Impact of a school-based food assistance program on household food insecurity in Greece, 2012–2019: a multi-year evaluation of the DIATROFI program

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Summary

Background Childhood food insecurity can persist among low socioeconomic areas in high-income countries. Universal Free School Meal (UFSM) programs are designed to respond to this pressing issue. This study aimed to conduct a multi-year evaluation of the DIATROFI Program's impact on household food insecurity in Greece.

Methods This study utilized data from 18,716 students (618 kindergarten to high schools), from low socioeconomic areas participating in the school-level UFSM Program DIATROFI between 2012 and 2019. Parents of students completed annual baseline and follow-up paper-based self-completed questionnaires. The primary outcome was household food insecurity, measured using the Food Security Survey Module (FSSM) at both questionnaires, and evaluated through mixed linear and logistic regression models with repeated measurements.

Findings Students' median age was 9 years old (Interquartile range (IQR): 6.5, 12.0), 51.6% (n = 9658) were girls, and 82.2% (n = 15,382) lived in low/medium socioeconomic affluence households. Households with food insecurity reduced from 51.5% (n = 9630) to 47.6% (n = 8901) after one school year. Food insecurity score declined steadily for four years of consecutive participation, compared to baseline score (one-year b:–0.26; 95% Confidence Interval (CI):–0.30, –0.22, and four-year –1.28; –1.53, –1.03). The likelihood of retaining food insecure status reduced from 17% after one-year participation (Odds Ratio (OR): 0.83; 95% CI: 0.79, 0.87) to 36% after four-year participation (0.64; 0.49, 0.82). The Program's impact on household food insecurity alleviation was greater among households with low parental education and low socioeconomic affluence.

Interpretation The DIATROFI Program effectively improved household food security during and after the Greek socioeconomic crisis. School-level UFSM programs targeting underprivileged students can improve household food insecurity, with a more pronounced effect with increased years of participation, and among economically disadvantaged households.

Funding The DIATROFI Program was funded through various national and private organizations, including national prefecture authorities, Greek payment authorities, philanthropic/charitable organizations, and private companies.

Keywords: Pediatric; Food accessibility; Food security; Food assistance

Abbreviations: FAO, Food and Agriculture Organization; FAS, Family Affluence Scale; FSSM, Food Security Survey Module; HBSC, Health and Behaviour in School-Aged Children; IQR, Interquartile Range; OR, Odds Ratio; SD, Standard Deviation; SES, Socioeconomic Status; UFSM, Universal Free School Meals program; WHO, World Health Organization

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Research in context

Evidence before this study

Researchers acknowledge the detrimental effects of childhood food insecurity on their overall development, health, and well-being. Researchers explored the available literature (PubMed and Google Scholar -including reports published in non-academic journal sources-, until 20/03/2024) for the effectiveness of school-based programs in improving household food security and child health. In the United States and European Union, numerous beneficial effects of Universal Free School Meal (UFSM) programs have been found, such as improvement in food insecurity, diet quality, overall health, academic performance, social cohesion, and potentially favorable weight outcomes and school violence. However, as no such program was found that evaluated the multiyear longitudinal effect of UFSM programs on household food insecurity, we evaluated the program's effectiveness in reducing student and household food insecurity over multiple years.

Added value of this study

The DIATROFI Program is the most extensive Greek UFSM and healthy nutrition promotion program delivered across schools in need in Greece, during and following the Greek socioeconomic crisis. This study provides the evidence of the first multi-year evaluation of the school-level UFSM DIATROFI Program (from 2012 to 2019) on household food insecurity among students aged 3–19. Our results showed that the improvement in food insecurity was more pronounced for students with longer duration of participation, and among those from households with low socioeconomic or low parental educational levels.

Implications of all the available evidence

Our study complements the evidence on the benefits of UFSM programs and highlights the significant long-term impact of implementing a nationwide school-based meal program on household food insecurity. Public health and government officials should account for the benefits of continuous food assistance programs at schools, free of charge for all students.

Introduction

The challenge of food insecurity persists globally, even within affluent nations,[1] with one in ten southern Europeans living in households with food insecurity.[2] Children and adolescents with food insecurity can suffer from compromised physical health, hindered development, nutritional deficiencies, and adverse mental health outcomes.[1,3,4] A common and effective strategy to address childhood food insecurity is the implementation of school meal programs,[5] with 139 countries reporting having a large-scale school meal program.[6] In particular, the most promising seem to be the universal free school meal programs (UFSMs) delivered to all students in participating schools, regions, or country.[7,8] According to a recent systematic review of over 40 relevant studies worldwide, UFSMs show strong indications of favorable effects on food security, diet quality, and weight.[8]

Greece, notably affected by the 2008 financial crisis, which lasted for about a decade, experienced a prolonged recession that significantly compromised the population's ability to access sufficient and nutritious food, highlighting the far-reaching consequences of economic upheavals on food security.[9–11] Responding to the severe Greek socioeconomic crisis, where one in four households with dependent children faced a high risk of poverty in 2012,[12] the DIATROFI Program was implemented aiming to alleviate food insecurity in areas with higher expected food insecurity, reaching about one in five schools nationwide while prioritizing those in greater need. Since 2012, this UFSM, operating on a school-level basis (i.e., delivering school meals to all students across each participating school), has successfully provided over 18 million nutritious meals to students in 880 schools located in areas with high food insecurity across Greece. The dual goal of the DIATROFI Program is to alleviate food insecurity and improve children's diet in financially constrained and socially disadvantaged communities by offering daily healthy meals.

Despite the program's main goals and continuous provision of food, one study has evaluated the program's impact on food insecurity,[13] which was limited to data for one school year (2012–2013). Another one evaluated the effectiveness of a one-year reduction in food security by comparing the program's daily meals to only education provision, with evidence of significant reduction only in the meal provision group.[14] There remains a gap in the literature regarding a comprehensive, multiyear assessment of the DIATROFI Program, particularly with respect to its primary goal: alleviating food insecurity. This study seeks to fill this gap by evaluating the impact of the DIATROFI Program on household food insecurity annually and across multiple school years between 2012 and 2019. A secondary objective of this study is to examine whether the program's impact on food insecurity was greater among families with low socioeconomic affluence.

Methods

Program design

The DIATROFI Program is a school-based food aid and healthy nutrition program with a dual goal; to minimize food insecurity in students living in socioeconomic underprivileged households and to promote healthy eating habits. A multi-interventional approach is

followed with the provision of a healthy, school meal on a daily basis accompanied by educational activities. To avoid stigmatization, all students within a school are offered with the opportunity to participate.

The DIATROFI meals

The DIATROFI meals are designed according to the National Dietary Guidelines of Greece for children and adolescents and the core principles of the Mediterranean diet.[13,15] All students in a school enrolled in the DIATROFI Program receive a prepacked fresh meal, consisting of a whole grain bakery product, a seasonal fruit and a dairy product. Meal options are adaptable to local product availability, seasonal variations, and cultural dietary habits, and are adapted-for-age, covering around one-third of their daily energy needs.[13,15,16] More details on the DIATROFI meals, their requirements, and nutritional value are published elsewhere.[16]

Meals are delivered and consumed early, within 9:30–10:30 am. This time window—which is the first break at Greek schools—has been decided taking into consideration the high rates of breakfast skipping among students with financial constraints. Meal preparation and distribution are assigned to food suppliers with high-quality standards.[16] The Program team ensures rigorous monitoring of these processes to uphold food safety and quality standards, including daily visits at school sites, unannounced inspections to DIATROFI food suppliers, and microbiological and chemical analysis in random meal samples.[16]

Educational activities

Furthermore, the DIATROFI initiative implements a comprehensive educational component, complementing meal provision, to foster healthy eating habits (e.g., fruits and vegetables intake, preference to whole grain products, daily breakfast consumption, etc.) and promote physical activity. Educational activities vary annually but consistently include age-appropriate tools such as posters, interactive workbooks, leaflets, and card games. Beyond printed materials, the initiative incorporates in-person and virtual health-promotion events facilitated by nutrition experts and culinary demonstrations by chefs, providing practical insights into healthy eating and meal preparation. Nevertheless, this publication will not examine the impact on outcomes beyond food insecurity.

Study sample

Study participants

The study population for the present study encompassed all students from primary and secondary schools who participated in the DIATROFI Program from September to June between 2012 and 2019 and whose families completed baseline and follow-up questionnaires during their year of participation. Students were considered first-time recipients of school meals if they had not received in any previous year (including the pilot phase of the study in 2011–2012). The initial year of participation varied from 2012 to 2019. Due to significant alterations to the program due to COVID-19 restrictions, data from 2020 and subsequent years were excluded.

School selection in the DIATROFI program

A mixed-methods approach is used to identify schools attended by students from socially underprivileged households. The program developed a robust algorithm to select schools by pinpointing low socioeconomic areas at the local level, focusing particularly on areas in close proximity to each school, where students are expected to reside, ensuring targeted assistance where it is most needed.

Recognizing the strong correlation between food insecurity and low socioeconomic status (SES), the program utilizes various sources of school- and area-specific information. In detail, through the participation form, school-specific information related to school characteristics and the estimated number of students facing food insecurity or financial hardships is provided by the school principals. These forms are distributed annually to all public schools in mainland Greece along with an overview of the DIATROFI Program. Additionally, data from the Ministry of Finance and the Hellenic Statistical Authority on the basis of area postal code and/or prefecture are collected. These include the current net taxable income, reasonable living expenses, the threshold to define the poverty line, the number of families with more than three children, the unemployment rate, and the presence of the Roma population or ethnic minorities.

Schools that apply to participate in the program are ranked based on school's average household food insecurity status. More specifically:

A) In case of schools that previously participated in the program, available food insecurity metrics are used (if response rate ≥30%). For the first implementation year (i.e., 2012–2013) the food insecurity metrics assessed in the pilot phase were used.
B) Else, in case of schools that have not previously participated in the program, the average students' household food insecurity status is indirectly assessed through linear regression and quantile regression models. These models account for all previously mentioned data from national authorities, and are also adjusted for school grade, special school category (e.g., intercultural school, school for students with special needs), the existence of school canteens, and the estimated rates of students from financially struggling households and/or students experiencing food insecurity, as reported in the application. Models are calibrated annually using data from schools participating in the previous school years.

Lastly, when further information is needed to evaluate the needs for food provision in specific schools, particularly those where the average students' food insecurity status cannot be assessed for reasons, such as very small sample size, incomplete application forms etc., personal interviews—designed by an expert in qualitative methodology—are conducted with principals, teachers, parents, or other school staff. This process—albeit a qualitative estimation—prevents the exclusion of schools at increased risk of food insecurity due to methodological barriers and helps identify specific needs for food provision.

Throughout the school year, the school selection is performed according to the food insecurity ranking based on the availability of funds. It should be noted that in some cases, schools were not considered as eligible due to food supply, geographical and other implementation constraints.

Final study population

As the questionnaires were anonymized, data linkage on baseline and follow-up responses accounted for multiple demographic parent and child characteristics. The linkage methodology, detailed in the Supplementary Methods, favored minimal false linkage rate. Following the data linkage, children with unavailable linked data, or baseline measurements for their first school year of participation were excluded. This resulted in an open pool of 23,383 individuals. As the program evaluated food insecurity at a household level, all but one child per family was randomly excluded, along with students who were not provided meals on a daily basis (Fig. 1). Additionally, only students with complete data on food security and model covariates were included. The final analytic sample on an annual evaluation basis included 18,716 children.

Differences in the sample size between school years may be attributed to the program's design for re-participation, as across schools participating for additional years, mostly the first-grade students received the school meals for the first time. Additional reasons may include the criteria for school inclusion, decline in response rate for multiple year of participation, and variations in funding.

Data collection

Questionnaire distribution

Annual paper-based questionnaires were given to students' parents/guardians, with a separate questionnaire completed for each child. Baseline questionnaires were disseminated before meal distribution (September or as soon as each school joined), and follow-up questionnaires were administered at the end of each school year. All schools received questionnaires from program organizers, which were distributed to parents for completion on behalf of each student. These completed questionnaires were then collected by the school principal and either returned via mail or collected onsite. Because questionnaires were anonymized, the research team developed a comprehensive protocol to link baseline and follow-up surveys to the same child and family, mentioned in detail in the Supplementary Methods.

Household food insecurity

The household food security was assessed using the Food Security Survey Module (FSSM) parent-completed questionnaire.[17] The FSSM has been examined for its validity in healthy adults in Greece with satisfactory reliability and validity.[18] Comprising 18 questions, the FSSM assesses behaviors and experiences characteristic of food insecurity as reported by the parents and their children. Examples of food insecurity-associated events assessed include the availability of adequate food for a balanced diet, meal skipping or portion reduction, and insufficient access to meals during periods of hunger, all within the context of household financial constraints. Responses yielded a score ranging from 0 to 18, where higher values indicated more severe food insecurity. The scores were categorized into four groups: high food security (0), marginal food security (1–2), low food security (3–7), and very low food security (8–18). Households with a score of ≥3 were classified as having food insecurity. The change in food security score was defined as the subtraction of each follow-up score from the initial baseline measurement.

If a respondent was missing less than half of the 18 questions (<50%) (≥50%: 2.6% at baseline and 2.5% at follow-up of the total sample), imputation was applied following standardized previously published methodology by the developers of the 18-item FSSM.[17] In brief, this method ranks all questions according to the severity of food insecurity that each is linked to and imputes missing responses as food insecurity-positive if a "more severe" response was positive, otherwise as negative. All questions are ranked from most severe (1st) to least severe (18th) based on the rate of affirmative responses indicating food insecurity within the population. For example, if Q1 and Q2 were affirmative responses, and Q3 was missing, Q3 would be imputed as an affirmative response. Conversely, if Q1 was affirmative but Q2 was negative, Q3 would be imputed as negative. This imputation strategy was guided by the hypothesis that missing data were not random, likely due to higher rates of missing data among low SES families.

Child and parental sociodemographic characteristics

Parents were asked to report child and parental sex (assigned at birth), age, country of birth, the highest educational attainment achieved by each parent, and their occupational status. Parents' educational level was defined as low (<9 years of education), medium (9–12), and high (>12), with the parental educational level

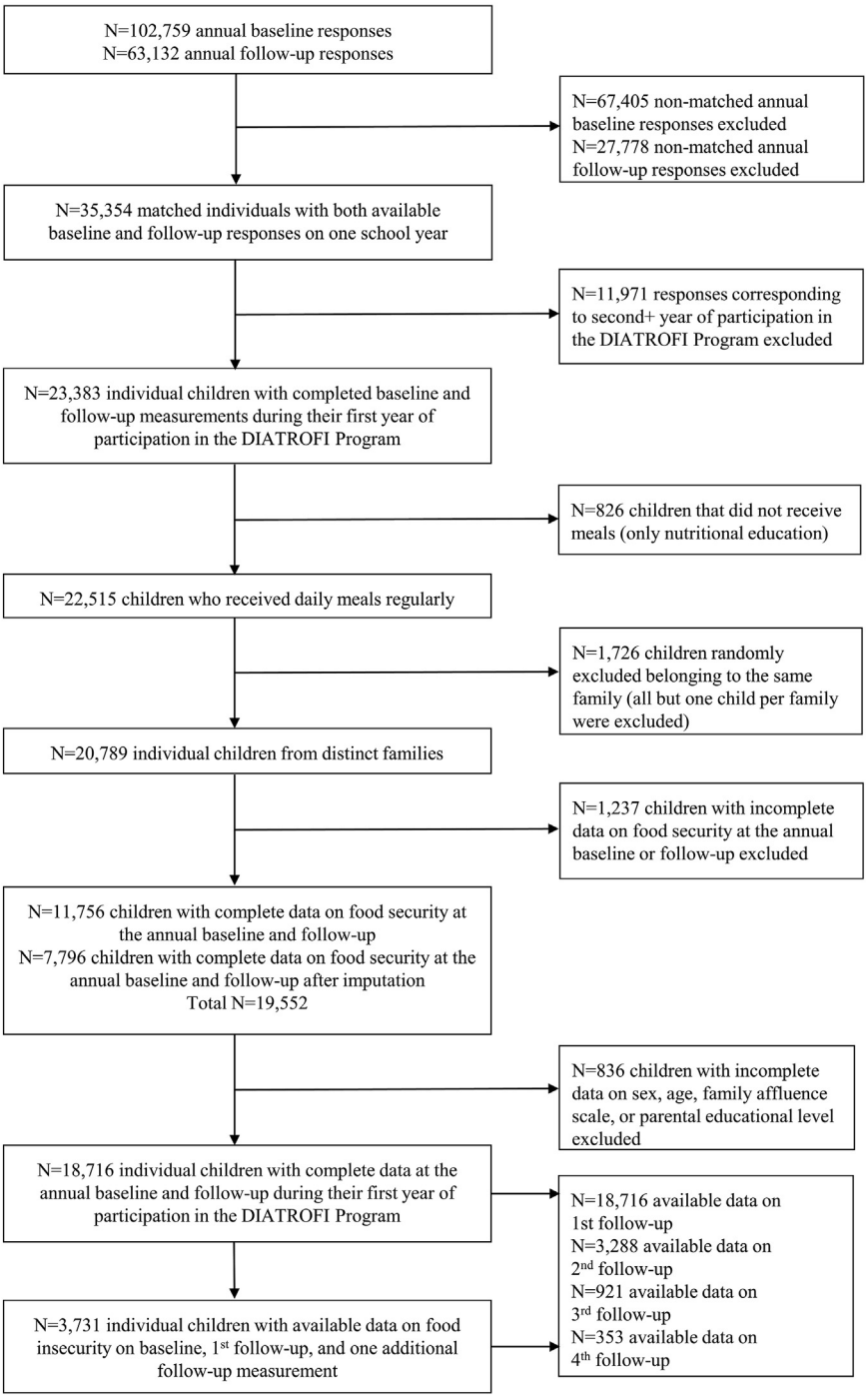

Fig. 1: Flow chart of sample inclusion in the DIATROFI Program.

indicating the highest educational level attained by one family member. The SES of each family was evaluated using the Family Affluence Scale (FAS),[19] a four–item scale, with scores ranging from 0 to 9 and three classifications: low (0–2), moderate (3–5), and high (6–9) family socioeconomic affluence. Developed within the framework of the World Health Organization (WHO) Health and Behaviour in School-Aged Children (HBSC) study, the FAS has been validated across various countries, including Greece.[20]

Respondents were requested to provide a self-selected personal four-digit ID number. Additionally, the schools' five-digit postal code was retrieved, and due to its nature, the four first digits were used to classify schools into areas. Areas including <0.4% of the sample were combined with the neighboring areas with similar sociodemographic and food security levels. In cases of missing data on sex, age, parental SES, or educational level at either baseline or follow-up, imputation was performed based on the available data at baseline or subsequent follow-up.

Bioethics

The DIATROFI Program undergoes annual approval procedures from the Greek Ministry of Education and Religious Affairs and is executed under its auspices. Bioethics approval has been received from the University of Athens Bioethics Committee and the Ethical Committee of the Prolepsis Institute (13,416, n.4, 14/10/2021). Students, parents, and the school staff were thoroughly informed about the program's design and overarching goals. Parents provide written informed consent annually, specifically for engaging in anonymous questionnaires.

Statistical analysis

Categorical variables are presented using absolute and relative frequencies (n (%)), while continuous variables are expressed as mean values ± standard deviation (SD) or median and Interquartile range (IQR) in case of non-normal distribution. Normality was assessed through graphical methods such as histograms, p–p plots, box-plots, and q–q plots.

The estimated change in food security score (adjusted mean) was derived from linear regression models, adjusting for students' age, sex, parental SES, educational level, and the duration of meal reception each year, separately, and for the total sample. Significant changes in crude or adjusted food insecurity difference scores were evaluated utilizing a one-sample t-test, while significant changes within various categories were examined through one-way variance analysis. Differences among categorical variables were tested using the Chi-squared test.

Mixed-effect repeated measures linear regression models were applied to assess the crude food security score from baseline to each consecutive year of participation. Additionally, mixed-effect logistic regression was conducted to explore the likelihood of retaining food insecurity status over consecutive years. Random intercepts for area and school year of initial participation were included in both models. Results are presented as beta coefficients or Odds Ratio (OR) and 95% Confidence Interval (95% CI). Interaction term analysis was integrated into separate models, including the same covariates, to examine the interaction between the change in food security score and (a) parental SES or (b) parental educational level, and mixed-effect linear regression models with repeated measures were stratified by family SES or parental educational level.

Sensitivity analysis was performed to evaluate disparities between unimputed and imputed mean differences in food security scores. Additionally, the association of each year's baseline and follow-up food security scores, accounting for both unimputed and imputed scores, was investigated to assess the degree to which imputation may have influenced the results.

The Statistical Package for Social Sciences (IBM SPSS, Chicago) version 20.0 was utilized for all analyses.

Role of the funding source

The funding entities did not exert any influence over the program's design and implementation, nor did they influence the data collection, analysis, data interpretation, and decision to submit the paper for publication.

Results

Descriptive statistics

Sociodemographic characteristics of 18,716 students and their families are shown in Table 1. The majority of students (71.6%) joined the program for the first time before the 2014–2015 school year. Overall, about half of the students were girls (51.6%), and the median age was 9.0 (IQR: 6.5, 12.0). Most families had low to medium highest parental educational level (53.6%), belonged to either low (27.6%) or medium (54.6%) SES levels, and one out of every nine households reported lacking income sources.

Change in food security during the first year of participation

The baseline, follow-up, mean difference, and classifications of food security score on an annual basis are presented in Table 2. The average one-year crude mean decrease on the food insecurity scale was 0.26 units (mean $\text{difference}_{\text{crude}}$: –0.26; SD: 2.82), with the decrease remaining significant for all years up to schoolyear 2016–2017. Households experiencing food insecurity reduced from 51.5% at baseline to 47.6% at the one-year follow-up.

The adjusted mean difference in food security score, in total and stratified by baseline food insecurity status on an annual basis is presented in Table 3. Overall, the program provided a mean decrease in food security score of –0.26 (SD: 0.19). Reduction in food insecurity score was more pronounced in households with food insecurity at baseline (mean $\text{difference}_{\text{adjusted:}}$ –0.29; SD 0.19 for low food security and –0.40; SD: 0.20 for very low food security) compared to households with high food security (–0.16; SD 0.13). These findings remained consistent in each schoolyear (all Ps < 0.001).

	Total	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018	2018–2019
Children's and adolescents' characteristics								
Total n. of students	18,716	2752 (14.7%)	10,653 (56.9%)	1104 (5.9%)	2437 (13.0%)	534 (2.9%)	518 (2.8%)	718 (3.8%)
Child age (median years, IQR)	9.0 (6.5, 12.0)	9.5 (6.5, 9.5)	9.5 (7.5, 9.5)	6.0 (6.0, 6.0)	8.0 (6.0, 8.0)	7.5 (6.5, 7.5)	12.0 (6.0, 12.0)	8.0 (6.0, 8.0)
Child sex (boys: n, %)	9058 (48.4%)	1316 (47.8%)	5044 (47.3%)	537 (48.6%)	1257 (51.6%)	276 (51.7%)	274 (52.9%)	354 (49.3%)
School (n, %)								
Kindergarten	1511 (8.1%)	122 (4.5%)	445 (4.2%)	169 (15.4%)	461 (19.3%)	81 (15.2%)	99 (19.7%)	134 (18.8%)
Primary	12,700 (68.4%)	1938 (70.5%)	7219 (68.2%)	777 (70.6%)	1675 (70.0%)	409 (76.6%)	156 (31.1%)	526 (73.7%)
Secondary	2884 (15.5%)	568 (20.7%)	1827 (17.2%)	153 (13.9%)	124 (5.2%)	35 (6.5%)	138 (27.5%)	39 (5.4%)
High	1485 (8.0%)	119 (4.3%)	1101 (10.4%)	1 (0.1%)	131 (5.5%)	9 (1.7%)	109 (21.7%)	15 (2.1%)
Paternal characteristics								
Paternal age (mean years, SD)	42.9 (6.6)	42.3 (6.3)	43.4 (6.4)	40.2 (6.1)	42.1 (6.8)	42.9 (7.0)	44.5 (8.4)	43.5 (7.3)
Paternal country of origin (Greece: n, %)	14,010 (76.4%)	1852 (70.3%)	8200 (78.2%)	749 (69.0%)	1786 (74.4%)	444 (83.6%)	372 (75.9%)	607 (86.3%)
Paternal educational level (n, %)								
Low (>9 years)	5706 (30.9%)	966 (35.5%)	3039 (28.9%)	363 (33.3%)	790 (32.8%)	147 (27.6%)	197 (39.6%)	204 (28.6%)
Medium (9–12 years)	7309 (39.6%)	1013 (37.3%)	4210 (40.1%)	452 (41.5%)	953 (39.5%)	212 (39.8%)	177 (35.5%)	292 (41.0%)
High (>12 years)	5446 (29.5%)	738 (27.2%)	3252 (31.0%)	274 (25.2%)	667 (27.7%)	174 (32.6%)	124 (24.9%)	217 (30.4%)
Paternal occupational status (available income: n, %)	14,968 (83.3%)	1981 (73.6%)	8611 (84.7%)	883 (82.8%)	2002 (85.7%)	470 (88.7%)	389 (80.5%)	632 (91.5%)
Maternal characteristics								
Maternal age (mean years, SD)	38.6 (5.9)	37.9 (5.6)	39.1 (5.7)	36.3 (5.8)	37.9 (6.2)	38.3 (6.0)	39.9 (7.7)	38.9 (6.5)
Maternal country of origin (Greece: n, %)	13,603 (73.8%)	1748 (67.1%)	7977 (75.4%)	726 (66.2%)	1734 (71.9%)	447 (84.3%)	375 (74.9%)	596 (83.6%)
Maternal educational level (n, %)								
Low (>9 years)	4450 (23.8%)	754 (27.5%)	2367 (22.3%)	302 (27.4%)	566 (23.3%)	128 (24.0%)	183 (35.5%)	150 (20.9%)
Medium (9–12 years)	7011 (37.5%)	1070 (39.0%)	4079 (38.3%)	391 (35.4%)	916 (37.6%)	167 (31.3%)	175 (34.0%)	213 (29.7%)
High (>12 years)	7226 (38.7%)	921 (33.5%)	4194 (39.4%)	410 (37.2%)	951 (39.1%)	238 (44.7%)	157 (30.5%)	355 (49.4%)
Maternal occupational status (available income: n, %)	8516 (46.7%)	1121 (41.6%)	5075 (48.9%)	455 (42.2%)	1036 (43.9%)	244 (46.4%)	208 (42.3%)	377 (53.7%)
Household characteristics								
Family affluence score (mean, SD)	3.7 (1.9)	3.4 (1.8)	3.8 (1.9)	3.5 (1.9)	3.6 (1.8)	4 (1.9)	3.5 (2)	4.1 (1.9)
Family affluence level (n, %)								
Low	5173 (27.6%)	922 (33.5%)	2744 (25.8%)	360 (32.6%)	694 (28.5%)	125 (23.4%)	172 (33.2%)	156 (21.7%)
Medium	10,209 (54.6%)	1442 (52.4%)	5926 (55.6%)	580 (52.5%)	1326 (54.4%)	281 (52.6%)	262 (50.6%)	392 (54.6%)
High	3334 (17.8%)	388 (14.1%)	1983 (18.6%)	164 (14.9%)	417 (17.1%)	128 (24.0%)	84 (16.2%)	170 (23.7%)
Parental educational level (n, %)								
Low (>9 years)	3122 (16.7%)	519 (18.9%)	1618 (15.2%)	216 (19.6%)	427 (17.5%)	89 (16.7%)	149 (28.8%)	104 (14.5%)
Medium (9–12 years)	6915 (36.9%)	1034 (37.6%)	4011 (37.6%)	406 (36.7%)	908 (37.3%)	155 (29.0%)	175 (33.8%)	226 (31.5%)
High (>12 years)	8679 (46.4%)	1199 (43.6%)	5024 (47.2%)	482 (43.7%)	1102 (45.2%)	290 (54.3%)	194 (37.4%)	388 (54.0%)
Parental income sources (n, %)								
No income source	1906 (10.8%)	501 (18.6%)	917 (9.2%)	130 (12.4%)	225 (9.9%)	38 (7.3%)	56 (12.0%)	39 (5.7%)
Available income source by one parent	8501 (48.0%)	1280 (47.5%)	4760 (47.6%)	525 (49.9%)	1147 (50.2%)	260 (49.8%)	237 (50.9%)	292 (42.7%)
Available income source by both parents	7289 (41.2%)	911 (33.9%)	4320 (43.2%)	396 (37.7%)	912 (39.9%)	224 (42.9%)	173 (37.1%)	353 (51.6%)
Household structure (n, %)								
Single parent households	1672 (9.1%)	202 (7.5%)	987 (9.4%)	99 (9.1%)	236 (9.9%)	25 (4.7%)	74 (14.7%)	49 (6.9%)
Two parent households	16,793 (90.9%)	2509 (92.5%)	9542 (90.6%)	993 (90.9%)	2153 (90.1%)	503 (95.3%)	430 (85.3%)	663 (93.1%)
No. of children in household (n, %)								
Single child	2914 (15.9%)	382 (13.9%)	1598 (15.4%)	204 (19.1%)	416 (17.5%)	104 (19.7%)	98 (19.8%)	112 (15.9%)

(Table 1 continues on next page)

	Total	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018	2018–2019
(Continued from previous page)								
Two children	10,352 (56.6%)	1530 (55.8%)	5927 (57.0%)	599 (55.9%)	1350 (57.0%)	294 (55.6%)	262 (52.8%)	390 (55.3%)
Three children	3583 (19.6%)	582 (21.2%)	2044 (19.7%)	185 (17.3%)	438 (18.5%)	97 (18.3%)	80 (16.1%)	157 (22.3%)
Four or more children	1453 (7.9%)	248 (9.1%)	821 (7.9%)	83 (7.7%)	165 (7.0%)	34 (6.4%)	56 (11.3%)	46 (6.5%)
Duration of meal provision (n, %)								
0–89 days	3145 (16.8%)	521 (18.9%)	1454 (13.7%)	29 (2.6%)	859 (35.3%)	25 (4.7%)	192 (37.1%)	65 (9.1%)
90–179 days	6851 (36.6%)	447 (16.3%)	4233 (39.7%)	453 (41.0%)	1309 (53.7%)	120 (22.5%)	284 (54.8%)	5 (0.7%)
180–280 days	8720 (46.6%)	1784 (64.8%)	4966 (46.6%)	622 (56.4%)	269 (11.0%)	389 (72.8%)	42 (8.1%)	648 (90.3%)

Categorical variables are presented number of observations (relative frequencies). Continuous variables are presented as mean values (Standard Deviation) in case of normal distribution and as median (Interquartile range) for non-normally distributed variables. All but one child from each family was randomly selected to be included in this sample. All children included are distinct. Parental educational level corresponds to the highest educational attainment achieved by one parent in the family. SD: Standard Deviation, n: number of observations, IQR: Interquartile Range.

***Table 1:* Descriptive characteristics of children participating in the DIATROFI program for the first time at baseline and their families, in total and across all schoolyears from 2012 to 2019 (18,716 children from distinct families).**

Mixed effect analysis with repeated follow-up measures up to 4 years

The change in food insecurity (crude decrease in score) among students with multiple years of DIATROFI Program participation is illustrated in Fig. 2. In general, the food security score reduction exhibited a declining linear trend, with the score decreasing by an average of −0.26 units (95% CI: −0.30, −0.22) after one year of participation, −0.67 (95% CI: −0.75, −0.58) after two years, −1.04 (95% CI: −1.20, −0.89) after three years, and −1.28 (95% CI: −1.53, −1.03) after four years, as compared to the baseline food security score (all Ps < 0.05).

The likelihood of a household remaining food insecure with each additional year of DIATROFI participation is shown in Fig. 2. Among students with one year of DIATROFI Program participation, there was a 17% lower likelihood of remaining food insecure (OR: 0.83; 95% CI: 0.79, 0.87). Among students with two years of DIATROFI Program participation, there was a 33% lower likelihood of remaining food insecure (OR: 0.67; 95% CI: 0.62, 0.73). The estimate for three years of program participation was similar (OR: 0.67; 95% CI: 0.58, 0.78). Finally, among students with four years of DIATROFI Program participation, there was a 36% lower likelihood of remaining food insecure (OR: 0.64; 95% CI: 0.49, 0.82).

Change in food insecurity stratified across various sociodemographic characteristics after one year of participation

The adjusted mean decrease in food security score according to various sociodemographic characteristics is presented in Supplementary Table S1. Students from households with parents having a low educational level, country of origin other than Greece, no available income source, one-parent households and low socioeconomic level exhibited a more substantial improvement in food insecurity.

Stratified fixed effect analysis with repeated follow-up measures up to 4 years

Improvement in food insecurity (crude score decrease) up to four consecutive years, stratified by family SES and parental educational level, is shown in Fig. 2.

Overall, students in low SES households experienced a more substantial improvement in food insecurity after one year (b:−0.54; 95% CI: −0.64, −0.44) and four years of participation (b:−1.88; 95% CI: −2.38, −1.38), compared to high SES households (all Ps-for-interaction < 0.05). Families with a medium SES indicated a significant decrease in score measurements after one years of participation (b:−0.19; 95% CI: −0.24, −0.13), leading to a four-year cumulative decrease of −1.09 score units (95% CI: −1.41, −0.76) (all Ps-for-interaction < 0.05).

A similar trend was observed in families with low parental educational levels. Specifically, at one year

	Total	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018	2018–2019
Food insecurity score								
Baseline (median, IQR)	3 (0, 6)	4 (1, 7)	3 (0, 6)	3 (0, 5)	2 (0, 6)	1 (0, 5)	3 (0, 7)	1 (0, 4)
Baseline (mean, SD)	3.83 (4.03)	4.49 (4.14)	3.81 (3.97)	3.66 (4.06)	3.54 (4.04)	3.08 (3.83)	4.57 (4.71)	2.72 (3.53)
Follow-up (median, IQR)	2 (0, 6)	3 (1, 6)	2 (0, 5)	2 (0, 5)	2 (0, 5)	1 (0, 5)	3 (0, 7)	1 (0, 4)
Follow-up (mean, SD)	3.57 (4.02)	4.26 (4.12)	3.50 (4.00)	3.39 (3.88)	3.42 (3.98)	2.99 (3.73)	4.32 (4.56)	2.59 (3.49)
Difference in score (mean, SD)	−0.26 (2.82)[b]	−0.22 (3.15)[b]	−0.32 (2.81)[b]	−0.27 (2.66)[b]	−0.11 (2.51)[a]	−0.09 (2.80)	−0.25 (3.18)	−0.13 (2.44)
Food insecurity categories (n, %)								
Baseline								
High food security	4984 (26.6%)	512 (18.6%)	2757 (25.9%)	326 (29.5%)	790 (32.4%)	185 (34.6%)	140 (27.0%)	274 (38.2%)
Marginal food security	4102 (21.9%)	591 (21.5%)	2384 (22.4%)	221 (20.0%)	496 (20.3%)	135 (25.3%)	96 (18.5%)	179 (24.9%)
Low food security	6263 (33.5%)	1047 (38.0%)	3613 (33.9%)	375 (34.0%)	747 (30.7%)	137 (25.7%)	158 (30.5%)	186 (25.9%)
Very low food security	3367 (18.0%)	602 (21.9%)	1899 (17.8%)	182 (16.5%)	404 (16.6%)	77 (14.4%)	124 (24.0%)	79 (11.0%)
Follow-up								
High food security	5729 (30.6%)	580 (21.1%)	3389 (31.8%)	340 (30.8%)	791 (32.4%)	192 (36.0%)	148 (28.6%)	289 (40.3%)
Marginal food security	4086 (21.8%)	591 (21.5%)	2301 (21.6%)	251 (22.7%)	545 (22.4%)	131 (24.5%)	93 (17.9%)	174 (24.2%)
Low food security	5768 (30.8%)	1027 (37.3%)	3204 (30.1%)	356 (32.3%)	711 (29.2%)	145 (27.1%)	150 (29.0%)	175 (24.4%)
Very low food security	3133 (16.8%)	554 (20.1%)	1759 (16.5%)	157 (14.2%)	390 (16.0%)	66 (12.4%)	127 (24.5%)	80 (11.1%)
p-value	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]

Difference in food insecurity denotes the difference between follow-up and baseline scores. p-values were obtained using paired $\chi 2$ for categorical variables and one sample t-test (food security score difference) for continuous variables. All but one child from each family was randomly selected to be included in this sample. All children in children included are distinct. Household s with high and marginal food security are classified as food secure households, while those considered as low or very low, as food insecure. SD: Standard Deviation, IQR: Interquartile Range. [a]p-value < 0.05. [b]p-value < 0.001.

Table 2: **Household food insecurity score and classifications at baseline and one schoolyear follow-up of children participating in the DIATROFI program for the first time, in total and across all schoolyears from 2012 to 2019 (18,716 children from distinct families).**

follow-up, the food security score decrease was –0.53 (95% CI: –0.66, –0.40) for low compared to –0.19 (95% CI: –0.24, –0.13) for high parental educational level, with this trend continuing up to four–years (b:–2.80; 95% CI: –3.42, –2.17) and (–0.67; –1.01, –0.33), respectively (all Ps-for-interaction < 0.05).

Sensitivity analysis

Students with imputed data on baseline and/or one-year follow-up were more likely to be part of families with food insecurity, no available income source, and low SES and parental educational level (Supplementary Tables S2 and S3). Similar was the case for students with missing data on food insecurity or model covariates. One-year decrease in food insecurity score was slightly higher in students with non-imputed scores (mean difference$_{crude}$: –0.27; SD: 2.70), than students with at least one imputed score (mean difference$_{crude}$: –0.24; SD: 2.98), although between group difference remained insignificant (p = 0.48). Students with higher baseline food insecurity and low SES where more likely to participate for multiple years, due to program's design (Supplementary Tables S4 and S5).

	Total	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018	2018–2019
Total change in food insecurity (mean, SD)	−0.26 (0.19)[a]	−0.22 (0.17)[a]	−0.32 (0.21)[a]	−0.27 (0.35)[a]	−0.11 (0.18)[a]	−0.09 (0.40)[a]	−0.25 (0.36)[a]	−0.13 (0.38)[a]
Household food security status (n, %)								
High food security	−0.16 (0.13)[a]	−0.14 (0.15)[a]	−0.21 (0.14)[a]	−0.17 (0.29)[a]	−0.04 (0.16)[a]	−0.03 (0.34)	−0.10 (0.26)[a]	−0.04 (0.36)
Marginal food security	−0.22 (0.16)[a]	−0.18 (0.15)[a]	−0.27 (0.18)[a]	−0.22 (0.30)[a]	−0.10 (0.17)[a]	−0.05 (0.37)	−0.18 (0.36)[a]	−0.10 (0.38)[a]
Low food security	−0.29 (0.19)[a]	−0.24 (0.16)[a]	−0.35 (0.21)[a]	−0.29 (0.36)[a]	−0.15 (0.18)[a]	−0.11 (0.42)[b]	−0.26 (0.36)[a]	−0.20 (0.38)[a]
Very low food security	−0.40 (0.20)[a]	−0.31 (0.17)[a]	−0.48 (0.23)[a]	−0.45 (0.38)[a]	−0.21 (0.17)[a]	−0.28 (0.49)[a]	−0.45 (0.39)[a]	−0.36 (0.35)[a]
p-value	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]

Linear regression models were used to estimate the decrease in food security score after adjusting for child sex, age, household socioeconomic affluence, highest parental educational attainment, and duration of meal reception. All linear regression models included the change in food security score as the dependent variable. p-values were obtained using one-sample t-test and analysis of variance for continuous variables (food security score difference). All but one child from each family was randomly selected to be included in this sample. All children included are distinct. Households with high and marginal food security can be classified as food secure households, while those considered as low or very low, as food insecure. SD: Standard Deviation. [a]p-value < 0.001. [b]p-value < 0.01.

Table 3: **Estimated annual mean decrease in food security score of children participating in the DIATROFI program for the first time after adjusting for confounders in total and across all schoolyears from 2012 to 2019 (18,716 children from distinct families).**

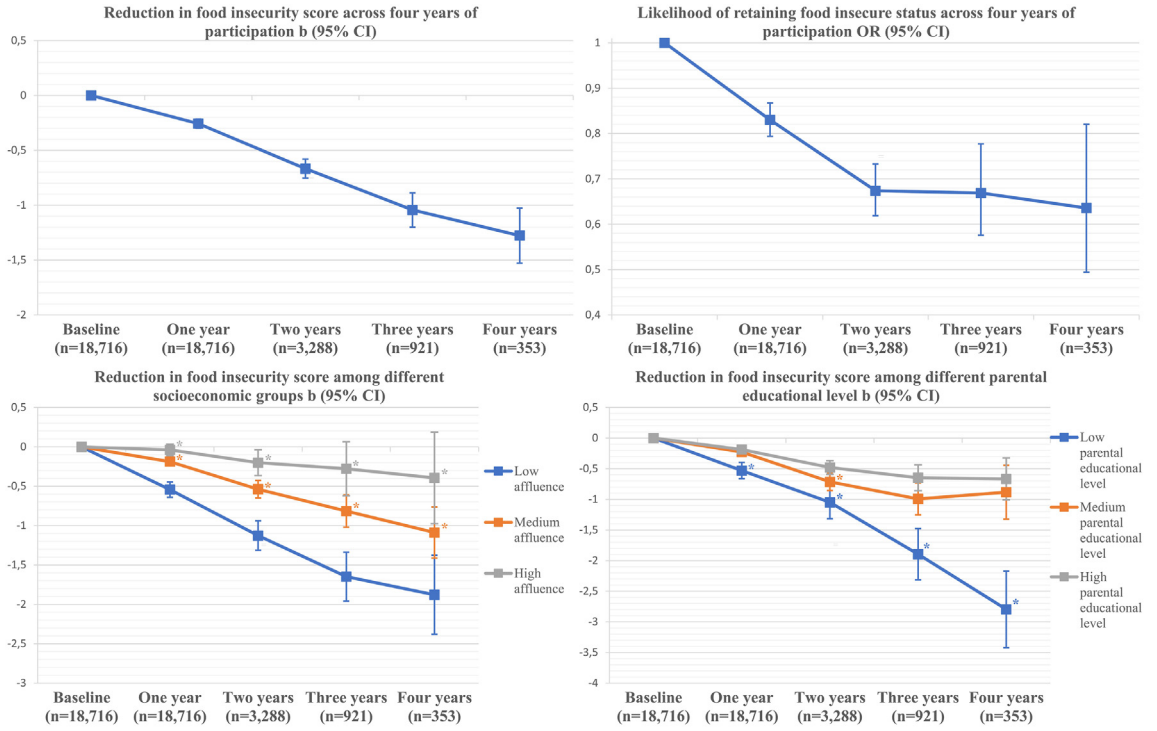

Fig. 2: Mixed effect linear and logistic regression models with repeated measures evaluating the improvement in household food insecurity (decrease in score) and likelihood of reporting household food insecurity status in children participating in the DIATROFI program for the first time at different follow-up periods in the total sample 2012–2019. *Top Right*: Mixed effect linear regression model with repeated measures. For each time point, the square indicates the beta coefficient and their corresponding bar, the 95% Confidence Intervals. *Top Left*: Mixed effect logistic regression model with repeated measures. For each time point, the square indicates the Odds Ratio and their corresponding bar, the 95% Confidence Intervals. *Bottom Right*: Mixed effect linear regression model with repeated measures stratified by Family Affluence level. For each time point, the square indicates the beta coefficient and their corresponding bar, the 95% Confidence Intervals. (*) denotes a p-value for interaction <0.05 at different time points, with high affluence level as the reference group. *Bottom Left*: Mixed effect linear regression model with repeated measures stratified by Parental educational level. For each time point, the square indicates the beta coefficient and their corresponding bar, the 95% Confidence Intervals. (*) denotes a p-value for interaction <0.05 at different time points, with low parental educational level as the reference group. All models were adjusted for child sex, age, parental highest educational level, and household affluence level. Household food insecurity score was imputed based on a previously published imputation methodology.[12] Random intercepts for area and school year of initial participation were included. All but one child from each family was randomly selected to be included in this sample. All children included are distinct. Parental educational level corresponds to the highest educational attainment achieved by one parent in the family. All interaction terms were included in separate models. The exact numerical results are presented in the Supplementary Table S7. b: Beta coefficient, 95% CI: 95% Confidence Interval.

The linear associations between baseline and follow-up food security score, prior to and after imputation, along with its corresponding score at follow-up, are shown in Supplementary Table S6. Notably, no substantial differences were identified between all models.

Discussion

The present study is the first to conduct a multi-year evaluation of the most extensive UFSM implemented in the immediate aftermath of the Greek socioeconomic crisis. Our study presents three major findings. First, the implementation of the DIATROFI Program led to significant and consistent reductions in students' household food insecurity year after year. Second, consecutive participation in the DIATROFI Program across multiple years was associated with a substantial, step-wise improvement in food security and reduced probability of experiencing persistent food insecurity. Third, students from families with low SES had a more pronounced improvement in food insecurity than students from families with higher SES, suggesting that the DIATROFI Program could help to reduce disparities in food insecurity. Collectively, these results demonstrate the significant impact of UFSMs to reduce household food insecurity among all students, and particularly those who might be at higher risk for the negative health and developmental consequences of childhood food insecurity.

Well-organized, UFSMs can comprehensively address food insecurity by improving access to all three dimensions: sufficient, safe, and nutritious food.[5,7,21] UFSMs, whether implemented at the national, state, or school-district level, have a longstanding presence around the world.[7] While several programs have proven effective in mitigating food insecurity, some face challenges, particularly when free food access is restricted for some students.[8,22] The US National School Lunch program has been shown to assist 3.2% of families with food insecurity to become fully food secure.[23] The DIATROFI Program demonstrated similar outcomes, with an estimated 3.9% reduction in food-insecure households within the first year and 6.3% of households with baseline food insecurity achieving high food security after one year. Additionally, multi-year evaluation revealed a consistent decline in food insecurity over subsequent years and reporting of persistent food insecurity. This study stands among the first to illustrate the significant multiyear impact of a nationwide UFSM on food insecurity.

The substantial improvement in food insecurity we observed can be partially attributed to the DIATROFI Program's focus on low SES areas, a practice common among high-income countries.[5] The DIATROFI Program effectively targeted areas with greater needs, including about one-third to half of households with food insecurity across each year, particularly as the post-socioeconomic crisis escalating food prices and limited purchasing power have adversely affected food consumption.[9–11] Beyond incorporating many students living in households with low socioeconomic affluence, the nutritional profile and meal quality further enhanced food security. The DIATROFI Program aimed to cover a significant portion of students' daily energy needs, enabling students to reduce hunger in school. Surpassing commercial alternatives in nutritional quality, the meals provided ample protein, monounsaturated fatty acids, and polyunsaturated fatty acids,[16] aiming to enhance the aforementioned benefits. Furthermore, the program envisioned to mitigate the adverse effects of food insecurity and hunger on diet quality and quality of life, and improve the eating habits and physical activity of students, while limiting stigma by providing school meals to all without discrimination.[24–26]

The effect of UFSMs on food insecurity can have far-reaching benefits for children, their parents, and households. For students, these programs can minimize the profound consequences of food insecurity on obesity,[3,4,8] nutritional deficiencies,[1,3,4] child behavioral development,[1] adolescent mental health,[4] unhealthy weight control practices, and exposure to school violence or bullying.[27] Thus, students can be empowered to reach their full potential, and counteract societal issues, including the lack of social cohesion.[1] Simultaneously by providing children access to nutritious meals, these programs can alleviate concerns and anxiety in parents stemming from their perceived inability to provide for their children.[28,29] Parents facing food insecurity often endure elevated psychological distress, potential depression, and even social isolation due to associated stigma.[28,30] By addressing food insecurity through healthy meal provision, families may preserve financial resources and increase their capability to cover food and other basic needs outside of school hours, thus alleviating the stress associated with balancing the family's financial commitments.[28] Across low socioeconomic areas, UFSMs play a vital role in addressing not only food insecurity but also in enhancing the overall health of children and all household members.

However, the benefits mentioned above should extend beyond low-income areas, particularly since students facing high or marginal food insecurity outside these zones may not meet inclusion criteria.[8] Despite ambitions to provide healthy meals to children regardless of socioeconomic criteria, significant barriers, including funding limitations, hinder the extension of such programs. These challenges are more pronounced in less developed countries, where similar programs and research are less common, leaving millions of food-insecure children without access to free, nutritious meals.[5,8] Additionally, this study demonstrated substantial improvements in food security among students from medium SES households, indicating that even in relatively prosperous areas, many families could benefit from such initiatives. Given the extensive benefits of UFSM, often going beyond food insecurity,[6–8] UFSM should aim to target ideally all children nationwide, and move past resorting to feeding those in higher need when funding is limited.

Another barriers in implementing USFM, are the somewhat-mixed evidence on the benefits of school meal programs providing free breakfast, mainly due to low participation rates.[8] Although the DIATROFI Program's meal resembled an early healthy meal, it achieved a high participation rate (almost 97% consumed a school meal), its nutritional quality likely played a key role in reducing food insecurity. Additionally, this and similar programs, do not provide meals on weekends, summer breaks, national holidays, or other extended breaks. However, USFM aims to enhance household food security, diet, and overall health in the long term, potentially reducing food insecurity even when the program is not operating.[6–8,28] Finally, school-based approaches can ensure broad accessibility and cost efficiency in reaching the highest number of children.

Limitations

While the student sample size is considerable, its distribution across the school year exhibits notable variability and is concentrated in the first two years of implementation. Although the availability of cuts resulted in a consistent decline in the sample size post-2014, the majority of students participated for the first

time during the program's earliest years. Additionally, the sample with available follow-up measurements post-two years of participation decreased substantially. This can be attributed to: (1) declining response rates following the initial participation year, (2) the inclusion for re-participation of schools with higher average food insecurity due to funding constraints, (3) the exclusion of additional follow-up responses past the COVID-19 pandemic.

Despite students having missing responses in the 18-item FSSM, imputation yielded comparable one-year improvement in food security among students with unimputed and imputed scores. Students with imputed responses on at least one of baseline and/or first year follow-up measurements were of lower SES and reported baseline increased food insecurity. Nevertheless, a strength of this imputation method is highlighted, since a large sample of low socioeconomic families, that were more likely to report food insecurity affirmative responses, was included in the analysis, without significantly altering the main outcome (decrease in food insecurity score). Moreover, food-insecure households, typically from lower socioeconomic backgrounds, had higher rates of missing data on food insecurity and other responses, confirming the initial hypothesis that missing data were non-random.

The absence of a control group is acknowledged, but due to the program's national scope and focus on low-socioeconomic areas, ethical considerations precluded its inclusion. Therefore, the researchers acknowledge the limitation in demonstrating a causal effect between program participation and food insecurity alleviation. Nevertheless, a randomized study was conducted to highlight this Program's one-year effectiveness, in which students were allocated to receiving only educational activities or both daily meals and educational activities.[14] As expected, food insecurity improved only in the latter, highlighting that daily food provision can effectively reduce food insecurity and provide sufficient efficacy signals for the long-term effectiveness of this Program.

Additionally, the sample included baseline measurements from various years; thus, models with multiple years incorporated a random effect based on the initial baseline measurement year. Finally, only certain scales of the household FSSM have been validated in the Greek population.

Conclusion

In Greece, a school-level UFSM showed strong indications that it was effective at reducing household food insecurity, particularly among the most disadvantaged households. Consistent participation in such programs may further reduce food insecurity, proposing a viable mechanism for mitigating this pressing public health issue. Public policy experts should regard UFSMs as valuable programs for mitigating food insecurity and should strive for food provision to be synonymous to school education in terms of national coverage, reaching all students across all schools, irrespective of SES. National-level UFSM programs should still be tailored to local contexts and needs, serving as a pragmatic and impactful intervention for addressing both child and household food insecurity at the local level. Future studies should focus on examining the broader impact of such programs to provide a comprehensive understanding of their potential in promoting food security, healthy dietary habits, healthy weight, and childhood well-being.

Contributors

DVD was responsible for conceptualization, investigation, formal analysis, methodology, and writing the original draft of the manuscript. AV was responsible for the validation of the statistical analysis of the data. DVD and AP were responsible for data curation. AV, FBH, AL, AP and CWL were responsible for review and editing of the manuscript. FBH and CWL were responsible for the conceptualization and supervision of the study. AV and AL were responsible for the project administration, program coordination, and funding acquisition. All authors approved the final text and had final responsibility for the decision to submit the manuscript for publication.

Data sharing statement

The data presented in this study are available upon reasonable request from the corresponding author.

Declaration of interests

Authors declare no competing interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanepe.2024.101004.

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