, the intervention may have supported a greater number of children in achieving clinically meaningful improvements. Comparing the effectiveness of the intervention between children from high-risk and non-high-risk families, the results were not statistically significant in the second group. This finding may be explained by the multi-component nature of the intervention, as in the high-risk group, the entire family participated in a 2-year school and community-based intervention, whereas in the all-families group, only the children received the school-based intervention, and thus the intervention comprised a single component. There is substantial evidence that active involvement of adult family members in interventions for the management of obesity enhances treatment outcomes for children [20–22]. Moreover, the present finding underscores the importance of designing multi-component interventions for obesity prevention and management, and tailoring them to high-risk populations, who may benefit more from targeted support than the general population [23].

Regarding the predictors of the weight status improvement, important children's and families' characteristics were identified. Children with obesity at baseline were more likely to achieve positive weight outcomes, indicating a higher responsiveness to the intervention. This observation aligns with previous findings in the literature, highlighting that higher BMI z-score at baseline is associated with a greater effect size of lifestyle interventions for childhood obesity management [24, 25]. Parental characteristics also influenced outcomes. Interestingly, maternal obesity was associated with children's weight status improvement over the two-year period. Traditionally, maternal obesity is an important risk factor for childhood obesity, while according to evidence, it is associated with poor weight outcomes among children [26, 27]. Nevertheless, our findings suggest the Feel4Diabetes study targeted the whole family ecosystem and more pronounced changes may have emerged in families where the weight issue was personally relevant. It is possible that mothers who were themselves living with obesity were more motivated to support lifestyle modifications, recognising the potential impact on both themselves and their children. On the other hand, higher maternal education was inversely associated with the reduction of BMI z-score, which

TABLE 3 | Distribution of children's beneficial weight outcome (a decrease of 0.2SDs in BMI z-score, in children with overweight or obesity) from baseline over the 2-year period, in high-risk families, in all families and excluding HR families.

	Total population ($N=2269$)	Intervention group ($N=1230$)	Control group ($N=1039$)	
High risk families				
Baseline to 2nd follow-up	13.5%	15.5%	11.2%	**0.002**[a]
	Total population ($N=7625$)	**Intervention group ($N=3992$)**	**Control group ($N=3633$)**	
ALL families (excluding high risk families)				
Baseline to 2nd follow-up	11.1%	11.7%	10.5%	0.086

[a]Bold indicates a statistically significant result at $\alpha=5\%$.

does not align with the existing evidence [28]. One possible explanation is that more educated mothers already supported children in healthy eating and active living, thus leaving less room for the Feel4Diabetes intervention.

Also, socioeconomic context emerged as an important factor for prospective weight status improvement. Children residing in HICs under austerity measures or LMICs, as well as those from families facing financial difficulties, had higher odds in achieving a positive weight outcome. A possible explanation is that children from socioeconomically disadvantaged backgrounds often have limited access to quality healthcare services and preventive health programs [29]. As a result, this tailored, multicomponent intervention strategy may have been an important opportunity for them to engage with structured support. This may have also led to greater motivation of families, especially for the good of their children. These findings challenge previous bibliography, where lifestyle interventions are seen to disproportionally benefit children from higher socioeconomic status. According to a recent systematic review by Lobstein et al., socioeconomic status and ethnic background are recognised not only as predictors for developing childhood overweight and obesity, but also as indicators of lower effectiveness of interventions, as children from lower socioeconomic backgrounds are less likely to achieve a beneficial weight outcome [30]. However, the authors emphasise that studies incorporating measures of social disparities are notably limited, which further underscores the added value of the present analysis. A systematic review by Beauchamp et al. emphasised that interventions relying on individual-level information provision and behaviour change tend to be ineffective among populations with lower socioeconomic status, whereas community-based and policy-level approaches are more successful in these groups [12]. This finding aligns with the effectiveness of the Feel4Diabetes study, which integrated school, community, and healthcare settings and tailored its approach to address the specific needs of underserved populations.

Another important finding of the study is that the proportion children achieving a positive weight outcome, increased from the first to the second follow-up. A 2024 Cochrane review evaluating the effectiveness of multicomponent interventions including physical activity and diet for the management of childhood obesity, highlighted that such interventions may result in little to no difference in BMI z-score longitudinally (i.e., at > 15 months), with pooled estimated showing minimal change (BMI z-score: MD = −0.02, 95% CI—0.06–0.01) [31]. Unlike other interventions, where weight amelioration plateau or diminish overtime, our results suggest a sustained and possibly accumulating benefit. This result could reflect a greater engagement of families over time and possibly an incremental habit formation.

The findings of the present study should be interpreted in the context of its strengths and limitations. A key strength is that data were collected from 2710 children and their families, across six European countries. The inclusion of families from low socioeconomic status across Europe adds particular value, given the well-documented link between lower SES and increased risk of obesity, as well as the lack of evidence regarding the effectiveness of such interventions in these population groups. Furthermore, this allows for valuable insights into health equity in childhood obesity prevention. Moreover, the application of standardised protocols and procedures across all study sites ensures methodological consistency. The use of prospective data to assess changes in children's BMI z-scores further strengthens the study design. Importantly, the implementation of the Feel4Diabetes intervention in real-world settings, underscores its practical relevance and scalability. However, several limitations should be acknowledged. First, the reliance on self-reported data at baseline may introduce reporting bias, particularly in relation to lifestyle and sociodemographic variables. Second, the two-year follow-up period led to the loss of reassessment data for 441 children (i.e., 16% of the total sample), possibly affecting the generalizability of the longitudinal findings. Furthermore, BMI (and BMI z-score) is an indirect measure of adiposity, while not capturing all dimensions of body composition. Finally, although the present analyses focus on the effectiveness and predictors of positive BMI z-score related outcomes, the interpretation of these findings should be considered alongside the process evaluation evidence from the Feel4Diabetes-study. Future research integrating effectiveness and implementation outcomes is needed in order to further inform the scalability and transferability of similar interventions.

TABLE 4 | Odds ratio (OR) and corresponding 95% Confidence Intervals (CI) from logistic regression evaluating the association between anthropometric and socio-demographic characteristics of high-risk children and their families and beneficial weight outcome (a decrease of 0.2SDs in BMI z-score, in children with overweight or obesity) over the 2-year period.

	Baseline to 2nd follow-up	
Characteristics	**OR (95% CI)**	***p***
Group		
Control	1 (reference)	
Intervention	**1.46 (1.14–1.87)**	**0.003**[a]
Region by income status[b]		
High Income	1 (reference)	
Under economic crisis	**2.12 (1.54–2.91)**	**< 0.001**[a]
Low income	**2.33 (1.65–3.30)**	**< 0.001**[a]
Children		
Age, years	1.07 (0.95–1.20)	0.292
Sex		
Boys	1 (reference)	
Girls	1.24 (0.97–1.58)	0.081
Weight category		
Overweight	1 (reference)	
Obesity	**1.55 (1.16–2.08)**	**0.003**[a]
Mother		
Age		
< 45 years	1 (reference)	
≥ 45 years	1.12 (0.81–1.55)	0.495
Weight category		
Normal weight	1 (reference)	
Overweight/Obesity	**1.31 (1.03–1.68)**	**0.030**[a]
Education		
≤ 9 years	1 (reference)	
> 9 years	**0.64 (0.41–0.99)**	**0.045**[a]
Occupation		0.465
Unemployed/Other	1 (reference)	
Full-/Part-time	0.90 (0.70–1.19)	
Father		
Age		
< 45 years	1 (reference)	
≥ 45 years	0.93 (0.71–1.22)	0.588
Weight category		
Normal weight	1 (reference)	
Overweight/Obesity	1.33 (0.94–1.89)	0.103
Education		
≤ 9 years	1 (reference)	
> 9 years	0.94 (0.60–1.48)	0.783
Occupation		
Unemployed/Other	1 (reference)	
Full-/Part-time	1.03 (0.69–1.52)	0.894
Family income status		
Easy	1 (reference)	
Difficult	**1.36 (1.06–1.74)**	**0.014**[a]

[a]Bold indicates a statistically significant result at $\alpha = 5\%$.
[b]Country income status according to Word Bank. High income: Belgium and Finland; Under economic crisis: Greece and Spain; Low income: Bulgaria and Hungary.

5 | Conclusions

In conclusion, the present analysis provides important evidence on the impact of a multi-component, school-, community- and family-based intervention on weight status among children from high-risk families across diverse socioeconomic contexts in Europe. Over the course of 2 years, children in the intervention group were significantly more likely to achieve a meaningful reduction in BMI z-score compared to their counterparts in the control group, with the effect becoming stronger over time. This finding provides evidence not only of the effectiveness but also the sustainability of the intervention's impact.

Notably, children from lower socioeconomic backgrounds—including those living in countries under economic crisis and those whose families faced financial difficulties—were more likely to experience beneficial outcomes, suggesting that when interventions are designed with equity and are adapted to each context, they can help bridge health gaps. In addition, certain family characteristics show the importance of considering household-level factors in intervention planning.

Overall, the findings support the implementation of targeted, long-term strategies that address both behavioural and structural drivers of childhood obesity. Interventions tailored to the needs of socially and economically vulnerable groups may not only be effective but also contribute to reducing health disparities among children.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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