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A school-based intervention for obesity prevention and management: Effectiveness and determinants of its success. The Feel4Diabetes study

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Summary

Background: Curbing the rise in overweight and obesity in childhood is of top priority in the public health agenda.

Objective: To examine the effectiveness of a 2-year school-based intervention on children's body mass index (BMI) *z*-score, considering children's baseline weight status, as well as to identify socio-demographic factors that could predict a positive weight outcome.

Methods: Data were collected from 9255 children 5–12 years, from six European countries, participating in the Feel4Diabetes study. The intervention group received a lifestyle intervention, aiming to promote a healthy and active lifestyle. Children's anthropometrics were measured at baseline and 2-year follow-up.

Results: Children with overweight, but not with obesity, at baseline randomized in the intervention group had a higher reduction in BMI *z*-scores compared to the control group. In logistic regression models, older age, female sex, overweight or obesity increased the likelihood of any decrease in BMI *z*-score in the intervention group.

Mother's obesity and a lower family income were associated with a decreased probability of a positive weight outcome from the intervention.

Conclusions: The Feel4Diabetes school-based intervention demonstrated that it could effectively improve the BMI *z*-score among children with overweight, but not with obesity. Family's characteristics (mother's weight and family income) may affect the effectiveness of such interventions and should be considered in relevant public health efforts.

KEYWORDS
children, determinants, intervention, obesity, overweight

1 | INTRODUCTION

Childhood obesity has been characterized as the epidemic of the 21st century, as over the last 40 years there has been a 10-fold increase in the disease's prevalence worldwide.[1] According to data reported from World Health Organization (WHO),[2] over 390 million children were overweight in 2022 around the globe, while taking a closer look into the European region, approximately one out of three children live with excess weight (overweight or obesity), as outlined in the WHO European Regional Obesity Report of 2022.[3] Even though excess body weight was once considered a high-income countries' (HICs) problem, currently a higher prevalence of overweight and obesity is recorded in low-medium income countries (LMICs),[4] as well as in areas of lower socioeconomic level within HICs,[5] highlighting the socioeconomic disparities of the disease. In more detail, disparities in childhood obesity, and particularly those linked to socioeconomic status (SES), are well documented and underscore the unequal burden of the disease.[6] These disparities stem from several interconnected factors, including parental practices, poor early-life nutrition, limited access to healthy and affordable food options and the widespread availability and affordability of energy-dense, nutrient-poor foods.[7] Additional challenges include the limited opportunities for physical activity, particularly in urban settings and areas of lower SES. This dynamic perpetuates a cycle of health inequity, as children from disadvantaged backgrounds face greater barriers to maintaining a healthy weight, further deepening the socioeconomic disparities of obesity.

Childhood obesity is a complex disease with multifaceted aetiology, attributed to the interaction of genetic factors, personal and psycho-social determinants, as well as to physical and social environmental factors that shape the context where children live, learn and play. Excess body weight can have serious consequences on children's physical and mental health, while evidence support that obesity tracks from childhood into adulthood.[8] According to the available data, one out of two children with obesity tend to become an adolescent with obesity while about 80% of adolescents with obesity maintain the excess body weight in adulthood. In addition, a systematic review and meta-analysis of 37 cohort studies of children aged 2–19 years suggests that high body mass index (BMI) in childhood is associated with 70% higher incidence of diabetes in adulthood and 20% higher incidence of coronary heart disease.[9] The escalating global trends of childhood overweight and obesity, coupled with the complex aetiology and the serious implications for children's physical and mental well-being, underscore the need to prioritize effective and holistic prevention strategies at early life stages in the public health agenda.

Currently, there is an abundance of intervention studies on childhood obesity prevention (primary, secondary and tertiary), with varying content and context of implementation. Regarding the content, there is a strength of evidence supporting interventions that combine both diet and physical activity components.[10] As for the context, according to a meta-analysis of 139 intervention studies, the vast majority of them (115) had a school component, while most of the time other settings (i.e., home, community and healthcare settings) were also included.[11] Even though the setting of the intervention is less important than the overall intervention content and the wider context of its implementation,[12] for specific age groups targeting the right setting seems to play a significant role. For young children, interventions implemented through home, health care and community settings seem to be beneficial, while for older children and adolescents the involvement of school is crucial for the successful outcome of the intervention.[13]

Nevertheless, despite the available data on interventions' content and context, associated with positive BMI outcomes for children, the role of the family's sociodemographic characteristics or the wider context of implementation (e.g., the country of residence) in predicting positive BMI outcomes remains unclear.[12] Considering all of the above, the objective of the present study was to examine the effectiveness of a European, school-based intervention on weight outcomes and identify the socio-demographic determinants that could predict a positive BMI outcome for children.

2 | METHODS

2.1 | Study design and sampling procedures

The present study is a secondary analysis of data from baseline and second year follow-up of the Feel4Diabetes study, a large school and community-based intervention aiming to promote healthy eating and

active living and tackle overweight and obesity for the prevention of type 2 diabetes. The Feel4Diabetes study (NCT02393872) was implemented from 2015 to 2019 among families from vulnerable groups in six European countries. In more detail, in Bulgaria and Hungary (low medium income countries—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. In more detail, in Greece, Spain, Finland and Belgium, municipalities were grouped into tertiles based on socioeconomic indices retrieved from official resources and authorities (e.g., in Greece, data were obtained from the Hellenic Statistical Authority), and 'vulnerable' areas were randomly selected from the tertile with the lowest education levels or the highest unemployment rates.[11–14]

Elementary schools were used as entry points to the community. The recruitment was based on a standardized, two-stage screening procedure. The first stage screening was delivered via the school setting, and all children attending the three first grades of elementary school as well as their parents, caregivers and/or grandparents were eligible to participate. During the first stage screening, 'high-risk' families were identified via the Finnish Diabetes Risk Score (FINDRISC) questionnaire, which was completed by parents/caregivers and/or grandparents. A family was considered 'high-risk' if at least one adult member met the cut-off of the questionnaire (this was defined as a FINDRISC score ≥9, given the young age of the participants) and thus was at high risk for developing type 2 diabetes. Following the completion of the self-administered questionnaire (i.e., the FINDRISC questionnaire), all the members of the high-risk families were invited to the second stage screening in order to undergo a medical assessment at local primary healthcare settings (or via home visits in Belgium).

The randomization to intervention and control group was done at municipality level on a 1:1 ratio and thus the participating schools and families were allocated to either intervention or control group based on their municipality of residence.

Within intervention and control group (municipalities) the Feel4Diabetes study comprised two components, the 'all-families' component and the 'high risk families' component. For the intervention municipalities, the 'all families' component was delivered via school settings during the school years 2016–2017 and 2017–2018, aimed at promoting a healthy and active lifestyle and was implemented by teachers, who at the beginning of each academic year participated in a training seminar. The schools randomized to the control municipalities, continued to follow the existing curriculum. The 'high-risk families' component that was delivered additionally, only to those families identified as having high risk for developing type 2 diabetes, outside the school setting—to avoid children's stigmatization—in any available local community centre. For the intervention municipalities, this component comprised counselling sessions during the first year and automated messages sent to participants' mobile phones during the second year of the intervention. For the control municipalities, the 'high-risk families' component comprised an annual counselling session, during which they received general guidance on adopting a balanced diet and an active lifestyle. A comprehensive description of the methodology of the Feel4Diabetes-study has been previously published.[14] The Feel4Diabetes intervention was registered at clinicaltrials.gov (registration number: NCT02393872).

2.2 | Measurements

2.2.1 | Anthropometry

Children's anthropometric indices were measured by trained researchers, using standardized protocols.[15] Body weight was measured without shoes and light clothing and recorded to the nearest 0.1 kg, using electronic weight scales. Height was measured using a portable stadiometer without shoes and recorded to the nearest 0.1 cm. BMI was calculated as the ratio of body weight (kg) to height squared (m^2). In children, BMI *z*-scores (*z*-BMI) were calculated for age and sex, and were categorized into normal weight, overweight and obesity as recommended by the International Obesity Task Force.[16] For the needs of this analysis, children found with underweight were excluded. In adults, the World Health Organization cut-offs for BMI values of 25 and 30 were used to define overweight and obesity.[17] Parents were asked to self-report their weight and height.

2.2.2 | Socio-demographic characteristics

On study entry, family socio-demographic data (e.g., parental gender, age, weight, height, educational attainment, region of residence and occupation status) were recorded via self-reported questionnaires. For the scope of the present study, the variables were dichotomized as following: parents' age: <45 and ≥45 years, educational attainment: <9 versus ≥9 years and family income status: 'difficult' versus 'easy' (reflecting the ease in covering the household expenditure).

2.3 | Ethics/written consent

The Feel4Diabetes study abided by the guidelines set down by the Declaration of Helsinki and the conventions of the Council of Europe on human rights and biomedicine. Prior to study commencement, each of the participating countries obtained ethics approval from the relevant Ethics Advisory Boards and local authorities. All families were issued an information letter that outlined in depth the study requirements, and parents/caregivers and grandparents signed written consent before their enrolment in the study.

2.4 | Statistical analysis

The level of statistical significance was set at $p < 0.05$. For continuous variables, the normality of the distribution was tested by the Kolmogorov–Smirnov test. Normally distributed continuous variables are presented as

means and standard deviations (SD), while categorical variables are presented as percentages (%). Between-group differences were assessed using Pearson's chi square test (χ^2 test). Logistic regression analyses were performed to examine associations between the positive weight outcome (dependent variable) and children's and family's socio-demographic characteristics at study entry (independent variables).

The statistical analysis was performed based on children's weight status at the beginning of the Feel4Diabetes study. The primary outcome of the present analysis was the improvement in children's weight status from baseline to the second follow-up (FU2). For this analysis, a positive weight outcome was defined as either a decrease or no change in children's BMI *z*-score. The longitudinal change in BMI *z*-score was derived by the difference between the BMI *z*-score at FU2 and BMI *z*-score at baseline. Furthermore, the characteristics that were assessed as potential predictors for a positive BMI outcome were children's sex and age as well as parents'/caregivers' anthropometric characteristics and sociodemographic factors assessed at baseline, namely, age group, weight status, educational level, region of residence and family income status per intervention or control arm.

3 | RESULTS

3.1 | Baseline characteristics of children and their families

For the scope of the present study, anthropometric data were collected from 9255 children (50.4% girls) aged 5–12 years (8.2 ± 1.0 years), along with anthropometric and socio-demographic data from their families (parents/caregivers and grandparents) who participated in the first stage screening (Table 1). Among these families, 53% were assigned to the intervention group, while 47% were randomized to the control group. Concerning children's weight status, 26.6% were categorized as having overweight or obesity, while 73.5% had normal weight at baseline.

Regarding baseline data of parents/caregivers, the majority of mothers and fathers were younger than 45 years old and had completed at least 9 years of education. Notably, and as presented in Table 1, the prevalence of overweight (including obesity) was twice as high among fathers compared to mothers. Lastly, in terms of family income status, 49.7% of families reported having difficulty covering the household monthly expenditures.

3.2 | Amelioration of children's weight status

After the 2-year intervention, there was a statistically significant reduction by 0.10 units in the BMI *z*-score of children with overweight (at baseline) belonging to the intervention group, compared to the control group ($p < 0.018$), where the reduction of BMI *z*-score was 0.05 units (Figure 1). For children with normal weight and obesity (at baseline), no significant differences were noted among the intervention and control groups.

3.3 | Children's and families' characteristics associated with a positive weight status outcome

Logistic regression was employed in order to unveil the characteristics of children and their families that benefitted the most from the Feel4Diabetes intervention (Table 2). Children's older age female sex, and overweight or obesity at baseline, were associated with higher likelihood of achieving a positive weight outcome in the intervention group, while in the control group only the presence of obesity at baseline was associated with a favourable weight outcome. While the region of residence was found to be associated with a significant weight outcome in the control group only, family's ability to easily cover the monthly expenditures was identified as a strong predictor for a positive BMI *z*-score outcome for children in both the intervention and control groups. Childrens whose families found it easy to cover the monthly expenditures were more likely to be benefitted from the school-based intervention (odds ratio (OR): 1.171, 95% confidence interval (CI): 1.043–1.314), compared to their peers who faced financial difficulties. Regarding parents' characteristics, mothers' overweight and obesity at baseline was found to be unfavourably associated with BMI *z*-score change over time in the control group, with the association being significant only for obesity in the intervention group. Children whose mothers were living with obesity were less likely to improve their weight status after the 2-year intervention (OR: 0.791, 95% CI: 0.651–0.962) ($p = 0.002$). Education of both parents was positively associated with favourable change in BMI *z*-score change over time in the control group, but not in the intervention group.

4 | DISCUSSION

The present study aimed to evaluate the effectiveness of a 2-year school-based intervention on children's weight status. Additionally, the socio-demographic characteristics of children and their families were assessed as potential predictors of a positive BMI *z*-score outcome.

Finding effective strategies to prevent overweight and obesity among children and adolescents is the cornerstone for ensuring a healthy future population. Regarding the first aim of the present study, the Feel4Diabetes school-based intervention was found to be effective in achieving a positive BMI *z*-score outcome among children with overweight, but not in children with normal weight or obesity. The lack of effect among children with obesity could be attributed to several factors. The intensity of the intervention, when combined with the challenges of already established obesity, may not have been sufficient to elicit significant changes in this group. Identifying subgroups that respond positively to interventions is crucial for refining public health strategies as well as for further tailoring those interventions to all sub-groups.

Concerning the magnitude of the effect, school and community-based interventions aiming to improve children's weight status, have achieved a relatively small improvement. In a recent meta-analysis of 37 studies that included 4019 children with overweight and obesity a

TABLE 1 Baseline anthropometric and socio-demographic characteristics of children and their families.

	Total population ($N = 9255$)	Intervention group ($N = 4903$)	Control group ($N = 4352$)	p[a]
Children				
Age (years)	8.2 ± 1.0	8.2 ± 1.0	8.2 ± 1.0	0.534
Sex				0.330
% girls	50.4%	50.7%	50.2%	
BMI z-score	0.674 ± 0.969	0.686 ± 0.966	0.660 ± 0.972	0.205
Weight category				0.603
Normal weight (%)	73.4%	73.1%	73.9%	
Overweight (%)	19.15	19.5%	18.6%	
Obesity (%)	7.5%	7.5%	7.5%	
Region by income status[b]				<0.001
High income countries (Belgium, Finland)	26.6%	31.6%	29.0%	
High income countries under economic crisis (Greece, Spain)	35.4%	37.0%	33.5%	
Low income (Bulgaria, Hungary)	35.7%	36.4%	34.9%	
Mother				
Age				0.053
% <45 years	90.4%	89.9%	90.9%	
Weight category				0.794
Normal weight (%)	66.0%	65.9%	66.1%	
Overweight (%)	22.8%	23.0%	22.5%	
Obesity (%)	11.2%	11.1%	11.4%	
Education				<0.001
% ≤ 9 years	6.2%	4.8%	7.9%	
Father				
Age				0.001
% <45 years	77.8%	76.4%	79.4%	
Weight category				0.590
Normal weight (%)	31.3%	31.2%	31.3%	
Overweight (%)	47.8%	48.3%	47.3%	
Obesity (%)	20.9%%	20.5%	21.4%	
Education				<0.001
% ≤ 9 years	18%	15.1%	21.3%	
Family income status[c]				
%Difficult	49.7%	49.7%	49.8%	0.474

Note: Values are means ± standard deviations or percentages (%).
Abbreviation: BMI, body mass index.
[a]Analysis of varaince effect or Pearson's Chi square test for the comparison between intervention and control groups.
[b]Country income status according to World Bank. High income: Belgium and Finland; under economic crisis: Greece and Spain; low income: Bulgaria and Hungary.
[c]Based on the question: how easy or difficult do you find it to cover the household expenditure? (six potential responses, merged into two).

mean difference of 0.06 units in BMI z-score (95% CI; 0.10–0.02) was reported during the follow-up measurements, among school aged children.[12] The results of the present analysis seem to be stronger than those reported in previous studies but were restricted to children with overweight. Nevertheless, it should be noted that these studies may differ from the Feel4diabetes intervention in terms of type and intensity of intervention and follow-up period. It may be concluded that not targeted school-based interventions may be effective in children with overweight, however, more intense interventions should be considered for the children's population with established obesity.

Regarding the second aim of the study, the analysis sought to identify the socioeconomic factors that were associated with the improvement of weight status among school-aged children. The findings indicated that girls and older children were more likely to achieve

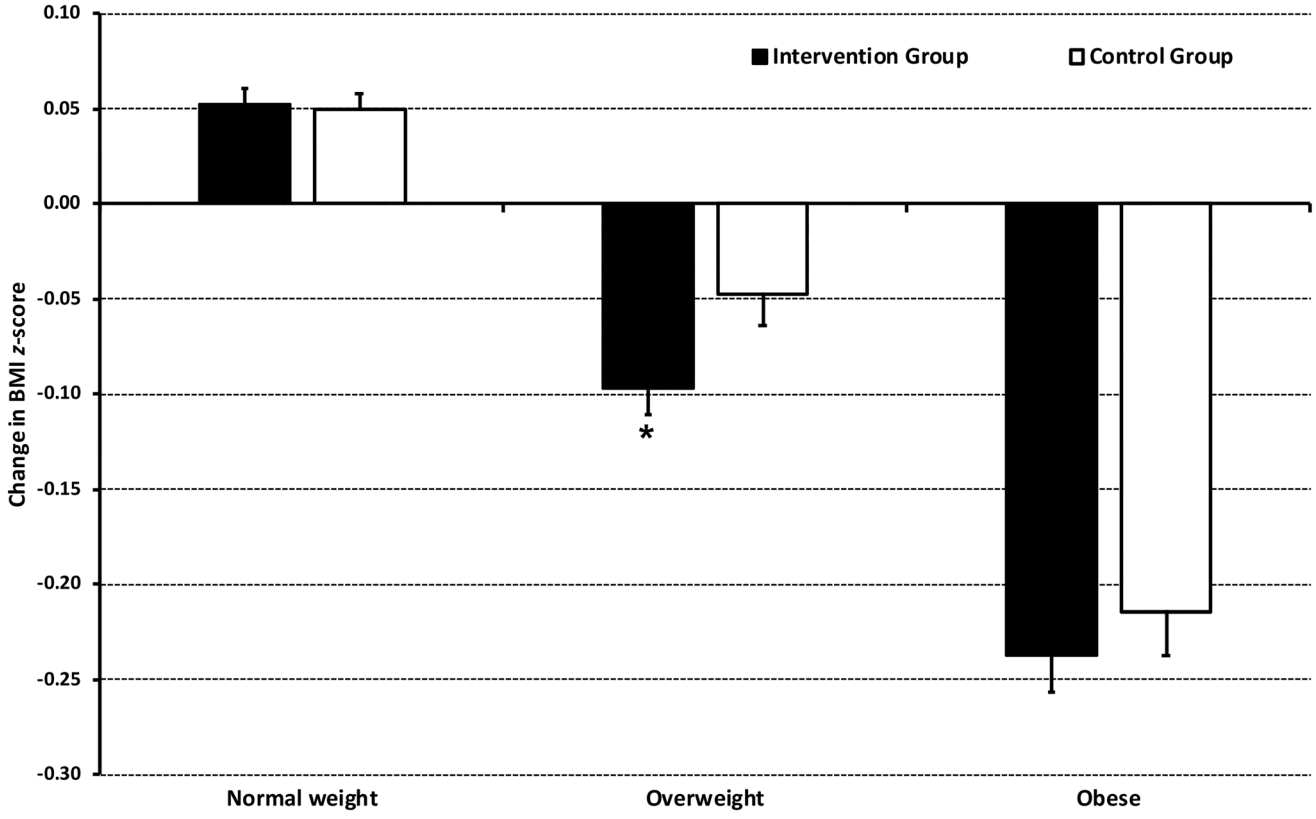

FIGURE 1 Body mass index (BMI) *z*-score changes from baseline to follow-up by weight category. *Indicates a statistically significant difference, compared to the control group at $p = 0.018$.

a positive weight outcome in the intervention, an observation that should be considered independent of any age- and sex-related differences in weight status over time, since no such associations were observed in the control group. Previous research on this topic has produced mixed results, without reaching consensus. Some studies suggest that boys are more likely to have a positive weight outcome,[18–20] while others report no significant difference between male and female children.[21,22] Concerning age, this study revealed that older children were more likely to achieve a positive weight outcome, contrary to existing literature, which either indicates no significant effect of age[18] or suggests that younger children are more likely to experience a greater reduction in BMI *z*-score during an intervention.[23] It is important to note that most of the referenced studies focus on interventions specifically targeting children with overweight or obesity. In contrast, the Feel4Diabetes school-based intervention aims to promote healthy eating and active living among all children, including those with overweight or obesity. Consequently, the intensity and content of the Feel4Diabetes intervention differs from those programmes exclusively targeting weight management in children with overweight or obesity.

Furthermore, this analysis holds additional value as it explores not only the characteristics of children but also the sociodemographic characteristics of their families, which are associated with the longitudinal success of a school-based lifestyle intervention. A significant finding of the study is that children with mothers who have obesity are less likely to achieve a positive weight outcome compared to their peers with mothers of normal weight in the intervention group, while in the control group both obesity and overweight were associated with weight outcome. This observation aligns with a substantial body of evidence indicating that parental obesity is a strong predictor of poor weight outcomes in children.[24] Additional evidence corroborates that parents' normal weight is associated with successful outcomes in weight management programs for children with obesity.[25] Findings from a community-based intervention for obesity management, revealed that children having a parent with overweight or obesity, were six times less likely to achieve a reduction in BMI *z*-score compared to their peers whose parents maintained a healthy weight.[18] The correlation between the weight of mothers and the weight outcomes of their offspring is reasonable, as parents not only share genetic predispositions with their children but also significantly influence the environment in which their children grow and live. Comparisons in the results between the intervention and the control groups may imply that any deviation from normal in mother's body weight may impact the weight status of the child over time. However, in the context of an intervention, obesity (and not overweight) of the mother may negatively impact its effectiveness. Interestingly, no such associations were found for father's weight status.

The present analysis revealed that children from families who found it easy to cover their monthly expenditures were more likely to improve their weight status prospectively. While substantial evidence

TABLE 2 Results from logistic regression evaluating the association between anthropometric and socio-demographic characteristics of children and their families and positive weight outcome (any decrease or no prospective increase in body mass index [BMI] *z*-score) in the intervention and the control groups.

	Intervention		Control	
	OR (95% CI)	***p***	**OR (95% CI)**	***p***
Children				
Age (years)	**1.127 (1.063–1.194)**	**<0.001**	0.984 (0.928–1.044)	0.589
Sex				
Boys	1 (reference)		1 (reference)	
Girls	**1.360 (1.216–1.522)**	**<0.001**	1.213 (1.077–1.366)	**<0.001**
Weight category				
Normal weight	1 (reference)		1 (reference)	
Overweight	**1.420 (1.229–1.641)**	**<0.001**	1.117 (0.957–1.303)	0.161
Obesity	**3.040 (2.380–3.885)**	**<0.001**	**2.971 (2.301–3.837)**	**<0.001**
Region by income status[a]				
High income	1 (reference)		1 (reference)	
Under economic crisis	0.897 (0.777–1.034)	0.134	**0.843 (0.728–0.978)**	**0.024**
Low income	0.878 (0.761–1.013)	0.075	**0.818 (0.707–0.947)**	**0.007**
Mother				
Age				
<45 years	1 (reference)		1 (reference)	
≥45 years	0.967 (0.801–1.168)	0.728	1.032 (0.836–1.274)	0.769
Weight category				
Normal weight	1 (reference)		1 (reference)	
Overweight	0.921 (0.802–1.058)	0.245	**0.797 (0.687–0.925)**	**0.003**
Obesity	**0.745 (0.619–0.898)**	**0.002**	**0.791 (0.651–0.962)**	**0.019**
Education				
≤9 years	1 (reference)		1 (reference)	
>9 years	1.152 (0.918–1.446)	0.223	**1.432 (1.165–1.761)**	**0.001**
Father				
Age				
<45 years	1 (reference)		1 (reference)	
≥45 years	1.019 (0.882–1.177)	0.799	0.928 (0.790–1.090)	0.362
Weight category				
Normal weight	1 (reference)		1 (reference)	
Overweight	0.952 (0.826–1.097)	0.497	0.988 (0.850–1.149)	0.877
Obesity	0.886 (0.743–1.056)	0.176	0.888 (0.739–1.067)	0.204
Education				
≤9 years	1 (reference)		1 (reference)	
>9 years	1.236 (0.980–1.561)	0.074	**1.432 (1.155–1.776)**	**0.001**
Family income status[b]				
Difficult	1 (reference)		1 (reference)	
Easy	**1.171 (1.043–1.314)**	**0.007**	**1.366 (1.209–1.544)**	**<0.001**

Note: Statistically significant findings at $p < 0.05$ are presented in bold.

[a]Country income status according to World Bank. High income: Belgium and Finland; under economic crisis: Greece and Spain; low income: Bulgaria and Hungary.

[b]Based on the question: How easy or difficult do you find it to cover the household expenditure? (six potential responses, merged into two).

exists to support the interplay between obesity and lower SES,[26] as observed in the control group in our study, to the best of our knowledge, this is the first time that family income status has been directly associated with prospective improvements in children's BMI *z*-score in the context of an intervention. This finding underscores the critical role of economic stability serving as a catalyst for effective weight

management interventions for children, and further indicates the necessity of additional support for children from disadvantaged backgrounds.

The findings of the present study should be interpreted in light of its strengths and limitations. A significant strength of this study is its large sample size, encompassing over 9255 children and their families from six European countries. This sample provides robust data and enhances the reliability of the findings. Another notable strength is the inclusion of families from low SES regions across various European countries, as lower SES is often linked with a higher prevalence of obesity due to socioeconomic disparities that can affect access to nutritious foods, opportunities for physical activity, and quality health services. Additionally, the use of standardized protocols and procedures across all centres ensures a more accurate and reliable assessment, thereby increasing the credibility and the generalizability of the findings. Furthermore, the fact that prospective data were used to assess the change in children's BMI *z*-score is an additional advantage of the study. Finally, perhaps the most significant strength of the Feel4Diabetes study was its implementation in real-world settings while demonstrating both cost-effectiveness and sustainability. However, the present study has also several limitations. Firstly, the baseline data from families are self-reported, which may introduce bias. Additionally, the 2-year interval between the initial assessment and the follow-up resulted in the loss of reassessment data for 2938 children (as baseline data were available for 12 193 children).

CONCLUSION

In conclusion, the Feel4Diabetes intervention offers valuable insights into the dynamics of childhood weight management and highlights the importance of various socio-demographic factors that can influence the effectiveness of such interventions. The Feel4Diabetes school-based intervention demonstrated its effectiveness in improving the BMI *z*-score among children with overweight. By focusing on baseline weight status and socio-demographic factors, this study highlights the complexity of designing effective interventions for childhood obesity prevention. The intervention's success, particularly when compared to previous studies, underscores the potential of comprehensive school-based strategies in managing childhood overweight. Additionally, this study highlights critical socio-demographic predictors which influence the success of weight management interventions. The novel association between family economic stability and prospective positive weight outcomes underscores the necessity for the provision of additional focus and support for children from disadvantaged backgrounds. Nevertheless, and despite the existence of potentially successful interventions, addressing childhood overweight and obesity necessitates substantial political will and commitment, as well as comprehensive changes within the regulatory and operational frameworks related to the health and education system. These adjustments should prioritize the creation of enabling environments for the promotion of healthy eating and active living for the entire population, with special emphasis on regions and neighbourhoods of lower SES. Additionally, interventions and policies should be continuous and cohesive, rather than fragmented, to ensure long-term sustainability and efficacy.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest to disclose.

DATA AVAILABILITY STATEMENT

The original data of this work are available upon reasonable request to the corresponding author.

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