

From adolescence to adulthood: the role of diet in preventing metabolic and mental health disorders

Edited by

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From adolescence to adulthood: the role of diet in preventing metabolic and mental health disorders

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Editorial: From adolescence to adulthood: the role of diet in preventing metabolic and mental health disorders

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KEYWORDS

adolescents, diet quality, Mediterranean diet, mental health, metabolic health

Editorial on the Research Topic

[From adolescence to adulthood: the role of diet in preventing metabolic and mental health disorders](#)

Adolescence is a pivotal developmental window during which dietary habits, psychosocial trajectories, and biological maturation converge to shape lifelong health. These years are marked by increasing autonomy over food choices alongside profound metabolic, neuroendocrine, and emotional changes, positioning adolescence as both a period of vulnerability and a powerful opportunity for prevention. In launching the Research Topic “*From adolescence to adulthood: the role of diet in the prevention of metabolic and mental health disorders*,” our aim was to integrate multidisciplinary evidence on how adolescent diet influences metabolic and psychological outcomes later in life.

This Research Topic brings together 10 contributions, including original research, cross-sectional epidemiological studies, and a scoping review, spanning diverse geographical and socioeconomic contexts, from Pakistan and Poland to Peru and Malaysia. Despite their heterogeneity, all contributions converge on a shared premise: adolescent diet is a modifiable determinant of obesity, cardiometabolic disease, mental health disorders, and disordered eating as individuals transition into early adulthood.

Collectively, the studies by [Falak et al.](#), [Cuyan-Zumaeta et al.](#), and [Di Nucci et al.](#) illustrate how dietary quality, emotional wellbeing, and broader lifestyle behaviors interact to shape adolescent health trajectories.

Several studies underscore the strong influence of socioeconomic and psychosocial factors on adolescent dietary quality. Evidence from South Asia shows that poor diet quality clusters among girls, younger adolescents, and those from lower socioeconomic backgrounds, and is closely linked to poorer academic performance and body image dissatisfaction, as reported by [Falak et al.](#) Comparable patterns are observed in European adolescents in the work by [Żwirska et al.](#), where snacking behaviors, fast food consumption, and dietary restraint vary markedly by BMI category. Importantly, higher fast food consumption among underweight adolescents challenges the assumption that lower body weight reflects healthier dietary behaviors, highlighting the complexity of adolescent nutrition.

These gradients extend beyond Europe. In a study by [Shahridzal et al.](#) among Malaysian adolescents with overweight and obesity reveals critically low adherence to fruit and vegetable intake recommendations, shaped by personal motivation, parental practices, and food availability within the home. Together, these findings demonstrate that adolescent dietary behavior cannot be separated from social inequality, family environment, and perceived body image.

Dietary behavior during adolescence is also closely intertwined with mental health. Collectively, the contributions support a bidirectional model in which diet quality, emotional wellbeing, and weight status reinforce one another. Adolescents consuming higher-quality carbohydrates exhibit lower levels of depression and anxiety, as shown by [Ülger et al.](#), while meal skipping is associated with higher anxiety symptoms. Emotional eating further emerges as a key behavioral pathway linking psychological distress to higher BMI, with emotional eating and mental wellbeing exerting opposing yet similarly sized influences on weight status, as reported by [Cuyan-Zumaeta et al.](#)

Across these dimensions, parents consistently emerge as key mediators of adolescent dietary trajectories. Large multinational data from [Castellano et al.](#) show that higher parental food literacy, fewer perceived barriers, stronger healthy-eating attitudes, and greater perceived enablers are associated with better adherence to protective dietary patterns, such as the Mediterranean diet, among children and adolescents. Framed within the COM-B model, these findings highlight parental empowerment as a scalable strategy for improving adolescent diet quality.

More specialized contributions further enrich this perspective. Research on parental knowledge, attitudes, and practices regarding metabolically healthy obesity in the work by [Zhong et al.](#) indicates that socioeconomic status, particularly income, strongly predicts parental engagement and understanding. At the population level, long-term analyses by [Tian et al.](#) document steady increases in the incidence and prevalence of anorexia nervosa among adolescents and young adults, particularly among females and younger cohorts, reflecting broader sociocultural pressures. Although not diet-specific, these trends unfold within increasingly obesogenic and diet-driven environments, reinforcing the relevance of nutritional context in eating disorder prevention.

Mechanistic insights strengthen the life-course framework emerging from this Research Topic. Population-based analyses from [Huang et al.](#) indicate that dietary inflammatory potential and socioeconomic disadvantage partially mediate associations between depression and gastrointestinal dysfunction. Although conducted in adults, these findings are highly relevant to adolescence, as inflammatory dietary patterns and social inequalities often originate earlier in life.

Taken together, the evidence assembled here reinforces that adolescent diet should not be conceptualized as an individual choice alone, but as the product of social inequality, family environment, and structural access to healthy foods. The

bidirectional relationship between diet and mental health underscores the need for integrated strategies addressing nutrition, emotional wellbeing, and sleep simultaneously. Parents and families emerge as critical leverage points, and strengthening parental food literacy and confidence, particularly among socioeconomically disadvantaged groups, offers a promising pathway to sustainable change. Despite these advances, most evidence remains cross-sectional, highlighting the need for longitudinal and interventional studies. Adolescence is not only a period of vulnerability but a window of opportunity, and interventions addressing diet quality, emotional wellbeing, and structural inequities are likely to yield the most durable benefits into adulthood.

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JL-G: Writing – original draft, Writing – review & editing.
AG-M: Writing – original draft, Writing – review & editing.

Conflict of interest

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Do mental wellbeing and emotional eating influence BMI similarly or differently? Evidence from a sample of Peruvian adolescents

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Background: The literature highlights that both mental wellbeing and emotional eating are closely related to BMI, but little is known about how these variables interact similarly or differently. Therefore, the aim of this study was to determine the predictive role of mental wellbeing and emotional eating on body mass index (BMI) in Peruvian adolescents.

Methods: This research used a non-experimental and predictive design. The sample consisted of 270 students aged 12–18 years from a public educational institution in the province of Tocache, Peru. The sample was selected through non-probability purposive sampling. The study employed the Mental Health Inventory (R-MHI-5), the Emotional Eating Scale (EES), and BMI was calculated using Quetelet's formula.

Results: Correlations revealed that mental wellbeing was negatively associated with BMI ($r = -0.277$, $p < 0.001$, 95% CI = $[-0.384, -0.163]$), whereas emotional eating was positively associated with BMI ($r = 0.274$, $p < 0.001$, 95% CI = $[0.160, 0.381]$). In the multiple regression analysis, Model 2 emerged as the most suitable (adjusted $R^2 = 0.112$, $F = 17.953$, $p < 0.001$, BIC = 1,318), explaining 11.2% of the variance in BMI. Standardized coefficients indicated that mental wellbeing had a significant negative effect on BMI ($\beta = -0.217$, 95% CI = $[-0.3353, -0.0997]$, $p < 0.001$), while emotional eating had a significant positive effect ($\beta = 0.213$, 95% CI = $[0.0952, 0.3308]$, $p < 0.001$). Moreover, both coefficients showed similar magnitudes.

Conclusion: The findings of this study confirm that mental wellbeing and emotional eating exert opposing yet similarly sized influences on BMI in Peruvian adolescents. These results underscore the importance of addressing both variables equitably in interventions aimed at improving adolescents' nutritional status.

KEYWORDS

mental wellbeing, mental health, emotional eating, BMI, adolescents

Introduction

The high prevalence of inadequate Body Mass Index (BMI) among adolescents is a growing concern in public health and nutrition (1). According to the latest report from the World Health Organization (WHO), 8% of children and adolescents aged 5–19 worldwide are classified as obese (1). In Peru, two studies conducted in Lima revealed that 14 and 15.9% of adolescents are obese (2, 3). Moreover, inadequate BMI has significant psychological and physical effects on adolescents. Psychologically, it is associated with issues such as low self-esteem, depression, anxiety, and behavioral disorders (4). Physically, overweight and obesity increase the risk of cardiovascular problems and long-term non-communicable diseases (5).

Emotional eating is a significant factor contributing to inadequate BMI levels among adolescents. According to a representative study conducted in the United States in 2024, 30% of American adolescents reported eating in response to negative emotions, indicative of emotional eating (6). Furthermore, emotional eating in adolescents is associated with physical, psychological, and social consequences (7–11). Physically, it is linked to an increased risk of obesity and cardiovascular diseases due to the consumption of calorie-dense, nutrient-poor foods. Psychologically, it exacerbates depressive symptoms and contributes to the development of eating disorders, such as binge eating, creating a negative cycle of body dissatisfaction and mental health issues. Socially, poor emotional regulation and family environment play a role in fostering emotional eating, impacting interpersonal relationships and overall wellbeing. Finally, scientific literature has consistently demonstrated an association between emotional eating and BMI (12).

Mental wellbeing during adolescence is a public health issue and a key determinant of obesity and overweight in this age group (4, 13, 14). The World Health Organization (WHO) reported that one in seven adolescents aged 10–19 worldwide experiences mental wellbeing challenges (15). Moreover, mental wellbeing significantly impacts social, emotional, physical, and educational health outcomes (16). In the educational domain, mental wellbeing issues among adolescents can lead to poor school adaptation, concentration problems, and low academic performance (17). Psychologically, these challenges may result in anxiety, depression, psychological stress, and even suicide (18). Socially, they are associated with school dropout or expulsion and problematic peer relationships, while physically, they are linked to an increased rate of risky health behaviors, such as substance use (17). Finally, studies have demonstrated a relationship between mental wellbeing and BMI in adolescents (4).

Several studies have demonstrated the interaction between mental wellbeing and Body Mass Index (BMI) in adolescents (4, 14, 19–21). Similarly, other research has highlighted the relationship between emotional eating and BMI in this age group (8, 10, 12). However, there is a lack of studies investigating the combined impact of mental wellbeing and emotional eating on BMI. Considering the aforementioned points and the scarcity of research exploring BMI prediction based on independent variables such as emotional eating and mental wellbeing, this study seeks to provide a significant contribution to this field.

This research is justified by its contribution to understanding the interplay between mental wellbeing, emotional eating, and BMI in a sample of adolescents from northern Peru. Understanding these dynamics is essential for designing strategies that promote better

physical and mental health during this critical developmental stage. Additionally, the study will have a social impact by providing valuable information to public and private organizations, enabling them to address issues such as obesity, emotional eating, and mental wellbeing from a public health and nutritional perspective. The data generated will also be instrumental for educational institutions in designing and implementing programs that target both mental wellbeing and emotional eating, aiming to reduce obesity within the educational context. Finally, the study's findings will raise awareness of the importance of mental wellbeing and emotional eating in adolescents, empowering them to adopt healthier habits that contribute to maintaining an adequate BMI.

The general objective of this study is to determine the predictive role of mental wellbeing and emotional eating on BMI in a sample of Peruvian adolescents. Additionally, the specific objectives are as follows: (1) to determine the predictive role of mental wellbeing on BMI in a sample of Peruvian adolescents. (2) To analyze the predictive role of emotional eating on BMI in a sample of Peruvian adolescents. (3) To determine differences in mental wellbeing according to sex in a sample of Peruvian adolescents.

Materials and methods

Study design

This study employed a quantitative approach with a non-experimental, cross-sectional, and predictive design. The dependent variable was BMI, while the independent variables included mental wellbeing and emotional eating (22, 23).

Sample

The non-probabilistic sample consisted of 270 adolescents from the second to fifth year of a public educational institution in the province of Tocache, Peru (22). Inclusion criteria included adolescents of both genders, aged 12–18 years, who provided informed assent and whose parents signed informed consent forms. Exclusion criteria included adolescents undergoing psychological treatment or with prior diagnoses of depression, anxiety, or chronic stress. The required sample size for a multiple regression model was estimated using the G*Power 3.1.9.7 statistical program (24). Calculations indicated that a sample of 107 individuals was sufficient to detect effects with a significance level of $\alpha = 0.05$, statistical power of 0.95, a moderate effect size ($f^2 = 0.15$), and two predictors. However, to ensure greater precision and robustness in the analyses, a larger sample size was selected for this study ($n = 270$). Data collection took place during the first 2 weeks of December 2024. The instruments were administered in person, with a response time of 6–8 min per adolescent, and anthropometric measurements (weight and height) were conducted within a 4-min range. These measurements were performed by two trained nutritionists, who underwent a standardization process prior to data collection, and a single measurement was taken. Participants' responses were anonymous and voluntary.

Table 1 shows that the study participants consisted of 270 adolescents with an average age of 15.04 years ($SD = 1.08$). The gender

distribution was balanced, with a slight majority of females (51.5%) compared to males (48.5%). Regarding grade level, nearly half of the participants were in third (40%) or fourth grade (35.9%) of secondary school, while approximately one in 10 were in second grade (10%), and a minority were in fifth grade (14.1%). Finally, concerning BMI, the majority had a healthy weight (68.9%), about a quarter were overweight (27%), and a minority were classified as obese (4.1%).

Instruments and measurement equipment

Emotional eating scale (EES)

The Emotional Eating Scale (EES) was developed by Garaulet et al. (25) to assess the influence of emotions on eating behaviors. This instrument consists of 10 items rated on a Likert scale ranging from “Never” (1) to “Always” (5). In the Spanish context, the average reliability value for the subscales of the EES was 0.7, indicating acceptable internal consistency. The temporal stability of the instrument was confirmed through test–retest reliability, with a correlation coefficient of 0.70. Additionally, the scale demonstrated good convergent validity with the Mindful Eating Questionnaire (MEQ). In this study, the instrument’s reliability was adequate, with a McDonald’s ω of 0.718. Therefore, the EES proves to have good validity and reliability.

Mental health inventory (R-MHI-5)

The Mental Health Inventory (R-MHI-5) was developed by Berwick et al. (26) and is a tool designed to assess mental wellbeing in adolescents and adults. The scale evaluates mental wellbeing through two dimensions: the first measures the presence of psychological wellbeing (items 2 and 4), while the second assesses the absence of psychological distress using reverse-scored items (items 1, 3, and 5). Both dimensions reflect the individual’s mood and overall wellbeing. The inventory consists of 5 items, with response options on a Likert scale ranging from “Never” (0), “Sometimes” (1), “Often” (2), to “Always” (3). The R-MHI-5 was validated by Rojas-Mendoza et al. (27). Confirmatory factor analysis results indicated that a two-factor correlated model demonstrated superior fit indices (CFI = 0.99; TLI = 0.99; SRMR = 0.04; RMSEA = 0.101) compared to a unidimensional model (CFI = 0.85; TLI = 0.71; SRMR = 0.23; RMSEA = 0.451). The dimensions showed adequate reliability: psychological wellbeing (ω = 0.88) and psychological distress (ω = 0.79). In this study, the instrument’s reliability was adequate, with a McDonald’s ω of 0.617.

BMI

The BMI of adolescents was assessed using anthropometric measurements (weight and height), along with age and sex (28–30). Weight was measured using the Tanita (Baby/Mon) digital scale, model 1,582, while height was determined using a standard stadiometer. Anthropometric measurements (weight and height) were conducted following a standardized process based on the WHO recommendations (31). The age and sex were collected through a sociodemographic questionnaire. Additionally, BMI categories were determined according to the age- and sex-specific cut-off points established by WHO (32). Adolescents were classified as underweight (< −2 SD), normal weight (−2 SD to +1 SD), overweight (> +1 SD to +2 SD), and obese (> +2 SD) based on the BMI-for-age z-scores.

Statistical techniques for data analysis

Data analysis was conducted using SPSS software (version 29) and RStudio (version 2023.12.0–0). Descriptive analysis included measures of central tendency, such as the mean and standard deviation. For inferential analysis, Pearson’s correlation coefficient, Student’s *t*-test, and multiple linear regression models were employed. Additionally, the Kolmogorov–Smirnov test was used to assess data normality. However, according to the Central Limit Theorem, which states that in samples larger than 30 participants, the sampling distribution tends to normality, ensuring the validity of statistical methods, normality of the variables is not a fundamental requirement for the application of parametric tests such as Student’s *t*-test, Pearson’s correlation, and linear regression, especially in studies with large sample sizes (33). Furthermore, Cohen’s *d* was calculated to interpret the effect size and the magnitude of observed differences. A significance level of 5% (0.05) was used to determine the statistical significance of correlations and the coefficients in the multiple linear regression model, with a 95% confidence interval.

Results

The analysis of Table 2 reveals significant differences in mental wellbeing by sex, with males ($M = 17.36$, $SD = 2.92$) reporting higher levels than females ($M = 16.65$, $SD = 2.51$), accompanied by a small but meaningful effect size ($p = 0.033$, 95% CI = [0.057, 1.366], $d = 0.2617$). However, no significant differences in mental wellbeing were observed across age groups ($p = 0.361$, 95% CI = [−0.389, 1.063], $d = 0.1232$). For emotional eating, no significant differences were found by age ($p = 0.753$, 95% CI = [−2.233, 1.617], $d = -0.0406$) or sex ($p = 0.051$, 95% CI = [−0.359, 0.012], $d = -0.2375$), although females ($M = 25.95$, $SD = 7.87$) tended to score higher than males ($M = 24.16$, $SD = 7.16$), reflecting a small effect size. Finally, BMI showed no significant differences either by age ($p = 0.469$, 95% CI = [−1.019, 0.471], $d = -0.0963$) or by sex ($p = 0.865$, 95% CI = [−0.742, 0.624], $d = -0.0207$), with very similar averages across

TABLE 1 Sociodemographic characteristics and BMI of the study sample ($n = 270$).

Characteristics	<i>n</i>	%
Age ($M \pm SD$)	$M = 15.04$	$SD = 1.08$
Sex		
Male	131	48.5
Female	139	51.5
Grade level		
Second	27	10.0
Third	108	40.0
Fourth	97	35.9
Fifth	38	14.1
BMI		
Healthy weight	186	68.9
Overweight	73	27
Obesity	11	4.1

M, Mean; *SD*, Standard deviation; *BMI*, Body mass index.

TABLE 2 Descriptive and comparative analysis of mental wellbeing, emotional eating, and BMI by sociodemographic variables.

Sociodemographic variables	Mental wellbeing		Emotional eating		BMI	
	M (SD)	<i>p</i> , CI, <i>d</i>	M (SD)	<i>p</i> , CI, <i>d</i>	M (SD)	<i>p</i> , CI, <i>d</i>
Age^a						
12–14 years	17.22 (2.86)	0.361	24.87 (7.32)	0.753	22.01 (2.91)	0.469
15 a 18 years	16.89 (2.67)	[−0.389, 1.063] 0.1232	25.18 (7.70)	[−2.233, 1.617] −0.0406	22.28 (2.82)	[−1.019, 0.471] −0.0963
Sex^a						
Male	17.36 (2.92)	0.033*	24.16 (7.16)	0.051	22.17 (2.85)	0.865
Female	16.65 (2.51)	[0.057, 1.366] 0.2617	25.95 (7.87)	[−0.359, 0.012] −0.2375	22.22 (2.85)	[−0.742, 0.624] −0.0207

CI, Confidence Interval; *Student's *t*-test; *d*, Cohen's *d*. BMI, body mass index. **p* < 0.05. * indicates the statistical test used.

TABLE 3 Correlation analysis between mental wellbeing, emotional eating, and BMI in adolescents.

Variables	Mental wellbeing	Emotional eating	BMI
Mental wellbeing	1		
Emotional eating	−0.279*** [−0.386, −0.165]	1	
BMI	−0.277*** [−0.384, −0.163]	0.274*** [0.160, 0.381]	1

***The relationship analysis was done using Pearson's correlation coefficient; BMI, body mass index.

the analyzed groups. These findings indicate that mental wellbeing is the only variable with significant differences, particularly in relation to sex, while emotional eating and BMI remain consistent across the sociodemographic groups studied.

Table 3 shows the correlations between mental wellbeing, emotional eating, and BMI in adolescents. The results indicate a significant negative correlation between mental wellbeing and BMI ($r = -0.277$, $p < 0.001$, 95% CI = [−0.384, −0.163]), suggesting that higher mental wellbeing is associated with lower BMI in adolescents. Conversely, emotional eating is positively correlated with BMI ($r = 0.274$, $p < 0.001$, 95% CI = [0.160, 0.381]), implying that a decrease in emotional eating is associated with a lower BMI.

Table 4 presents the analysis of the multiple regression model, concluding that Model 2, compared to Model 1, is statistically significant both globally (adjusted $R^2 = 0.112$, $F = 17.953$, $p < 0.001$) and in the individual coefficients of the predictive variables ($p < 0.001$). Additionally, the lower BIC value in Model 2 (BIC = 1,318) supports that this model is more suitable and efficient for predicting BMI in the studied population. Regarding the explanatory power of the predictors, the adjusted coefficient of determination (adjusted $R^2 = 0.112$) indicates that mental wellbeing and emotional eating jointly explain 11.2% of the variability in adolescents' BMI. The standardized coefficients show that mental wellbeing has a significant negative effect on BMI ($\beta = -0.217$, 95% CI = [−0.3353, −0.0997], $p < 0.001$), while emotional eating exerts a significant positive effect ($\beta = 0.213$, 95% CI = [0.0952, 0.3308], $p < 0.001$). Both coefficients have similar magnitudes. These findings indicate that better mental wellbeing is associated with a lower BMI, while higher emotional eating is linked to an increased BMI in the evaluated adolescents.

In summary, the results show that, in descriptive and comparative terms, mental wellbeing exhibits significant differences by sex, being higher in males ($M = 17.36$, $SD = 2.92$) than in females ($M = 16.65$, $SD = 2.51$; $p = 0.033$, 95% CI = [0.057, 1.366], $d = 0.2617$). Correlation analyses reveal that mental wellbeing is negatively associated with

BMI ($r = -0.277$, $p < 0.001$, 95% CI = [−0.384, −0.163]), while emotional eating is positively associated with BMI ($r = 0.274$, $p < 0.001$, 95% CI = [0.160, 0.381]). In the multiple regression analysis, Model 2 emerges as the most suitable (adjusted $R^2 = 0.112$, $F = 17.953$, $p < 0.001$, BIC = 1,318), explaining 11.2% of the variability in BMI. The standardized coefficients indicate that mental wellbeing has a significant negative effect on BMI ($\beta = -0.217$, 95% CI = [−0.3353, −0.0997], $p < 0.001$), whereas emotional eating exerts a significant positive effect ($\beta = 0.213$, 95% CI = [0.0952, 0.3308], $p < 0.001$). Both coefficients show similar magnitudes.

Discussion

The high prevalence of inadequate BMI in adolescents represents a growing public health concern. Globally, 8% of children and adolescents aged 5–19 are classified as obese (1). In Peru, studies conducted in Lima report obesity rates of 14 and 15.9% (2, 3). This issue leads to psychological effects, such as low self-esteem, depression, and anxiety (4), as well as physical consequences, including overweight, obesity, and an increased risk of cardiovascular and non-communicable diseases (5). Inadequate mental wellbeing and emotional eating are significant factors contributing to unhealthy BMI values in adolescents (4, 12). Within this context, the primary objective of the present study is to determine the relationship between mental wellbeing, emotional eating, and BMI in a sample of Peruvian adolescents.

The present study found a significant negative association between mental wellbeing and BMI ($r = -0.277$, $p < 0.001$, 95% CI = [−0.384, −0.163]). Additionally, multiple regression analysis ($\beta = -0.217$, 95% CI = [−0.3353, −0.0997], $p < 0.001$) revealed that mental wellbeing is a significant predictor of BMI, suggesting that adolescents with higher levels of mental wellbeing are more likely to have lower BMI. These findings align with previous research. For

TABLE 4 Multiple regression model.

Model		Standardized coefficients		t	TOL	VIF	p
		β	CI				
1	(Constant)			7.724			< 0.001
	Mental wellbeing	−0.215	[−0.3352, −0.0958]	−3.544	0.896	1.116	< 0.001
	Emotional eating	0.219	[0.1007, 0.3377]	3.641	0.913	1.095	< 0.001
	Age	0.047	[−0.0674, 0.1618]	0.812	0.977	1.023	0.418
	Sex	−0.040	[−0.3106, 0.1490]	−0.693	0.970	1.031	0.489
2	(Constant)			17.952			< 0.001
	Mental wellbeing	−0.217	[−0.3353, −0.0997]	−3.635	0.922	1.084	< 0.001
	Emotional eating	0.213	[0.0952, 0.3308]	3.561	0.922	1.084	< 0.001

Dependent variable: body mass index (BMI); Model 1: R^2 adjusted = 0.109, ANOVA F ($F = 9.259, p < 0.001$), BIC = 1,328; Model 2: R^2 adjusted = 0.112, ANOVA F ($F = 17.953, p < 0.001$), BIC = 1,318. CI = Confidence interval.

instance, Chen et al. (19), in a study involving over 1 million adolescents from Europe and North America, reported that BMI was correlated with mental wellbeing. Specifically, adolescents with low body weight, overweight, or obesity exhibited more psychosomatic symptoms compared to those with healthy weight. Similarly, Nauli et al. (14), identified a correlation between nutritional status and mental wellbeing scores among Islamic adolescents. Förster et al. (20) also demonstrated a significant negative association between BMI and scores on the psychological wellbeing scale. In the same vein, Beltrán-Garrayo et al. (21), in a prospective study examining the relationship between obesity and mental health disorders from childhood to adolescence, found that adolescents with obesity exhibited a higher prevalence of mental health disorders. Moreover, psychological comorbidities increased over a five-year period, and childhood obesity was associated with a higher risk of psychological diagnoses in adolescence.

Scientific literature has shown that mental wellbeing issues, such as depression, anxiety, and low self-esteem, are more prevalent in adolescents with obesity compared to their non-obese peers (34). Depression, in particular, is closely linked to obesity, as the latter is considered an inflammatory state associated with depressive disorders (35). Mental health disorders, such as depression, can trigger inflammatory processes that are related to metabolic alterations and increased body weight (36). Additionally, mental wellbeing disturbances in adolescents are associated with increased release of stress-related neurotransmitters, such as cortisol and norepinephrine (37). Elevated and sustained cortisol levels are linked to abdominal fat accumulation, insulin resistance, and the development of unhealthy eating patterns (38). This imbalance can lead to frequent consumption of energy-dense foods, such as junk food, contributing to a higher Body Mass Index (BMI), overweight, and obesity (39). Stress and poor mental wellbeing also affect leptin function, a key hormone in appetite regulation and energy balance, resulting in excessive food consumption (40). Moreover, impaired mental wellbeing is associated with unhealthy lifestyles, including sedentary behavior, sleep disturbances, and disorganized eating habits, all of which increase the risk of overweight and obesity (35). Finally, adolescent mental wellbeing, both in the short and long term, is closely tied to higher body weight and its consequences, including cardiovascular diseases, type 2 diabetes, and other related conditions (19, 41). This highlights the critical importance of addressing mental wellbeing as a

fundamental component in the prevention and treatment of adolescent overweight and obesity.

On the other hand, this study also found a positive association between emotional eating and BMI ($r = 0.274, p < 0.001$, 95% CI = [0.160, 0.381]). Additionally, multiple regression analysis ($\beta = 0.213$, 95% CI = [0.0952, 0.3308], $p < 0.001$) revealed that emotional eating is a significant predictor of BMI, suggesting that adolescents with higher levels of emotional eating are more likely to have higher BMI. Similar results were reported by Bektas and Gürkan Kübrn (12), who demonstrated that adolescent BMI was positively correlated with emotional eating. Their study also showed that 14.1% of the variance in BMI levels was explained by emotional eating and self-efficacy in weight control. Likewise, Rachmawati et al. (10) found that emotional eating and the consumption of high-calorie snacks were associated with higher BMI, contributing to overweight in this population. Additionally, Shriver et al. (8) revealed that emotional eating was positively related to adiposity in late-stage adolescents.

Emotional eating is associated with increased BMI in adolescents due to several factors. First, eating in response to emotions rather than physical hunger activates the hypothalamic–pituitary–adrenal axis, increasing cortisol release, a hormone that stimulates appetite, particularly for sugar- and fat-rich foods (42). Second, consuming these foods triggers dopamine release in the brain, creating a pleasurable sensation that reinforces the habit of eating in response to negative emotions (43). Third, psychological factors such as low self-esteem, anxiety, and stress hinder healthy emotional regulation, promoting maladaptive eating patterns (44). Finally, emotional eating can contribute to overweight and obesity by establishing a cycle in which consuming calorie-dense foods as a coping strategy perpetuates energy imbalances, metabolic disruptions, and feelings of guilt, exacerbating the problem (45). This negative and cyclical dynamic underscores the need for further studies to deepen the understanding of these variables and the development of interventions targeting them to improve adolescents' quality of life.

In this comparative study, significant differences in mental wellbeing were identified by sex, with males ($M = 17.36$, $SD = 2.92$) reporting higher levels than female adolescents ($M = 16.65$, $SD = 2.51$; $p = 0.033$, 95% CI [0.057, 1.366], $d = 0.26$). This indicates that, on average, males reported higher mental wellbeing compared to females, and this difference is statistically significant. The effect size ($d = 0.26$) suggests a small magnitude

according to Cohen's criteria, indicating that while the difference is significant, its practical impact may be limited. Several studies have reported significant sex differences in mental wellbeing among adolescents, with findings showing higher wellbeing levels in males compared to females (46–49). Females tend to be more emotionally expressive, which may lead to a greater perception and reporting of emotional distress (50). Additionally, males often use coping strategies focused on distraction or externalization, whereas females may lean toward rumination, increasing their vulnerability to mental wellbeing issues (45, 51). Furthermore, societal expectations and gender roles may place additional burdens on female adolescents, negatively impacting their mental wellbeing (52). These findings highlight the importance of considering sex differences in the development of targeted interventions to support adolescent mental wellbeing.

According to the adjusted R^2 obtained from the multiple regression analysis (adjusted $R^2 = 0.112$), 11.2% of the variability in Body Mass Index (BMI) is explained by mental wellbeing and emotional eating. This indicates that the remaining 88.8% of BMI variability is associated with other variables not included in the model. These variables may include various factors influencing BMI, such as familial, social, and physical aspects, among others. Therefore, the 11.2% variability in BMI can be attributed to the combined influence of mental wellbeing and emotional eating.

Additionally, the study's results revealed that the standardized coefficients showed that mental wellbeing and emotional eating have similar effects on BMI (mental wellbeing: $\beta = -0.217$, 95% CI = $[-0.3353, -0.0997]$, $p < 0.001$; emotional eating: $\beta = 0.213$, 95% CI = $[0.0952, 0.3308]$, $p < 0.001$). This suggests that both variables contribute proportionally to the model, albeit in opposite directions. This finding implies that psychological factors, such as mental health, and behavioral factors, such as maladaptive eating behaviors, exert equivalent influence on BMI. This equivalence highlights the need to address both dimensions in an integrated manner within explanatory models and intervention designs. The relative balance of these factors underscores that psychological aspects, like mental wellbeing, can have as significant an impact as behavioral factors like emotional eating in weight regulation. This interplay emphasizes the importance of considering the interaction and synergy between these two factors to develop effective strategies for promoting holistic health in adolescents.

Public health implications

According to the results of this study, the implications for the field of nutritional public health are significant. First, it is recommended that programs aimed at reducing Body Mass Index (BMI) in adolescents adopt an integrated approach that considers mental health. This can be achieved by implementing strategies and developing skills that promote adolescent mental wellbeing. Additionally, intervention plans should address emotional eating by emphasizing the importance of understanding the underlying reasons for eating—whether to satisfy a physical need or as a response to emotions. In this regard, it is essential to educate adolescents about the risks and implications of emotional eating, fostering greater awareness of their eating patterns and the impact these have on their physical and mental health. Second,

public health interventions, particularly in nutritional public health, should adopt a holistic perspective. This means not limiting efforts solely to the physical aspect but also integrating the mental and emotional-behavioral components of adolescents. Such an integrated approach would more effectively address the multiple dimensions influencing BMI and the overall health of this age group, thereby promoting more sustainable and personalized interventions. Finally, the finding that mental wellbeing and emotional eating have a similar impact on adolescents' BMI underscores the need for intervention programs to emphasize both constructs equally. Consequently, public health policies aimed at reducing BMI in this population must be multifaceted, integrating strategies that address not only physical factors but also mental and emotional-behavioral aspects. This holistic approach will enable the design of more comprehensive and effective interventions, promoting the overall wellbeing of adolescents.

Limitations and future perspectives

The results of this study are significant and highly relevant, as previously mentioned and discussed. However, it is important to acknowledge certain limitations. First, the cross-sectional design does not allow for causal relationships to be established between BMI and the variables evaluated in adolescents, limiting the findings to correlations. Additionally, the non-probabilistic sample was restricted to adolescents from a specific geographic region in northern Peru, which limits the generalizability of the results to other populations with different sociodemographic and cultural characteristics. One of the limitations of this study is that variables such as diet, physical activity, or socioeconomic status, among others, were neither collected nor adjusted for, despite being key determinants of BMI. This may influence the results and should be interpreted within this context. This aspect could be considered as an objective for future studies. Finally, the use of self-reported instruments may be subject to social desirability bias and potential errors in participants' perception or recall, which should be considered when interpreting the findings. In terms of future perspectives, it is recommended that research explore the variables considered in this study using alternative statistical approaches, such as mediation, moderation, or structural equation modeling. Moreover, it would be valuable to assess the dynamics between mental wellbeing and emotional eating through longitudinal studies to observe changes and patterns over time. Future studies should include more diverse samples, considering geographic, socioeconomic, and cultural origins, to examine whether these findings replicate in different contexts. Finally, incorporating additional explanatory factors of BMI, such as contextual and familial influences, is suggested to achieve a more comprehensive understanding of the factors affecting BMI in adolescents.

Conclusion

The results of this study indicate that mental wellbeing and emotional eating exert opposing but equally significant influences

on BMI in Peruvian adolescents. Higher mental wellbeing is associated with lower BMI, whereas higher emotional eating correlates with increased BMI. These findings highlight the need for interventions that integrate both psychological and behavioral factors to improve adolescents' nutritional status and overall wellbeing. From a public health perspective, addressing mental wellbeing alongside dietary habits is essential for effective BMI management. Schools, healthcare institutions, and policymakers should implement strategies that promote mental wellbeing and equip adolescents with coping mechanisms to reduce emotional eating. Despite its contributions, this study has limitations. The cross-sectional design does not establish causality, and the non-probabilistic sample limits generalizability. Future research should employ longitudinal designs and incorporate additional factors such as physical activity and socioeconomic status to enhance understanding of BMI regulation in adolescents. In conclusion, mental wellbeing and emotional eating play a crucial role in BMI variations among adolescents. Their balanced yet opposite influence underscores the need for multidimensional interventions that address both mental health and eating behaviors to develop more effective public health strategies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of the Faculty of Health Sciences at Universidad Peruana Unión (2024-CEB-FCS-UPeU-No. 264). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

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Factors associated with vegetable and fruit intake among adolescents with overweight and obesity in Selangor from 2020 to 2021

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Background: Substantial scientific evidence firmly advocates consumption of vegetables and fruits for maintenance of overall health and protection against chronic diseases, such as obesity. However, prevalence of fruit and vegetable intake among adolescents in Malaysia remains low, whereas the data on factors associated with vegetable and fruit intake among adolescents were limited.

Objective: This study aims to determine the prevalence of fruit and vegetable intake and the factors that influence the Malaysian adolescents' consumption of fruits and vegetables.

Methods: A cross-sectional study was conducted from November 2021 to August 2022 by distribution of an online validated questionnaire on various platforms to recruit school-going adolescents aged 13 to 17 years old (Form 1–5) in Selangor. Respondents were screened and data of eligible participants were included as subjects. Descriptive statistics, chi square analysis, and generalized linear model with Poisson-loglinear distribution and the robust estimator were employed for data analysis.

Results: A total of 277 adolescents participated in this study. Overall, low prevalence of adequate vegetable consumption was observed (23.5%). Of the participants surveyed, 14.8% of adolescents with thinness, 25.2% and 15.0% of adolescents with overweight and obesity, and 27.1% of normal-weight adolescents met the recommended daily intake (>3 servings), whereas 64.1% of adolescents with overweight and obesity and 65% of normal-weight participants consumed at least two servings of fruits a day. The findings revealed significant association between BMI-for-age ($X^2_{(1,N=277)} = 5.236, p = 0.022$) and adolescent fruit intake. On the other hand, overweight and obese adolescents reporting positive intention (PR: 1.146, 95% CI: 1.002, 1.310, $p = 0.047$) and parental allowance (PR: 1.125, 95% CI: 1.011, 1.252, $p = 0.030$) were observed to have 14.6% and 12.5% higher prevalence of fruit consumption, respectively, while availability at home (PR: 0.849, 95% CI: 0.731, 0.987, $p = 0.033$) showed significantly lower prevalence of fruit intake with more reports of home availability.

Conclusion: The study suggests that personal, social-environmental, and physical-environmental factors influence vegetable and fruit intake among adolescents, particularly fruit intake consumption behaviors among overweight

and obese adolescent population in Selangor. The enunciation of these intake correlates could potentially be incorporated in future development of intervention strategies to effectively promote fruit and vegetable intake.

KEYWORDS

vegetables, fruits, prevalence, factors, personal, social-environmental, physical-environmental, adolescents

1 Introduction

Adequate consumption of vegetables and fruits is a key strategy in the prevention of obesity. The WHO reported that up to 43% and 16% of the individuals worldwide were either overweight or obese (1). In Malaysia, obesity has been at the forefront of public health issues, with 50.1% of the population either overweight or obese. A high prevalence was also observed among the Malaysian adolescents, with 15.0% of them being overweight and 14.8% of them obese (2). Adequate intake of vegetables and fruits can protect against obesity by counteracting excessive adiposity. Vegetables and fruits do this by increasing bioavailable fibers in the body, which lowers hunger and increases satiety, leading to a decrease in overeating, which is one of the major causes of obesity (3). Another study of the effects of vegetables and fruits against obesity showed a reduction in fat mass composition and body mass index, as well as a 12% decrease in the risk of abdominal obesity among the participants, who have complied with the standard recommendations of vegetable and fruit intake (4). Thus, the importance of adequate vegetable and fruit intake in reducing obesity is further enunciated.

However, despite the known benefits of vegetable and fruit consumption, a low prevalence of vegetable and fruit intake is still observed globally. In 2019, the global prevalence of dietary patterns among adolescents indicated that 34.5% and 20.6% of adolescents have fruits and vegetables less than once a day, a substantial contrast to the recommended five daily servings of fruits and vegetables (5). Similarly, a study conducted in five Southeast Asian countries (Thailand, Myanmar, Indonesia, India, and Sri Lanka) showed that 76% of adolescents aged 13–15 years across all five countries failed to meet the recommended number of servings of fruits and vegetables (6). Similarly, in Malaysia, the prevalence of vegetable and fruit consumption (at least five servings daily) is also extremely low, especially among adolescents, at only 23.5% in the National Health and Morbidity Survey (NHMS) 2017 (7), a drop from the 28.7% prevalence reported in the NHMS 2012 (8). The recent prevalence reported by the Adolescent Health Survey 2022 shows an even lower prevalence, with only 16.1% of adolescents meeting the recommended intake of vegetables and fruits (9).

Studies have emphasized the association of personal, social, and physical-environmental factors with vegetable and fruit intake. Deliens et al. explained that factors such as personal and individualized factors act as key contributors to food decisions, underscoring their significant role in shaping dietary habits. This is due to their close relation to human behaviors shaped from childhood (10). Within the domain of personal factors, evidence

has shown several aspects linked to vegetable and fruit intake among adolescents. Rohin et al. (11), in their study in rural Terengganu, found that knowledge, attitude, liking, self-efficacy, intention, and habit were important determinants of vegetable and fruit consumption behaviors. This was further supported by Rahmawati et al. (12) and Hill et al. (13), whereby their studies demonstrated a significantly positive association between knowledge and vegetable and fruit intake. On the other hand, a Thai study has also reported significant associations between positive attitudes toward vegetables and fruits with adequate vegetable and fruit intake (14), while Woodruff (15), Salwa et al. (16), and Moraes et al. (17) reported that determinants such as preference or liking, positive behavioral intentions, and higher levels of self-efficacy toward vegetables and fruits can birth similar results.

Social or social-environmental factors act as another domain closely associated with vegetable and fruit consumption behaviors (11, 18). A network of social relationships is a crucial source of support and seems to have an important impact on health behaviors. This includes relationships and communities that surround the individuals at home, school, workplace, and neighborhood. Substantial evidence supports this notion with evidence of significant associations between vegetable and fruit intake with determinants such as positive parental modelling (18), reinforcing family rules of demand and allows (19), as well as peer influence (20), all can significantly impact the dietary behavior of adolescents toward vegetables and fruits.

On top of that, physical-environmental factors also substantially contribute to the adolescents' consumption behavior toward vegetables and fruits, with emphasis on food availability as the sole most impactful physical-environmental factor in vegetable and fruit consumption. Growing evidence suggests that food availability at home is strongly related to the dietary intake of adolescents. It has been reported that adolescents with lower food availability at home contribute to consuming less fruit (21). Findings from the Family Life, Activity, Sun, Health, and Eating (FLASHE) study revealed that an increased intake of vegetables and fruits would occur when there was a higher availability of vegetables (22). Gustafson and colleagues studied the direct and indirect impacts of food purchasing behaviors, as well as home, school, and consumer food environments, on dietary intake among rural adolescents (23).

The prevalence of obesity and overweightness in Malaysia is widespread across the country. According to the NHMS 2022, Selangor ranked as one of the highest for population obesity among all regions of Malaysia (9). The national data revealed that 17.5% of the populations in Selangor were overweight while 12.6 were

obese. Koo et al. (24) highlighted that the increasing prevalence of obesity and overweightness in Selangor was also proportional to the spike in other non-communicable diseases. On top of that, fruit and vegetable intake within the region was consistently low for the past several years, with the latest data revealing only 14.3% consuming adequate vegetables and fruits as per the recommendation (9). This hence forth put Selangor as one of the focus areas for public health interventions. Given the escalating prevalence of obesity and NCDs, it is especially crucial to focus on vegetable and fruit intake as a catalyst for change. The factors associated with the consumption of vegetables and fruits should be highlighted in a multi-sectoral effort. This collaborative approach can help design a tailored intervention strategy to address the issues of obesity and promote the consumption of vegetables and fruits among adolescents. This present study aims to support such developments by provided regional data to better tailor future interventions for highest effectiveness.

Moreover, research on vegetable and fruit intake and behaviors among the adolescents in Selangor, especially those who are overweight or obese, is currently limited. In 2020, we found that there is a relatively apparent gap in research focusing on specific factors or predictors that influence fruit and vegetable consumption within this specific population (obese and overweight adolescents) in Selangor. Existing regional data for the past years consistently covered the prevalence of intake among the adolescents in general (7), however there is a notable scarcity of data and information on the factors that contribute to such behaviors, especially within this population. Therefore, given the importance of said data in regional adolescent public health development and intervention, this study aims to bridge this gap by investigating the factors associated with vegetable and fruit intake behaviors among adolescents with overweight and obesity in Selangor. The goal is to contribute to the improvement of the current situation. We hypothesize that a significant association can be found between factors such as personal, social-environmental, and physical-environment, and vegetable and fruit intake among overweight and obese adolescents in Selangor.

2 Materials and methods

2.1 Research design and population

This study adopted a cross-sectional research design. From November 2021 to August 2022, 9 months were utilized for the completion of this study. The target population of this study, as specified in the inclusion criteria, was school-going Malaysian adolescents between the ages of 13 to 17 living in Selangor, Malaysia. Non-Malaysians and individuals with diet-related or chronic diseases were excluded from the study.

The sample size was calculated using Cochran's single proportion formula for sample size calculation (25). The sample size calculation for this study includes a confidence interval (z) of 95% = 1.96, with an estimated prevalence of the population that consume fruit and vegetables (p) at only 23.5% (7) and a margin of error (e) of 0.05. The sample size calculated amounted to 277 participants.

This study adopted convenience sampling as the sampling method. An online questionnaire (Google form) on vegetable and fruit intake was designed and advertised on various social media platforms (such as WhatsApp, Telegram, Facebook, and Instagram) and aimed to recruit participants in the state of Selangor. Non-Selangor citizens were excluded from this study. Eligible participants' who have signed the consent form were included as part of the study.

2.2 Ethical approval

This study was conducted with ethical approval (Code: UKM PPI/111/8/JEP-2022-226) from the Human Research Ethics Committee of Universiti Kebangsaan Malaysia.

2.3 Data collection

The main means of data collection was a four-part self-reporting online questionnaire. Part 1 and Part 2 ask for sociodemographic factors and anthropometry measurements. Part 3 and Part 4 ask questions on the frequency of fruit and vegetable intake and the factors that influenced it. This version of the questionnaire was validated by Rohin et al. (11) and De Bourdeaudhuij et al. (26), respectively for the Malay and English version.

Part 1: Sociodemographic factors

This section explains the collected data on the adolescents' sociodemographic factors, including age, sex, ethnicity, parents' education level, and household income.

Part 2: Anthropometry measurements

The respondents self-reported their body weight and height. Their body mass indexes (BMI) were then calculated and categorized according to the BMI-for-age z-score (BAZ). Respondents were categorized into groups, which included "thin" if their BAZ values were < -2 SD, "normal" if their BAZ values were between ≥ -2 SD and $\leq +1$ SD, and "overweight" if their BAZ values were $> +1$ SD and "obese" if their BAZ values $> +2$ SD.

Part 3: Frequency of vegetable and fruit intake

This questionnaire comprised questions on the frequency and amount of vegetable and fruit intake. There are two separate sections: frequency and amount of intake. For frequency, the participants were asked how often they consumed vegetables and fruits in a week. The response categories were never, 1 day, 2–4 days, 5–6 days, and every day. For amount, the participants were also asked how many servings of vegetables and fruits they consumed per day, with the response categories being No, one, two, three, four and five or more servings. The amount of participants' vegetable and fruit intake was assessed using the Malaysian Dietary Guidelines for Children and Adolescents 2023 (MDGCA 2023) (27) to determine whether they met the recommended servings, which are five servings (three servings of vegetables and two servings of fruits) daily.

Part 4: Factors associated with vegetable and fruit intake

This section has questions regarding the personal, social-environmental, and physical-environmental correlates of fruit and vegetable intake, as adapted from De Bourdeaudhuij et al. (26) and Malay version of De Bourdeaudhuij et al.'s questionnaire (26) adapted and validated by Rohin et al. (11). Validation of this questionnaire revealed that the internal consistency and test-retest reliability of the scales range between Cronbach's α values of 0.52 to 0.89 and Intraclass Correlation Coefficient (ICC) values of 0.52 to 0.85, which were comparable between all five countries involved in the testing (26). Permission to use the questionnaires was obtained from both authors. For this study, different components were included to fully encompass the possible domains of the possible associated factors, including personal factors (knowledge, attitude, liking, self-efficacy, intention, and habit), social-environmental factors (parental modelling, peer modelling, parental encouragement, parental demand, and parental allowance), and physical-environmental factors (availability of fruits and vegetables at home, school, friends' homes, and leisure places). The response category for all these questions was in the form of Likert scales: from Fully Agree (+2) to Fully Disagree (−2) and Very Often (+2) to Never (−2).

2.4 Data analysis

Statistical Package for the Social Sciences Statistics (SPSS version 28) was used to analyze the collected data. This study employed four main statistical analysis to fulfil the research objectives. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to present the demography and characteristic of the study population. Data on adequacy of vegetable and fruit intake was obtained from computing frequency of intake and number of daily servings into new dichotomous variables. Cases with intake of 7 days and 3 or more daily number of servings (two or more for fruit intake) were denoted as 1, while other entries were put as 0, following the Malaysian Dietary Guidelines for Children and Adolescents 2023 (27). Frequencies and percentages were then used to present the prevalence of vegetable and fruit intake within the population. The chi-square test was used to identify the associations between sociodemographic factors such as age, gender, ethnicity, parent's education level, household income status, and BMI-for-Age with vegetable and fruit intake. Generalized linear model (GLM) with Poisson loglinear distribution and the robust estimator was employed to model the adolescent vegetable and fruit intake based on potential associated factors, including personal factors (knowledge, attitude, liking, self-efficacy, intention, and habit), social-environmental factors (parental modelling, peer modelling, parental encouragement, parental demand, and parental allowance), and physical-environmental factors (availability of fruits and vegetables at home, school, friends' homes, and leisure places). These variables were treated as scores of −2 to +2, and included into the model as continuous variables. A *p*-value of <0.05 was applied as the cut-off for significance.

TABLE 1 Sociodemographic characteristics of adolescents (*N* = 277).

Sociodemographic factors	Frequency ¹ (<i>N</i>)	Percentage ¹ (%)
Age		
13	49	17.7
14	36	13.0
15	63	22.7
16	83	30.0
17	46	16.6
Sex		
Male	146	52.7
Female	131	47.3
Ethnicity		
Malay	89	32.1
Chinese	125	45.1
Indian	56	20.2
Others	7	2.5
Parents' education level		
Primary	34	12.3
Secondary	127	45.8
Tertiary	116	41.9
Household income status		
B40	88	31.8
M40	111	40.1
T20	78	28.2
BMI-for-age		
Normal/thinness	134	48.4
Overweight/obesity	143	51.6

¹ Descriptive statistics was employed to obtain sociodemographic information of the sample.

3 Results

3.1 Sociodemographic factors

Table 1 shows the sociodemographic information of the participants in this study. A total of 277 adolescents aged 13–17 years (mean age and SD) participated in this study. More than half of the participants are male (*n* = 146, 52.7%). In terms of ethnicity, most are Chinese (*n* = 125, 45%) and have parents with at least secondary school education (*n* = 127, 45.8%). Meanwhile, 40.1% of the participants have moderate family income (*n* = 111). Most of the participants were either overweight or obese (*n* = 143, 51.6%), while others had normal BMI or were thin (*n* = 134, 48.4%).

3.2 Prevalence of vegetable and fruit intake

Table 2 shows the prevalence of vegetable and fruit intake by BMI-for-age status. In this study, the overall prevalence of

TABLE 2 Prevalence of vegetables and fruits of adolescents by BMI-for-age.

	Vegetable intake < 3 servings/day N (%) ¹	Vegetable intake ≥ 3 servings/day N (%) ¹	Fruit intake < 2 servings/day N (%) ¹	Fruit intake ≥ 2 servings/day N (%) ¹
Overall	212 (76.5)	65 (23.5)	117 (42.2)	160 (57.8)
BMI-for-age				
Thinness	23 (85.2)	4 (14.8)	13 (48.1)	14 (51.9)
Normal	78 (72.9)	29 (27.1)	53 (49.5)	54 (50.5)
Overweight	77 (74.8)	26 (25.2)	37 (35.9)	66 (64.1)
Obesity	34 (85.0)	6 (15.0)	14 (35.0)	26 (65.0)

¹ Descriptive statistics was used to determine the prevalence of vegetable and fruit intake.

adolescents who met the recommended intake of vegetables and fruit were 23.5% and 57.8%, respectively. A lower percentage of overweight (25.2%) and obese (15.0%) adolescents consumed more than three servings of vegetables. However, the lowest prevalence was observed among thin adolescents (14.8%), while 27.1% of normal BMI adolescents contributed to the overall prevalence. As for fruit consumption of more than two servings, up to 57.8% of all adolescents consumed the recommended amount of fruits, which includes 51.9% of thin adolescents, 50.5% of adolescents with normal BMI, and 64.1% and 65% of overweight and obese adolescents, respectively.

3.3 Association of sociodemographic factors with vegetable and fruit intake

The associations between sociodemographic factors and vegetable and fruit intake of the adolescents are shown in Tables 3, 4. Fisher's exact test was applied when the expected frequencies assumption was violated for ethnicity in Table 4. The findings observed a significant association between sociodemographic factor, BMI-for-age ($\chi^2_{(1, N=277)} = 5.236, p = 0.022$), with fruit intake among overall adolescents. However, no significant association was found between sociodemographic factors and vegetable intake of all adolescents. Similarly, when observing the association between all the sociodemographic factors and the vegetable and fruit intake of overweight and obese participants, no significant association was found. Intake specified among overweight and obese participants; no significant association was found.

3.4 Personal, social-environmental, and physical-environmental factors associated with vegetable and fruit intake

Tables 5, 6 show the associations among personal, social-environmental, and physical environmental factors and the prevalence of vegetable and fruit intake among the adolescent participants, particularly adolescents with overweightness and obesity.

This study observed significant association between physical-environmental factors with adequate vegetable intake among

the overall adolescent sample. Adolescents with positive reports of availability at friend's house (PR: 0.804, 95% CI: 0.669, 0.967, $p = 0.020$) and at places of leisure (PR: 0.755, 95% CI: 0.590, 0.967, $p = 0.026$) both revealed 19.6% and 24.5% lower prevalence of vegetable consumption. Meanwhile, personal and social-environmental factors did not portray any significant influence on the population vegetable consumption.

On the other hand, the study highlighted self-efficacy (PR: 1.102, 95% CI: 1.013, 1.198, $p = 0.024$), and intention (PR: 1.126, 95% CI: 1.013, 1.251, $p = 0.028$) as significant correlates of fruit intake among the general adolescent population, with positive self-efficacy and intention fostering higher prevalence of fruit consumption within the population. In contrast, habit (PR: 0.909, 95% CI: 0.830, 0.996, $p = 0.41$), and the physical-environmental factor, availability at places of leisure (PR: 0.874, 95% CI: 0.793, 0.963, $p = 0.006$), significantly lower prevalence of fruit intake among the general adolescent population, while no significant association were found among social-environmental factors and fruit intake within the overall adolescent sample.

For overweight and obese adolescents, the findings indicated no significant association between the personal, social-environmental, and physical-environmental factors with vegetable intake. However, overweight and obese adolescents reporting positive intention (PR: 1.146, 95% CI: 1.002, 1.310, $p = 0.047$) and parental allowance (PR: 1.125, 95% CI: 1.011, 1.252, $p = 0.030$) were observed to have 14.6% and 12.5% higher prevalence of fruit consumption, respectively, while availability at home (PR: 0.849, 95% CI: 0.731, 0.987, $p = 0.033$) showed significantly lower prevalence of fruit intake with more reports of home availability.

4 Discussion

4.1 Prevalence of vegetable and fruit intake

The findings of this study revealed a low consumption of fruits and vegetables observed among overweight and obese adolescents in Selangor. From the results, only 23.5% of the adolescent participants have met the recommended daily intake of vegetables, set at equal to or more than three servings per day, as suggested by the Malaysian Dietary Guideline for Children and Adolescents 2023, in line with standards of the World Health Organization (27, 28). In comparison, the national prevalence of vegetable intake, as of 2022, was at 27.1%, which is like the prevalence found

TABLE 3 Associations of sociodemographic factors with fruit and vegetable intake of overall adolescents.

Sociodemographic factors	Fruit intake ¹		χ^2	Vegetable intake ¹		χ^2
	< 2 servings <i>n</i> = 117	≥ 2 servings <i>n</i> = 160		< 3 servings/day <i>n</i> = 212	≥ 3 servings/day <i>n</i> = 65	
Age			4.092			3.592
13	24 (20.5)	25 (15.6)		33 (15.6)	16 (24.6)	
14	15 (12.8)	21 (13.1)		27 (12.7)	9 (13.8)	
15	28 (23.9)	35 (21.9)		50 (23.6)	13 (20.0)	
16	28 (23.9)	55 (34.4)		64 (30.2)	19 (29.2)	
17	22 (18.8)	24 (15.0)		38 (17.9)	8 (12.3)	
Gender			1.293			0.005
Male	57 (48.7)	89 (55.6)		112 (52.8)	34 (52.3)	
Female	60 (51.3)	71 (44.4)		100 (47.2)	31 (47.7)	
Ethnicity			0.859			2.567
Malay	40 (34.2)	49 (30.6)		73 (34.4)	16 (24.6)	
Chinese	53 (45.3)	72 (45.0)		91 (42.9)	34 (52.3)	
Indian	21 (17.9)	35 (21.9)		43 (20.3)	13 (20.0)	
Others	3 (2.6)	4 (2.5)		5 (2.4)	2 (3.1)	
Parent's education level			0.245			1.175
Primary	14 (12.0)	20 (12.5)		25 (11.8)	9 (13.8)	
Secondary	52 (44.4)	75 (46.9)		101 (47.6)	26 (40.0)	
Tertiary	51 (43.6)	65 (40.6)		86 (40.6)	30 (46.2)	
Household income status			1.140			0.423
Bottom 40%	34 (29.1)	54 (33.8)		67 (31.6)	21 (32.3)	
Middle 40%	51 (43.6)	60 (37.5)		87 (41.0)	24 (36.9)	
Top 20%	32 (27.4)	46 (28.7)		58 (27.4)	20 (30.8)	
BMI-for-age			5.236*			0.195
Normal/thinness	66 (56.4)	68 (42.5)		101 (47.6)	33 (50.8)	
Overweight/obesity	51 (43.6)	92 (57.5)		111 (52.4)	32 (49.2)	

¹ Association between sociodemographic and physical characteristics and vegetable and fruit intake of overall adolescents: Chi square analysis

*Significant association between BMI-for-age and vegetable intake: $p < 0.05$.

in this study (9). In retrospect to both rates, the NHMS 2017 observed a higher percentage of adolescents meeting the vegetable intake recommendation, which had been at 36.0% (7). At the same time, Rohin et al. (11) found that vegetable intake among adolescents in rural Terengganu showed that only 9% had adequate vegetable intake as per the recommendation, which had been substantially lower than that of this study as well as the national prevalence. However, rurality may play a part in these contrasting results. As studies suggest, rurality and sociodemographic factors do affect health literacy (29). Nevertheless, despite the fluctuating rates observed, the findings across these studies suggest that the prevalence of adequate vegetable intake remains low in the country, especially accounting for the national prevalence across the years.

57.8% of the adolescents were reported to have two or more servings of fruit per day, as per the recommendation of the MDGCA 2023 (27). This was significantly higher than the national prevalence of NHMS 2022, which was at 37.3% (9). Meanwhile, the

NHMS 2017 reported up to 46.8% of adequate fruit intake among adolescents (7). This suggests that both reports of the national prevalence were lower compared to the findings of this study. Jamaludin et al. (30) found that in Marang and Hulu Terengganu, lower rates of prevalence were observed, with adequate fruit intake among adolescents was 21.7%. Similarly, a study in Ghana reported only 35.7% of adolescents had adequate fruit intake (31). Although this study suggests a higher prevalence of fruit intake of more than 50% among adolescents in Selangor, other studies, as well as the national prevalence, ultimately suggest a low prevalence of adequate fruit intake among adolescents nationally.

Among the participants with overweight and obesity, the findings showed that 25.2% of overweight and 15.0% of obese adolescents had met the recommended serving of vegetables per day, indicating that only a few of the participants achieved the recommended intake suggested in the Malaysian Dietary Guideline for Children and Adolescents (MDGCA) 2023 (27). In NHMS

TABLE 4 Associations of sociodemographic factors with fruit and vegetable intake of overweight and obese adolescents.

Sociodemographic factors	Fruit intake ¹		χ^2	Vegetable intake ¹		χ^2
	< 2 servings <i>n</i> = 51	≥ 2 servings <i>n</i> = 92		< 3 servings/day <i>n</i> = 111	≥ 3 servings/day <i>n</i> = 32	
Age			5.274			2.676
13	10 (19.6)	14 (15.2)		16 (14.4)	8 (25.0)	
14	8 (15.7)	13 (14.1)		17 (16.3)	4 (12.5)	
15	15 (29.4)	17 (18.5)		24 (21.6)	8 (25.0)	
16	11 (21.6)	36 (39.1)		38 (34.2)	9 (28.1)	
17	7 (13.7)	12 (13.0)		16 (14.4)	3 (9.4)	
Gender			0.526			0.364
Male	29 (56.9)	58 (63.0)		69 (62.2)	18 (56.3)	
Female	22 (43.1)	34 (37.0)		42 (37.8)	14 (43.8)	
Ethnicity			2.382			2.723
Malay	17 (33.3)	27 (29.3)		37 (33.3)	7 (21.9)	
Chinese	22 (43.1)	35 (38.0)		41 (36.9)	16 (50.0)	
Indian	10 (19.6)	28 (30.4)		29 (26.1)	9 (28.1)	
Others	2 (3.9)	2 (2.2)		4 (3.6)	0 (0)	
Parent's education level			4.991			4.361
Primary	1 (2.0)	12 (13.0)		8 (7.2)	5 (15.6)	
Secondary	26 (51.0)	44 (47.8)		59 (53.2)	11 (34.4)	
Tertiary	24 (47.1)	36 (39.1)		44 (39.6)	16 (50.0)	
Household income status			4.741			1.166
Bottom 40%	11 (23.4)	36 (39.1)		37 (33.3)	10 (31.3)	
Middle 40%	23 (43.4)	39 (34.1)		43 (38.7)	10 (31.3)	
Top 20%	17 (39.5)	26 (27.7)		31 (27.9)	12 (37.5)	

^aFisher's exact test was applied.

¹Association between sociodemographic and physical characteristics and vegetable and fruit intake of obese and overweight adolescents: Chi square analysis.

2017, adequate vegetable intake among overweight and obese adolescents was reported at 9.1% and 5.9%, respectively (7). Similarly, Selamat et al. (32) reported only 3.6% of overweight and obese adolescents had met the recommended intake for vegetables. The current study showed a greater number of adequate vegetable intakes among overweight and obese adolescents as compared to the national prevalence reported in NHMS 2017 (7). Seidu et al. (31), in comparison, revealed a higher prevalence, with 28.7% of overweight and 33.1% of obese adolescents had adequate vegetable consumption, and higher than our study prevalence.

On the other hand, our study reported a total of 64.1% of overweight and 65.0% of obese adolescents to be having adequate fruit intake daily. In contrast, lower percentage of overweight (27.5%) and obese (32.8%) adolescents consumed adequate amounts of fruits were reported in NHMS 2017 (7). Comparable to the findings on vegetable intake, this study showed a higher number of adequate fruit intake among overweight and obese adolescents compared to the percentage reported in NHMS 2017 (7). Seidu et al. (31) also found comparable results in Ghana with 33.0% of overweight and 26.4% of adolescents with obesity have met the recommended intake for fruits. Meanwhile, Selamat

et al. (32) also found relatively similar results with only 32.6% of overweight and obese adolescents having adequate intake of fruits.

In contrast, the present study suggests higher intake of fruits among overweight and obese adolescents compared to those of normal weight, which may contradict the general consensus. This could potentially be attributed to societal pressure. For the past several years, a rise in knowledgeable social media influencers (SMI) covering various range of topics including healthy lifestyles and diets has shifted the societal expectations among Malaysian youth (33). It has then led a social contagion mimicking the healthy diet and lifestyle of SMIs, which became prevalent among adolescents, due to their susceptibility to peer influence and social media (34). On top of that, Farhat et al. (35) revealed that adolescents with overweight and obesity are significantly influenced by stigmatization and social comparison, which was seen to have significant associations with social media usage (36). With such trends circulating, it can be postulated that the higher intake of fruits among overweight and obese adolescents could be the result of societal conformity.

Overall, our study shows evidence that the prevalence of vegetable intake among overweight and obese adolescents remains

TABLE 5 Personal, social-environmental, and physical-environmental factors associated with vegetable and fruit intake of overall adolescents.

Factors	Vegetable intake ¹		Fruit intake ¹	
	PR	95% CI	PR	95% CI
Personal				
Knowledge	1.107	0.896, 1.368	0.985	0.892, 1.089
Attitude	1.090	0.858, 1.386	0.988	0.907, 1.078
Liking	0.882	0.730, 1.064	1.118	0.999, 1.252
Self-efficacy	1.125	0.952, 1.329	1.102	1.013, 1.198*
Intention	0.931	0.780, 1.111	1.126	1.013, 1.251*
Habit	1.067	0.856, 1.330	0.909	0.830, 0.996*
Social-environmental				
Parental modeling	1.189	0.906, 1.561	0.945	0.838, 1.065
Peer modeling	0.911	0.697, 1.192	0.962	0.857, 1.079
Parental encouragement	0.986	0.680, 1.428	1.028	0.865, 1.221
Parental demand	1.031	0.868, 1.226	1.044	0.955, 1.142
Parental allowance	0.938	0.780, 1.127	1.045	0.958, 1.139
Physical-environmental				
Availability at home	1.102	0.829, 1.463	0.969	0.849, 1.106
Availability at school	1.109	0.917, 1.341	0.950	0.876, 1.031
Availability at a friend's house	0.804	0.669, 0.967*	0.971	0.883, 1.069
Availability at leisure place	0.755	0.590, 0.967*	0.874	0.793, 0.963*

Vegetable intake: *p-value < 0.05; **p-value < 0.001.
Fruit intake: *p-value < 0.05; **p-value < 0.001.
¹ Association between personal, social-environmental, and physical-environmental predictors and vegetable and fruit intake of overall adolescents: generalized linear model (GLM).
*Significant association between availability at school and at leisure place, with vegetable intake: p < 0.05.
*Significant association between self-efficacy, intention, habit, and availability at leisure place, with fruit intake: p < 0.05.

low, reflective of the national prevalence. Meanwhile, the rates for adequate fruit intake were relatively high compared to all the previous studies (7, 31, 32). However, there are generally limited studies which focus on fruit intake as an individual entity, especially among adolescents with overweight and obesity.

4.2 Demographic factors and vegetable and fruit intake

The chi-square test revealed no associations between the sociodemographic factors and vegetable and fruit intake. Likewise, when examining the relationship between sociodemographic factors and vegetable and fruit intake among overweight and obese participants, no significant associations were identified. Similar findings were observed in previous research studies, where sociodemographic factors, particularly age, gender, and ethnicity, were not associated with the vegetables and fruit intake of their samples (36–39).
In this context, our findings align with the result from Jongenelis et al. (40), which showed no significant association

TABLE 6 Personal, social-environmental, and physical-environmental factors associated with vegetable and fruit intake of overweight and obese adolescents.

Factors	Vegetable intake ¹		Fruit intake ¹	
	PR	95% CI	PR	95% CI
Personal				
Knowledge	1.168	0.845, 1.614	1.000	0.886, 1.129
Attitude	1.301	0.897, 1.889	1.023	0.917, 1.142
Liking	0.899	0.689, 1.172	1.013	0.904, 1.134
Self-efficacy	1.232	0.930, 1.631	1.039	0.925, 1.168
Intention	0.887	0.707, 1.113	1.146	1.002, 1.310*
Habit	0.951	0.669, 1.352	0.899	0.798, 1.012
Social-environmental				
Parental modeling	1.352	0.915, 1.998	0.978	0.833, 1.148
Peer modeling	0.822	0.576, 1.171	0.936	0.807, 1.086
Parental encouragement	1.125	0.687, 1.842	1.118	0.885, 1.412
Parental demand	1.020	0.772, 1.346	1.012	0.905, 1.130
Parental allowance	0.890	0.650, 1.219	1.125	1.011, 1.252*
Physical-environmental				
Availability at home	1.109	0.685, 1.796	0.849	0.731, 0.987*
Availability at school	1.280	0.926, 1.771	0.907	0.804, 1.023
Availability at a friend's house	0.830	0.643, 1.071	0.900	0.780, 1.038
Availability at leisure place	0.794	0.540, 1.166	0.996	0.888, 1.117

Fruit Intake: *p-value < 0.05; **p-value < 0.001.
¹ Association between personal, social-environmental, and physical-environmental predictors and vegetable and fruit intake of obese and overweight adolescents: generalized linear model (GLM).
*Significant association between intention, parental allowance, and home availability with fruit intake: p < 0.05.

between sociodemographic factors of age, location, socio-economic position and adequate vegetable intake, however the study instead revealed significant differences in vegetable intake between sexes. In the same study, Jongenelis et al. (40) also revealed that age significantly influence fruit intake among their sample, but the study suggested otherwise for sex, location, and socio-economic position. Albani et al. (41) then suggested that age and sex are not significant influence of vegetable intake, while fruit intake was observed to be influence by age only. This constitutes a relatively similar stand with the findings of Jongenelis et al. (40) for fruit intake, but contrasts with their findings on vegetable intake. The findings also contrast with the present study, where sociodemographic factors do not significantly influence with fruit and vegetable intake (41). In comparison to the present study, Amini et al. (42) suggested that socio-economic status and location positively affects vegetable and fruit intake, contradicting the findings of the present study as well as the of Jongenelis et al. (40).
On another note, parents' education level and household income status were also seen to not have a significant influence on vegetable and fruit intake among adolescents, as reported by Safdar et al. (43) and Drouillet-Pinard et al. (44). However, other studies like Antonogeorgos et al. (45) and Longacre et al. (46) have

found that both parents' education level and household income status do have a significant influence on vegetables and fruit intake in adolescents. The studies suggest that adolescents who had parents with higher education levels and higher household income status would have increased consumption of vegetables and fruits, possibly due to the higher health and nutrition literacy that comes with a higher education tier. Moreover, Hamzah et al. (47) showed that a higher level of health literacy in individuals was observed in higher-income households, compared to the other socioeconomic tiers, for up to 53.4% (47). Parents and familial health and nutrition literacy act as a precursor for facilitating healthy eating behaviors among the children of the household. This notion was supported by researchers Chang et al. (48), who highlighted the importance of dietary literacy as a promoter of health status and good eating behaviors of school-age children and adolescents as evidence supported by their research (48).

4.3 Physical characteristics and fruit and vegetable intake

On the other hand, this study has found physical characteristics, particularly BMI-for-Age ($p = 0.022$), as a significant factor in fruit intake among adolescents. This study found that individuals with obesity and overweight had higher adequate fruit intake compared to adolescents with thinness and normal weight, revealing a positive association. Similarly, Ham and Kim (49) revealed a significant positive association between fruit intake and BMI among adolescents. However, our findings constitute a different standing from the ISAAC Global Research, which revealed an inverse relationship between BMI and the intake of fruits and vegetables among adolescents in their cohort (50). This notion aligned with the study by Sharma et al. (51) which revealed that adequate intake of fruits was observed to have paradoxical effects, the anti-obesity factor to the prevention of adiposity. The findings of our study may not have reflected this concept, and a higher percentage of overweight and obese adolescents had adequate intake of vegetables and fruits compared to those with normal weight and thinness.

4.4 Personal, social-environmental, physical-environmental factors, and fruit and vegetable intake

The findings of this study emphasized several personal, social-environmental, and physical-environmental factors as significant predictors of vegetable and fruit intake. The general adolescent sample found self-efficacy, intention, habit, and availability at places of leisure potentially determining adolescent fruit intake behavior, while vegetable intake of this population was shown to be influenced by availability at a friend's house or at leisure places.

Meanwhile, the overweight and obese adolescent population found factors such as intention, parental allowance, and home availability, associated with the population's fruit consumption, whereas vegetable intake was found not affected by the all potential determinants.

The findings indicate significant influence of personal factors such as self-efficacy, intentions, and habits on adolescent vegetables and fruits consumption. Cross-sectional studies by Rohin et al. (11) and Sato et al. (52) revealed similar findings, with correlations between higher consumption of vegetables with positive attitudes and personality attributes toward vegetable and fruit consumption among Malaysian and Japanese adolescents. This was consistent with the study conducted in Bangladesh and the US, whereby adolescents with greater intentions are more likely to consume vegetables and fruits compared to those with poor intentions (53). Moreover, González-Gil et al. (54) found that female European adolescents with healthy dietary patterns or habits consumed a significantly greater number of fruits. Habits were also considered as a significant predictor of vegetable and fruit intake among UK adolescents. However, the result from this European study has a possibility of cofounders such as health purposes or the awareness of the important effects of a sufficient number of vegetables and fruit consumption. Even so, positive attitude, good intentions and good habits were still suggested as crucial elements to be implemented in the adolescents' dietary practices (55). Contrarily, studies suggested liking as a personal indicator of fruit intake (56). Preferences or liking are personal aspects nurtured through physiological growth such as sensory development and sensitivity transitioning throughout age. A past study emphasized that a child with higher sensory sensitivity toward a certain taste, such as bitterness, has been shown to be less accepting of vegetables. However, it was enunciated that the sensory sensitivity has the potential to decrease throughout the years and thus may increase acceptability toward bitterness and hence can be nurtured to increase vegetable intake (57). This study has also shown a higher intake of vegetables going into adulthood compared to during childhood.

The findings of our study also demonstrated a significant association between social-environmental factors, namely parental allowance, with fruit consumption among overweight and obese adolescents. This is consistent with findings by Fu et al. (58) and Bailey-Davis et al. (19) who revealed that vegetable and fruit intake among adolescents are significantly associated and can be facilitated by positive parent modelling and family rules such as demand and allow, but contrasts with Rohin et al. (11), who reported parental modelling, parental encouragement, parental demand, and parental allowance were not associated with neither vegetable nor fruit intake of the Malay adolescents in rural Terengganu.

In a way similar to Rohin et al. (11), the present study finds parental modeling, parental encouragement, parental demand, and parental allowance were not significantly associated with vegetable. However, parental allowance was found to influence fruit intake among our overweight and obese adolescents. Nevertheless, Rohin et al. (11) postulated that their findings can be attributed to the potential dominance of personal character. This notion was supported by the findings revealed by Deliens et al. (10), which suggested better effectiveness in increasing vegetable intake seen through improvement of personal or individual subject norms. In addition, the increase in autonomous functioning—also a facilitator of self-efficacy—present during adolescence constituted a strive of freedom from dependence on parents, which consequently leads to less time spend with parents and siblings and may diminish familial-motivated decision-making (59, 60).

Vegetables and fruit intake of adolescents have also shown significant association with physical-environmental factors. This study highlighted that greater availability of fruits in different environments would increase adolescents' intake of fruits. The availability of fruits at home appeared as a significant factor in the fruit intake of overweight and obese adolescents. The current outcome is similar to the findings from the Family Life, Activity, Sun, Health and Eating (FLASHE) study, where adolescents' fruit intake was significantly affected by home availability (22). Home availability of fruits also showed a significant association with fruit intake of adolescent girls in a Brazilian study (42). The findings of this study also suggest that the availability of fruits at friends' houses and leisure places as significant predictors of vegetable and fruit intake. In contrast, some findings also found that availability at a friend's houses was not significantly related to the daily fruit intake of school children in European countries (61). However, availability at leisure places was found to be a significant determinant for adolescents' vegetable intake, although not fruit intake, in the study by Rohin et al. (11). The possible explanation for these factors could be due to the time and frequency spent in certain locations, namely home or school, and their fruit consumption mainly depends on the availability of fruits at those places (62). A study by Gustafson et al. (23) and Azeredo et al. (61) also reported findings in contrast to ours, whereby school environments with higher availability of fruits promote the fruit consumption of adolescents compared to those with lower fruit availability.

4.5 Limitation

Several limitations have been accounted for in this study. First, due to the COVID-19 pandemic, data collection was carried out using self-reported online questionnaires, which might increase the risk of over- or underreporting the participants' vegetable and fruit intake. It must also be accounted that the use of technology as the primary medium for data collection may skew the demographic representation within the sample, as it favors more tech-savvy individuals and those with internet accessibility. Adolescents with limited access to the internet may not be able to participate and inadvertently be excluded from the sample. However, due to the COVID-19 restrictions enforced by the government such as strict bans on gatherings and temporary shut-down of education institutions, an online data collection was the viable option at that point in time. In turn participants also had to self-report their weight and height, which increases risk of inaccurate BMI estimation.

4.6 Suggestion

To counter these limitations, future research should employ physical forms of data collection, through printed questionnaires and guided data collection sessions at the target institutions by trained enumerators and researchers. Anthropometric data should also be collected on-site

and be conducted by trained personnel using the right anthropometric equipment such as the SECA weighing scale for measuring body weight and a stadiometer for measuring height.

5 Conclusion

This study has demonstrated a low prevalence of vegetable and fruit intake among adolescents in Selangor, with majority of the sample population did not the standard recommendation of vegetable intake, while more than 50% was revealed to have sufficient consumption of fruits. The findings suggested a higher incidence of inadequate vegetable and fruit intake among adolescents with thinness, followed by obese and overweight adolescents. An association was observed between BMI-for-age of overall adolescents and vegetable and fruit intake. However, no association between other sociodemographic factors was found. Similarly, there had been no association observed between all the sociodemographic factors and vegetable and fruit intake among overweight and obese adolescents. The findings also indicated that fruit intake among overweight and obese adolescents was significantly influenced by personal, social-environmental, and physical-environmental factors, respectively, namely intention, parental allowance, and availability at home. However, the factors portrayed no significant association with vegetable and intake. Nevertheless, this study suggests several personal, social-environmental, and physical-environmental factors as significant correlates of adequate fruit and vegetable intake among adolescents, especially overweight and obese adolescents, and has the potential as reliable source of data for tailoring effective future intervention strategies with the aim to enhance the intake of vegetables and fruits among overweight and obese adolescents in Selangor.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Jawatankuasa Etika Penyelidikan Universiti Kebangsaan Malaysia (Code of Approval: UKM PPI/111/8/JEP-2022-226). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

SS: Resources, Writing – original draft, Writing – review & editing, Investigation. ML: Data curation, Investigation, Methodology, Project administration, Validation, Writing – original draft. RA: Conceptualization, Funding acquisition,

Supervision, Writing – review & editing. NM: Formal analysis, Software, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2025.1539506/full#supplementary-material>

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Assessing the dietary habits and nutritional status of secondary school students in Kraków and the Myślenice district (2016–2017): implications for public health

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Adolescence is a period of rapid growth and development, making proper nutrition essential for overall health and fitness, as well as proper physical and cognitive development. The aim of this study was to assess consumption patterns of everyday food, fast food, and snacks among adolescents aged 12–16 years, depending on sex and nutritional status. The survey was conducted in the Myślenice district (a second-level local government unit) and in Kraków, Poland, between 2016 and 2017. It included secondary school students aged 12–16. The survey of children after obtaining consent from parents was conducted based on the validated FFQ questionnaire. Anthropometric measurements included body weight, height, body fat percentage, and waist and hip circumference. Depending on the BMI value, the children were divided into three groups—underweight, overweight and obese, and with normal body weight. Significant differences in the frequency of fast food consumption and snacking were observed between boys and girls, depending on BMI. The more frequent consumption of whole meal bread by overweight and obese adolescents, along with their lower intake of foods high in simple sugars and fast food, may suggest conscious attempts to control their diet, reflecting changing eating habits among young people. In contrast, the higher fast food consumption among underweight girls, compared to other groups, may suggest a potential link between low body weight and a tendency to consume foods with low nutritional value. Special attention should be given to snacking habits, as they play a significant role in shaping young people's diet.

KEYWORDS

dietary habits, fast food products, nutrition, nutritional status, secondary school students, snacking

1 Introduction

Adolescence is a period of rapid growth and development, making proper nutrition essential for overall health and fitness, as well as proper physical and cognitive development. Adequate intake of essential nutrients, including vitamins and micronutrients, plays a crucial role in a young person's performance at school. In addition to the energy value of meals, the

timing and frequency of food consumption also significantly affect proper and effective nutrition (1).

Maintaining a healthy body weight depends on a balanced relationship between energy intake and expenditure (2–5). Both underweight and excess weight (overweight and unhealthy weight) increase the risk of numerous health conditions, negatively impacting both quality of life and life expectancy. In European countries, the prevalence of overweight and obesity among children is estimated at 10–20%, while in Poland, it reaches 18%. Addressing the growing problem of overweight and obesity from an early age is essential for long-term public health benefits (6, 7). Excess body weight also increases the risk of hypertension, hypercholesterolemia, stroke, sleep apnea, gallbladder disease and bronchial asthma. In children and adolescents, it is further linked to numerous psychological consequences such as low self-esteem, depression and suicidal thoughts. Genetic predisposition accounts for approximately 25–45% of obesity cases, while other risk factors include behavioral, environmental, socio-cultural and socioeconomic influences, primarily poor eating habits and low levels of physical activity. The challenges associated with obesity treatment, including high costs, highlight the need for effective preventive measures across the entire pediatric population, with particular attention to children from economically disadvantaged backgrounds and low socioeconomic status. Preventive measures should be implemented on global, national, regional and local levels to effectively combat overweight and obesity (8).

Malnutrition contributes to the early onset of diet-related chronic diseases, including cardiovascular disease, type 2 diabetes, cancer, obesity, and osteoporosis (9). In addition, unhealthy behaviors and poor dietary choices in childhood are strong predictors of adult health and are linked to an increased risk of chronic conditions such as obesity, cardiovascular disease, type 2 diabetes, and certain types of cancer (10). Moreover, eating habits formed in childhood and adolescence play a key role in shaping future food preferences, diet quality and body weight, making them essential for establishing lifelong health-promoting habits (11).

Nutritional behavior is shaped by a combination of physiological, environmental, psychological, cultural, socioeconomic and genetic factors (12). However, the complex interplay between these influences is not fully understood (10, 13). In highly developed countries such as Poland, non-economic factors play a particularly significant role in establishing dietary habits. These include environmental, psychological and socio-cultural factors such as education, occupation, lifestyle, customs, age, sex and place of residence (12). Research also suggests that nutritional knowledge impacts food preferences (14). While not all factors influencing eating habits can be modified, many can be shaped. Environmental exposure and food experiences play a crucial role in the development of eating behaviors in children and adolescents (15).

A key factor influencing human eating behavior is social modeling, where individuals look to others as a guide to what and how much to eat (16). When children enter school, they experience lifestyle and dietary changes, becoming highly receptive to new behaviors through imitation. During this period, the school environment begins to play a role as significant as that of parents (12, 16). Found that social modeling is especially strong when individuals seek to identify with a role model or perceive themselves as similar to them. This process is, at least in part, driven by unconscious behavioral imitation.

Children's eating behavior is significantly related to parental education levels and family financial status. Higher education and income levels are associated with a lower incidence of eating disorders (17). Research indicates that fruit and vegetable consumption during youth has a protective effect against cancer. Conversely, the widespread availability of high-energy foods rich in sugar, fat and salt promotes dietary preferences that are not in line with nutritional guidelines, contributing to excessive weight gain, obesity and other diet-related diseases (17). In the context of children's diets, the phenomenon of "McDonaldization" is reflected in the widespread availability and consumption of ultra-processed foods high in sugar, salt, and fat and low in nutritional value. These eating habits are emblematic of the Western dietary pattern, which has been associated with numerous adverse health outcomes in children and adolescents (18). Studies have shown that adherence to a Western diet increases the risk of obesity, insulin resistance, and other cardiometabolic disorders. A systematic review found that children following Western dietary patterns had higher body mass index (BMI), waist circumference, and glucose and triglyceride levels compared to those with healthier diets. In addition, high consumption of ultra-processed foods has been linked to poorer academic performance, with adolescents scoring lower in mathematics, reading, and writing (19). Early-life exposure to Western diets may also induce long-term changes in the gut microbiome, potentially affecting lifelong health. Moreover, a diet rich in fat and low in fiber—another hallmark of the Western pattern—was linked to increased rates of asthma and other allergic conditions in children (20).

The aim of this study was to assess consumption patterns of everyday food, fast food, and snacks among adolescents aged 12–16 years, depending on sex and nutritional status. The results of the study may constitute a valuable contribution to the development of obesity prevention strategies and nutritional education. Proper nutrition of a developing organism has a fundamental impact on its biological efficiency, learning capabilities and well-being. With this in mind, the results of the study may contribute to updating information on the nutritional status and eating habits of young people. Thanks to this, it will be possible to undertake appropriate educational activities for young people and their parents so that their eating behaviors are correct in the future. Obesity is not only a health problem, but also a social and economic one.

2 Materials and methods

2.1 Study description

The survey was conducted in the Myślenice district (a second-level local government unit) and in Kraków, Poland, between 2016 and 2017. It included secondary school students aged 12–16 and their parents. The list of schools in the Myślenice district was prepared and provided to us by the Myślenice District Office, while in Krakow, the survey included those schools that agreed to conduct the survey. Children were included in the study whose parents agreed to have their child surveyed and completed a questionnaire that included questions about parental education. Inclusion criteria for the study were as follows: (1) students aged between 12 and 16 years; (2) enrollment in a participating secondary school in the Myślenice district or Kraków; (3) provision of informed consent by a parent or

legal guardian; and (4) availability of completed questionnaires from both the student and the parent, including information regarding parental education. Exclusion criteria included: (1) lack of parental consent for the child's participation; (2) incomplete survey data from either the student or the parent; (3) participant withdrawal at any stage of the study; and (4) schools that declined to participate in Kraków. The 715 parents were offered to complete the questionnaire, of which 15 did not agree to the survey. The surveys among parents were conducted with the participation of the school principals, who helped to pass them on to parents during class meetings or through students. The questionnaire was filled out by students, parents only filled out questions about the birth certificate. Both parents and students filled out the questionnaire at home. In the end, 700 children started the survey (they answered the first question). Complete survey questionnaires (parents and children) were obtained from 664 participants. All necessary consents were obtained from school principals and parents through the Department of Promotion and Health Protection at the District Office in Myślenice.

The study was approved by the Bioethics Committee of Jagiellonian University (no. K/ZDS/007167) and was conducted with the consent of school authorities, legal guardians, and the children themselves. It included both a questionnaire survey and anthropometric measurements. Participation in the study was voluntary, and participants could withdraw from the study at any stage. Participants were informed that anonymity and the aims and scope of the study would be preserved, and they gave informed consent to participate.

2.2 Questionnaire surveys

The survey questionnaire used in the study consisted of 29 questions, consisted of a section based on the Eating Habits and Eating Beliefs Questionnaire developed by the Behavioral Nutrition Team of the Committee on Human Nutrition of the Polish Academy of Sciences, approved and recommended for research in the Polish population (21), as well as a set of original, author-designed survey questions. No formal validation of the survey instrument and reliability testing was done. Both in the Myślenice district and Kraków, children without parental consent were excluded from participation. However, no child was excluded due to numerical limitations, ensuring that no participant felt 'inferior' or excluded for unknown reasons. Parents were informed about the purpose and methodology of the study by teachers and staff from the District Office. The parental survey included socio-economic questions concerning the family.

Parents were informed about the purpose and method of conducting the tests by teachers and employees of the District Office. The survey for parents included questions: socio-economic questions regarding the family. The survey questionnaire completed by the children included questions about the number and regularity of meals during the day, snacking between meals and the frequency of food consumption for selected products and beverages with possible answers and scoring: (1 = does not eat, 2 = less often, 3 = once a month, 4 = 1–2 times a week, 5 = 3–4 times a week, 6 = every day).

The questionnaires were distributed with the assistance of school authorities, who facilitated their delivery to parents during class meetings or through students. Teachers informed parents about the purpose and methodology of the survey.

2.3 Anthropometric measurements

Anthropometric measurements included body weight, height, body fat percentage, and waist and hip circumference. These measurements were conducted only for children who did not object and whose parents had provided consent for their participation. Measurements were taken in the school nurse's office or a designated room, with boys and girls assessed separately. The procedure followed the guidelines of the Institute of Mother and Child (22, 23).

Body weight and body fat percentage were measured using a TANITA BF 556 electronic scale with an accuracy of 0.1 kg. Waist and hip circumference was measured with a measuring tape accurate to 1 mm, while height was recorded with a TANITA height meter.

Body mass index (BMI) was calculated for each child based on their measurements. Height, weight and BMI were then compared to centile charts from the OLAF project (24). Children with a BMI above the 95th percentile for their age and sex were classified as obese, while those with a value between 85th and 95th percentile were considered overweight. A BMI between the 15th and 85th percentile was categorized as normal weight. Underweight was defined as a BMI between the 5th and 15th percentile, while a BMI below the 5th percentile indicated significant underweight.

2.4 Statistical analysis

For statistical analysis, all data were encoded in Excel 2010 and imported into IBM SPSS Statistics version 25. The study population was described using numbers and percentages of people with a given characteristic. Quantitative characteristics were presented as mean and standard deviation. To assess differences between the groups of children based on sex and BMI, the non-parametric Kruskal-Wallis analysis of variance (for many independent samples) was used. The chi² test was used to analyses qualitative variables. Additionally, BMI was calculated and compared to centile grids from the OLAF project. The level of statistical significance was set at $\alpha = 0.05$.

3 Results

Of the 664 children surveyed, 314 were boys (47.3%) and 350 were girls (52.7%). The mean age of the participants was 13.85 ± 0.78 years. Among mothers, the most common level of education was secondary (40.5%), followed by higher education, vocational education and primary education. Among fathers, the highest proportion had vocational education (39.2%), followed by secondary education, university education and primary education (Table 1).

Significant differences were observed between boys and girls in the frequency of consumption of selected food products, fast food, and snacks, depending on BMI. The mean frequency of consumption for these products, categorized by sex and BMI, is presented in Table. Overweight and obese boys and girls consumed wholemeal bread significantly more often than their normal-weight and underweight peers (Table 2). Significant differences were also noted in the consumption of wheat bread, butter, sugar, crisps, potato crisps and savory snacks, with overweight and obese girls consuming these products significantly less often than normal-weight and underweight girls ($p < 0.05$). Additionally, both overweight and obese boys and

TABLE 1 Characteristics of children's demographic features by gender.

Population characteristics	General (n) %	Boys (n) %	Girls (n) %
Age (Years) X ± SD	N = 664	N = 314	N = 350
	13,8 ± 0,78	13,9 ± 0,78	13,8 ± 0,78
Mother's education	N = 640	N = 300	N = 340
Primary education	(14) 2.2	(8) 2.7	(6) 1.8
Elementary vocational	(138) 21.6	(57) 19.0	(81) 23.8
Secondary education	(259) 40,5	(128) 42.7	(131) 38.5
Higher vocational	(45) 7.0	(23) 7.7	(22) 6.5
Higher	(184) 28.8	(84) 28.0	(100) 29.4
Father's education	N = 623	N = 289	N = 334
Primary education	(25) 4.0	(13) 4.5	(12) 3.6
Elementary vocational	(244) 39.2	(112) 38.8	(132) 39.5
Secondary education	(212) 34.0	(94) 32.5	(118) 35.3
Higher vocational	(57) 9.1	(29) 10.0	(28) 8.4
Higher	(85) 13.6	(41) 14.2	(44) 13.2
Mother's education type	N = 508	N = 247	N = 261
Technical	(190) 37.4	(91) 36.8	(99) 37.9
Humanities	(114) 22.4	(54) 21.9	(60) 23.0
Biological medicine	(64) 12.6	(31) 12.6	(33) 12.6
Economics	(140) 27.6	(71) 28.7	(69) 26.4
Father's education type	N = 497	N = 239	N = 258
Technical	(417) 83.9	(204) 85.4	(213) 82.6
Humanities	(30) 6.0	(13) 5.4	(17) 6.6
Biological medicine	(7) 1.4	(2) 0.8	(5) 1.9
Economics	(43) 8.7	(20) 8.4	(23) 8.91

N, number of subjects; n, number of subjects in subgroup; X ± SD, mean ± standard deviation. Bold values indicate the total number of responses for each category (e.g., number of people, % of participants).

girls ate sweets significantly less frequently than adolescents with normal weight or underweight (Table 2).

No significant differences in BMI-related consumption patterns were observed between boys and girls for cereals, pasta, rice, white cheese, yellow cheese, yoghurt, fish, poultry, red meat, eggs, vegetable oils, margarines, vegetables, fruit, fruit juices and unsalted nuts. Fruit was consumed by 85.2% of overweight and obese girls and 65.7% of underweight and normal-weight boys. Overweight and obese boys ate fruit significantly less often than their normal-weight and underweight counterparts. They were also significantly less likely to consume pastries than boys with a normal weight or underweight (Table 3). In the underweight category, sweets were consumed by 73.5% of girls and 65.7% of boys, while in the overweight and obesity category, they were consumed by 42.6% of girls and 46.0% of boys. Overweight and obese girls consumed significantly less often sweets and significantly more often fruit compared to normal-weight and underweight girls (Table 3).

Fast food was consumed once a month by 68.5% of overweight and obese girls and 44.4% of overweight and obese boys. No significant differences in fast food consumption were observed among boys across BMI categories. In contrast, underweight girls consumed these products significantly more often than both overweight and obese boys and girls (Figure 1).

4 Discussion

Eating habits are established in childhood, with a school-age child's dietary choices largely shaped by their environment, particularly parental behavior. Children observe family members' eating habits, including whether they follow hygiene practices, share meals at the table or engage in other activities such as reading, watching TV or listening to the radio while eating. While parents determine what their child eats, the child ultimately decides how much to consume. The family plays a crucial role in shaping food preferences, and the home has been identified as the primary source of nutritional knowledge (25).

A healthy diet enhances physical performance, increases stress resilience and supports immune function. It also helps maintain optimal total cholesterol and triglyceride levels, regulates carbohydrate metabolism and promotes a healthy body weight (26, 27). Poor nutrition and lack of physical activity play a key role in the development of various diseases, including obesity, diabetes, cardiovascular diseases, postural defects and osteoporosis (28, 29). In recent years, the prevalence of overweight and obese children and adolescents has risen globally, affecting both developed and developing countries (14, 30, 31).

TABLE 2 Frequency of selected food product consumption in the study group by sex and BMI.

Product	Underweight (A)		Normal weight (B)		Overweight and obesity (C)		ANOVA Kruskal- Wallis rank <i>p</i>
	C X ± SD	D X ± SD	C X ± SD	D X ± SD	C X ± SD	D X ± SD	
Goats, pasta, rice	4.1 ± 1.1	4.4 ± 0.8	4.2 ± 0.8	4.3 ± 0.9	4.0 ± 0.7	4.1 ± 0.9	ABC-C 0.1702 ABC-D 0.1249
Bread (bread, wheat rolls)	5.6 ± 1.0	5.9 ± 0.5	5.8 ± 0.6	5.6 ± 0.9	5.5 ± 1.1	5.2 ± 1.4	ABC-C 0.0505 ABC-D 0.0059
Wholemeal bread	2.9 ± 1.8	3.7 ± 1.6	3.3 ± 1.7	3.5 ± 1.6	4.0 ± 1.6	4.1 ± 1.6	ABC-C 0.0022 ABC-D 0.0330
Milk	5.1 ± 1.2	4.9 ± 1.0	5.0 ± 1.2	4.8 ± 1.2	4.5 ± 1.4	4.3 ± 1.5	ABC-C 0.0116 ABC-D 0.1862
White cheese	3.4 ± 1.2	3.4 ± 1.1	3.3 ± 1.3	3.5 ± 1.3	3.5 ± 1.4	3.8 ± 1.2	ABC-C 0.3778 ABC-D 0.1475
Yellow cheese	4.7 ± 0.8	4.3 ± 1.2	4.5 ± 1.2	4.2 ± 1.2	4.3 ± 1.3	4.2 ± 1.3	ABC-C 0.3791 ABC-D 0.8913
Various yoghurts	4.2 ± 1.1	4.5 ± 1.0	4.3 ± 1.3	4.4 ± 1.1	4.0 ± 1.2	4.2 ± 1.5	ABC-C 0.3500 ABC-D 0.5947
Fish and fish products	3.4 ± 0.9	3.4 ± 1.0	3.3 ± 1.0	3.3 ± 0.9	3.4 ± 1.0	3.4 ± 1.0	ABC-C 0.8718 ABC-D 0.7467
Poultry	0.9 ± 0.8	4.3 ± 1.0	4.4 ± 0.7	4.3 ± 0.8	4.4 ± 0.6	4.2 ± 1.0	ABC-C 0.7289 ABC-D 0.8272
Red meat	3.6 ± 1.2	3.2 ± 1.2	3.6 ± 1.2	3.2 ± 1.2	3.4 ± 1.2	2.9 ± 1.2	ABC-C 0.3018 ABC-D 0.3939
Eggs	4.2 ± 0.7	4.0 ± 0.9	3.9 ± 1.0	4.0 ± 1.0	3.9 ± 1.0	4.1 ± 0.9	ABC-C 0.4059 ABC-D 0.8267
Vegetable oils, margarine	4.7 ± 1.2	4.2 ± 1.6	4.2 ± 1.6	4.2 ± 1.6	4.0 ± 1.6	4.2 ± 1.4	ABC-C 0.0617 ABC-D 0.9954
Butter	5.1 ± 1.4	5.3 ± 1.2	4.9 ± 1.5	4.6 ± 1.7	5.1 ± 1.6	4.1 ± 1.9	ABC-C 0.0884 ABC-D 0.0009
Raw vegetables (vegetable juices)	4.3 ± 1.5	4.0 ± 1.4	4.0 ± 1.5	4.1 ± 1.5	4.0 ± 1.6	4.4 ± 1.4	ABC-C 0.3372 ABC-D 0.3646
Cooked vegetables	3.7 ± 1.5	3.9 ± 1.3	3.7 ± 1.4	4.0 ± 1.4	3.9 ± 1.3	4.0 ± 1.3	ABC-C 0.7483 ABC-D 0.9325
Raw fruit and fruit juices	5.1 ± 1.3	5.3 ± 0.8	5.0 ± 1.1	5.3 ± 1.0	5.0 ± 1.1	5.5 ± 0.7	ABC-C 0.6987 ABC-D 0.4662
Legume seeds	3.3 ± 1.1	3.2 ± 1.0	2.8 ± 1.0	2.9 ± 1.0	2.9 ± 1.2	3.1 ± 0.9	ABC-C 0.0099 ABC-D 0.1314
Unsalted nuts	2.4 ± 1.0	3.0 ± 1.0	2.5 ± 1.1	2.6 ± 1.1	2.3 ± 1.1	2.6 ± 1.0	ABC-C 0.5861 ABC-D 0.0865
Sweets	5.0 ± 1.0	5.1 ± 1.0	4.9 ± 1.0	4.7 ± 1.1	4.5 ± 1.1	4.5 ± 1.1	ABC-C 0.0221 ABC-D 0.0156
Sugar	5.3 ± 1.5	5.6 ± 0.8	5.2 ± 1.3	5.1 ± 1.3	5.0 ± 1.4	4.7 ± 1.6	ABC-C 0.2568 ABC-D 0.0020
Chips, crisps, savory sticks	3.7 ± 1.0	3.9 ± 1.2	3.8 ± 1.2	3.6 ± 1.1	3.6 ± 1.0	3.2 ± 1.0	ABC-C 0.4245 ABC-D 0.0183

X ± SD, mean ± standard deviation; p, significance level; C – boys, D – girls, A – underweight, B – normal weight, C – overweight and obesity; The frequency of consumption scale: 1- does not eat, 2- less often, 3- once a month, 4-1-2 times a week, 5-3-4 times a week, 6- every day.

Bold values indicate statistically significant results ($p < 0.05$).

Preliminary findings from the international HBSC study on the health behaviors of young people aged 11–15, in which Poland has participated for many years, indicated that excess body weight

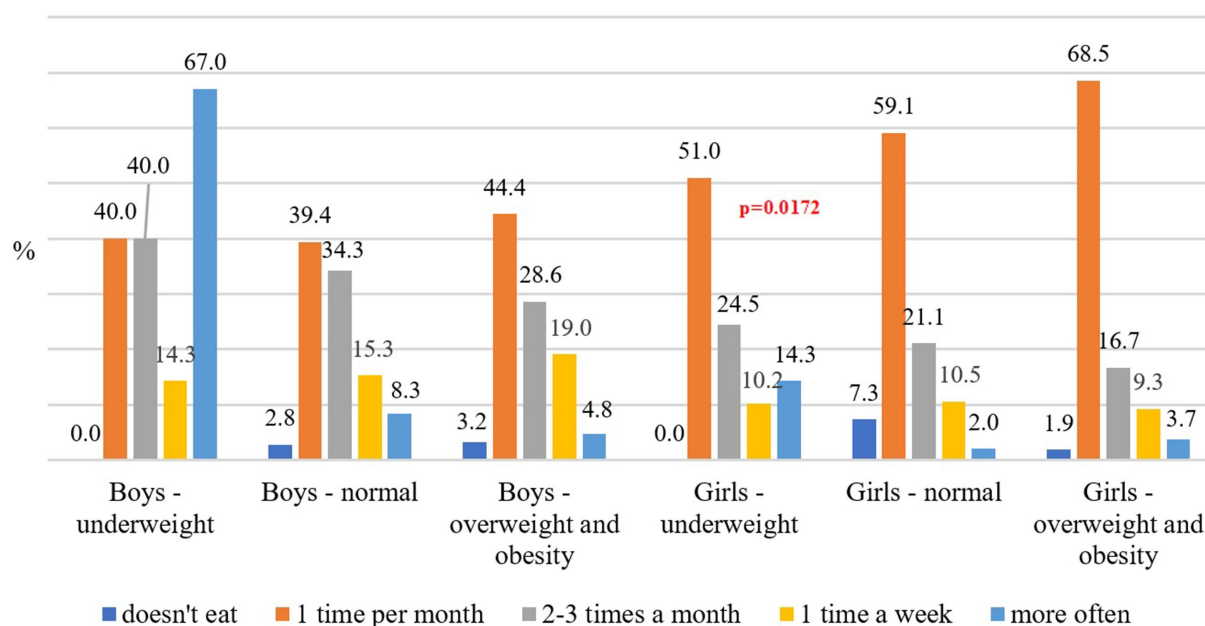
affects 29.7% of boys and 14.3% of girls (based on World Health Organization criteria, 2007). These percentages are slightly higher than those reported in the 2014 edition of the study. Between 2014

TABLE 3 Consumption of selected food products in the study group by sex and BMI.

Product	Answers	Underweight (A)		Normal weight (B)		Overweight and obesity (C)		Chi-square p	
		C (%)	D (%)	C (%)	D (%)	C (%)	D (%)		
Sweets	Yes	65.7	73.5	58.3	54.7	46.0	42.6	ABC-C	0.1157
	No	34.3	26.5	41.7	45.3	54.0	57.4	ABC-D	0.0064
Bread confectionery	Yes	31.4	20.4	19.0	15.4	7.9	11.1	ABC-C	0.0131
	No	68.6	79.6	81.0	84.6	92.1	88.9	ABC-D	0.4268
Fruit	Yes	65.7	61.2	65.7	76.5	46.0	85.2	ABC-C	0.0159
	No	34.3	38.8	34.3	23.5	54.0	14.8	ABC-D	0.0156
Raisins	Yes	2.9	0	1.9	4.0	3.2	3.7	ABC-C	0.7934
	No	97.1	100.0	98.1	96.0	96.8	96.3	ABC-D	0.3608
Crisps. Nuts	Yes	34.3	24.5	31.5	17.0	23.8	9.3	ABC-C	0.4352
	No	65.7	75.5	68.5	83.0	76.2	90.7	ABC-D	0.1186
Yoghurt. Cream cheese	Yes	57.1	59.2	49.1	49.4	44.4	42.6	ABC-C	0.4838
	No	42.9	40.8	50.9	50.6	55.6	57.4	ABC-D	0.2389
Corn chips	Yes	17.1	10.2	15.3	13.0	11.1	13.0	ABC-C	0.6463
	No	82.9	89.8	84.7	87.0	88.9	87.0	ABC-D	0.8648

C – boys, D – girls, A – underweight, B – normal weight, C – overweight and obesity, p – significance level.

Bold values indicate statistically significant results ($p < 0.05$).


FIGURE 1

Frequency of fast-food consumption depending on sex and BMI.

and 2018, the prevalence of overweight among young people increased from 19.9 to 21.7%, with a more pronounced increase among boys compared to girls, particularly in 13-year-olds of both sexes (32, 33).

The development of overweight and obesity among children and adolescents is strongly influenced by technological advancements and improved economic conditions. An increasing number of young people lead sedentary lifestyles, spending leisure

time passively in front of computers or TV screens, which reduces physical activity. Additionally, a high-energy diet, along with excessive consumption of fast food, sweets and highly sweetened drinks, contributes to a positive energy balance and weight gain (9, 11, 23, 34–36).

A varied diet is essential to meeting the body's nutritional needs. A Polish study on the health behaviors of secondary school students in the Pomeranian Voivodeship found that white meat was consumed

an average of 2.4 times a week, while red meat was eaten twice a week. Legumes and fish appeared in the respondents' diets only once per week (37). Maintaining a healthy body weight during adolescence is crucial, as research estimates that 70–80% of adolescents diagnosed with obesity will remain obese in adulthood (38). This is supported by findings from a study by Krawczyńska et al., who reported that among adolescents aged 16–18 attending vocational school, overweight and obesity were the most prevalent health concerns, affecting 11.68% of students (39).

A national nutrition survey found that bread is a fundamental component of the diet of young people aged 10–17. White wheat bread was the most commonly consumed, with 18% of boys and 21.7% of girls eating it once a day, and 27.3% of boys and 23.6% of girls consuming it several times a day. Whole meal or seeded brown bread and white rye bread were consumed less frequently, with most respondents reporting intake between 1–3 times a month and 1–3 times a week. A significant proportion did not consume these products at all: 30.4% of boys and 26.7% of girls did not eat dark bread, while 24.5% of boys and 24.1% of girls did not eat light rye bread. Breakfast cereals were relatively popular, with 10.1% of boys and 9.3% of girls consuming them at least once a day. Most respondents ate cereals 2–3 times a week (30.2% of boys and 26.3% of girls) or once a week (22.3 and 21.2%, respectively). Pasta and rice were consumed by nearly all participants. Fruit is another essential component of the daily diet; however, the survey revealed that fruit consumption was lower than recommended across all age groups of children and adolescents (40).

Bielaszka et al. (41) reported that overweight and obese boys and girls were significantly more likely to eat whole meal bread than their normal-weight and underweight peers. Dark bread, which is a source of dietary fiber and numerous minerals and vitamins, is not consumed frequently enough by schoolchildren. The authors found that only 8% of children ate dark bread daily, while 49% consumed it less than several times a week. Significant differences were also observed in the consumption of wheat bread, butter, sugar, crisps, chips and salty sticks. Overweight and obese girls consumed these products significantly less often than girls with normal weight and those who were not overweight. Similarly, both overweight and obese boys and girls ate sweets significantly less often than their normal-weight and non-overweight peers. Crisps, corn-based extruded snacks and other savory snacks remain highly popular, especially among younger generations. However, these products can be a potential source of acrylamide, a toxic compound that may form during frying and baking (42). Studies have shown that consuming crisps is associated with higher levels of anxiety, depression and emotional stress, as well as increased somatic symptoms, cognitive difficulties and fatigue compared to eating fruit (43). It is recommended to limit the sweetening of food for children and adolescents and to avoid sweets whenever possible. However, even the youngest children frequently consumed foods and drinks with added sugar, sometimes multiple times a day. The problem was even more pronounced in older age groups, where a clear increase was observed in the percentage of individuals adding sugar to food and drinks several times a day. In addition, children and adolescents were generally unlikely to avoid sweets, with most consuming them at least once a week or more often. The self-administered survey did not reveal any significant differences between boys and girls in BMI-related consumption patterns of groats, pasta, rice, white cheese, yellow cheese, yoghurt, margarine and fruit

juices. Children and adolescents primarily consumed vegetable oils and butter in accordance with dietary recommendations. However, some respondents reported excessive butter consumption, with intake occurring several times a day (40). Our study also found no significant differences between boys and girls in BMI-related consumption patterns of vegetable oil.

Meat is an important source of nutrients in children's diets, and it is recommended to consume lean meat, particularly poultry. In the Polish nutrition survey, poultry was the most commonly consumed meat among children and adolescents (40). However, pork, which has a higher fat content, was also relatively prevalent in their diet. Both younger and older children should primarily consume boiled or roasted meat, while limiting the intake of processed products. Despite this recommendation, a significant proportion of the respondents across all age groups consumed sausages relatively frequently (40). Our study found no significant differences between boys and girls in BMI-related consumption patterns of poultry and red meat.

Fish is an important source of high-quality protein, vitamins A (retinol), D and E, iodine, selenium and fat, especially long-chain n-3 polyunsaturated fatty acids. Increasing evidence suggests that fish consumption supports child development and learning, promotes eye health, and protects against cardiovascular disease and certain types of cancer (44). Eggs are another nutritionally valuable food, offering a range of health benefits. Their components have been associated with antimicrobial, anti-adhesive, immunomodulatory, antitumor, antihypertensive and antioxidant effects. Eggs also contain protease inhibitors, essential nutrients and functional lipids, highlighting their importance in human health, disease prevention and treatment. In our study, no significant differences were observed between boys and girls in BMI-related consumption patterns of fish, unsalted nuts and eggs. Although nuts are high in calories, they contain fatty acids, vegetable proteins, fiber, vitamins, minerals, carotenoids and phytosterols, which have potential antioxidant effects (45).

Fruit and vegetables are widely recognized as health-promoting foods due to their numerous compounds associated with a reduced risk of cardiovascular disease, obesity and certain types of cancer (46, 47). They are also rich in vitamins and minerals and serve as a source of phytochemicals, which exert protective effects through antioxidant, phytoestrogen and anti-inflammatory properties (48). The fiber found in vegetables, fruit and whole grains helps increase satiety after meals, reducing cravings for unhealthy foods and sugar. Additionally, fiber intake is negatively correlated with the risk of chronic diseases such as obesity, type 2 diabetes, cancer and cardiovascular disease. While the precise mechanisms underlying fiber's role in metabolic health are not fully understood, it is believed to influence nutrient absorption, transit rate, and the production of short-chain fatty acids and gut hormones by altering intestinal viscosity (49). Our study found no significant differences between boys and girls in BMI-related consumption patterns of fruit and vegetables.

Kiciak et al. (50) found that nearly half of the respondents consumed fruit and vegetables several times a day. Approximately 25% of girls ate fruit and vegetables 1–2 times a day, compared to 20% of boys. The proportion of young people who consumed fruit and vegetables several times a week ranged between 23 and 28% (50).

Sochacka-Tatar and Stypuła (50) found that most teenagers consumed snacks between meals, with 38.8% reporting regular snacking. This behavior was most common among students attending technical secondary school and least common among middle school

students. Nearly 95% of the respondents frequently ate crisps or sweets, with secondary school students consuming these products significantly more often. Fast food consumption was also widespread, as only 12.9% of the respondents reported not eating fast food at all (51). In our study, 68.5% of overweight and obese girls and 44.4% of overweight and obese boys consumed fast food once a month. While no significant differences were observed in fast food consumption among boys, malnourished girls consumed these products significantly more often. The frequent consumption of fast food among malnourished or food-insecure adolescent girls is influenced by a combination of economic hardship, accessibility, and psychosocial factors. The observed higher consumption of fast food among underweight girls is indeed intriguing; however, the discussion does not address potential structural determinants, such as food insecurity. International research has shown that underweight status can coexist with high intake of inexpensive, highly processed foods, particularly in economically disadvantaged populations. In such contexts, limited financial resources may lead individuals to rely on energy-dense but nutrient-poor foods, which, despite their caloric content, may not support adequate weight gain or nutritional adequacy. Including such socioeconomic considerations would provide a more nuanced understanding of the findings and could inform more targeted public health interventions (52, 53).

Wojtyła et al. found that 77% of adolescents snacked between meals, with 25% also snacking at night, most often on high-calorie foods. However, a significant proportion of secondary school students also consumed fruit between main meals (54). In our study, a higher percentage of overweight and obese girls compared to underweight and normal-weight boys snacked on fruit, while overweight and obese boys were significantly less likely to do so. Pastries were consumed more frequently by boys and girls with malnutrition, with overweight and obese boys consuming them significantly less often than their normal-weight and malnourished counterparts. Sweets were consumed by a large proportion of malnourished girls and boys, whereas overweight and obese girls and boys snacked on sweets less frequently. Additionally, overweight and obese girls were significantly less likely to snack on sweets and significantly more likely to snack on fruit compared to normal-weight and malnourished girls. This may indicate a conscious attempt by this group to control their diet.

In the study by Mikulec et al. (55) the epidemic situation, according to 50.0% of boys and 62.7% of girls, influenced their eating behavior. There were no significant differences in the number of meals consumed before the pandemic ($p = 0.43$) and during it ($p = 0.12$) between boys and girls. Before the pandemic, people eating 3 meals dominated in both groups (47.1% of boys and 45.2% of girls). During social isolation, the number of people eating 5 or more meals a day increased in both groups by 13.2 percentage points (boys) and by 10.5 percentage points (girls), and the number of people eating 3 meals decreased by 11.8 percentage points (boys) and by 15.2 percentage points (girls). A significant difference was observed in the regularity of eating meals during the pandemic between girls and boys. Among girls, 62.3% and among boys 48.0% declared that they did not eat meals regularly during the pandemic. There was no significant difference in the frequency of meals and increased appetite between girls and boys. Similar results were observed by Pietrobelli et al. (56) who observed an increase in the number of meals consumed more often among boys than girls.

Previous research has shown that most young people have unhealthy eating habits, including a monotonous diet lacking

nutritionally rich foods. These habits contribute to abnormal development and an increased risk of eating disorders (57). Numerous studies have also demonstrated a link between children's and adolescents' eating habits and parental education levels. Children of parents with higher education were less likely to experience dietary problems. Low fruit and vegetable consumption has been associated with limited availability of these products and lower educational status (58–60). Kazimierzczak et al. (61) and Wojtyniak et al. (62) found that individuals with higher education are more likely to consume fruit and vegetables. In our survey, mothers most commonly reported having secondary education, while primary education was the least frequently declared. Among fathers vocational education was the most common, whereas primary education was the least reported.

School education plays a key role in teaching young people about health and helping them apply these skills in practice. However, research indicates that students' health behaviors are not adequately shaped. To eliminate unhealthy habits, it is essential to promote self-esteem and a sense of responsibility for one's own health. This growing concern highlights the need for initiatives that promote a healthy lifestyle and educate children and adolescents on proper nutrition and physical activity. Educational activities targeting parents and adolescents play an important role in shaping healthy eating habits and often have positive short-term outcomes. In the long term, such efforts should contribute to expanding health knowledge, fostering pro-health attitudes, and developing practical skills along with appropriate hygiene and health-related habits. Children and adolescents acquire basic nutritional knowledge primarily at home by observing the behavior of household members and through direct guidance from parents. Family eating habits have a statistically significant influence on adolescents' nutritional awareness. Further education occurs at school, where students' eating behaviors can be shaped through classroom instruction, the types of meals provided, and the offerings of the school shop (63).

Attention is now being drawn, not only to the problem of the supply of energy (carbohydrates and fats) and protein in food, but additionally to two other dimensions, i.e., the deficit of micronutrients (micronutrients, vitamins), and the occurrence of overweight and obesity. In this context, the phenomenon of Double Burden of Malnutrition (DBM), consisting in the simultaneous occurrence of nutritional deficiencies and overweight or obesity, is increasingly identified. At the same time, the concept of triple burden or even multiple burden of malnutrition is emerging in the literature, which refers to the overlap of different forms of malnutrition - both quantitative and qualitative - within a population, household or even an individual. The rapid increase in the prevalence of overweight and obesity is directly linked to dynamic changes in food systems - in particular the increasing availability of cheap, ultra-processed foods and sweetened beverages, as well as a significant reduction in physical activity. Ultra-processed foods, an essential component of the modern diet, provide significant amounts of calories but lack dietary fiber, vitamins and minerals, which not only promotes the development of obesity but also exacerbates micronutrient deficiencies. In addition, reduced physical activity reduces energy expenditure. These deficiencies may also result from disturbances in the absorption, distribution and excretion of nutrients. In addition, chronic low-grade inflammation accompanying obesity can lead to abnormal micronutrient metabolism, which exacerbates deficiencies despite apparently sufficient energy intake (64). Although DBM mainly affects low- and middle-income countries (65), a similar problem is also observed in highly developed countries (66). Children and adolescents

who are exposed to malnutrition (both in terms of energy and quality) develop less well, have learning difficulties and are more likely to fall ill. In addition to long-term chronic health effects, malnutrition also has its day-to-day consequences, such as fatigue, apathy, lack of energy, disruption of processes related to brain function. Endocrine disorders are also common in such cases, which develop in secret for a long time, and one of the first visible symptoms can be menstrual disorders in girls (67).

There is currently a discussion in the world about food security after 2015. This time caesura is related to the fact that 2015 was adopted as the time point for achieving the goals of reducing hunger in the world. The challenge of the world society is to solve the problems of hunger and malnutrition in the world. However, it turns out that malnutrition is a deeper and broader problem than just consuming the right amount of energy and protein, which has been the main focus so far, and which was reflected in the concept of the so-called “undernourishment,” i.e., consuming dietary energy for an active and healthy life. Currently, many micronutrients important for human health have been identified, but most of them are not widely measured. Three of the commonly measured micronutrient deficiencies and related disorders refer to the lack of vitamin A, iron (anemia) and iodine (68).

Both excess and deficiency of nutrients in daily food adversely affect a child's development. An imbalance between the energy value of consumed food and energy expenditure can lead to malnutrition, overweight and obesity. Malnutrition can be caused by the supply of foods with low energy and nutritional value, but at the same time by an increase in the body's energy demand. Children and adolescents exposed to malnutrition (both in terms of energy and quality) develop worse, have problems with learning, and fall ill more often. The lack of appropriate vitamins and microelements in the diet, in addition to long-term chronic health effects, has its daily consequences, such as fatigue, apathy, lack of energy, disorders of processes related to brain function. Endocrine diseases are also common in such cases, which develop in secret for a long time, and one of the first visible symptoms may be menstrual disorders in girls (67).

The current study makes a valuable contribution to the literature on adolescents' eating habits, particularly in the context of differences based on sex and BMI. It provides a deeper understanding of the relationship between these factors, an aspect that is often overlooked in similar research. In addition, the wide range of analyzed food categories, including both healthy and less favorable dietary choices, allows for a more comprehensive assessment of eating habits within the study group. An important feature of this study is its focus on snacking habits, which can significantly impact the overall energy and nutritional value of the diet. The analysis offers new insights into several key areas, including differences in snacking habits among children with different BMIs, a topic rarely addressed in the literature. Moreover, it identifies specific product groups that are more or less frequently consumed by children who are overweight, obese or malnourished. Another innovative aspect is the clear emphasis on the role of sex differences in shaping food choices among adolescents.

The findings of this study may contribute to the development of strategies for nutrition education and obesity prevention. They provide valuable data for public health organizations to use in health promotion activities targeting children and adolescents worldwide. Additionally, the study helps identify global nutritional trends among young people, serving as a foundation for developing international nutritional recommendations. The results can also support initiatives that promote healthy eating habits in schools, highlighting the importance of

nutrition education and the impact of the family environment on children's diet.

The study has several key strengths. The large and diverse sample size (664 children) enhances the reliability and representativeness of the findings. The inclusion of multiple variables, such as eating habits and socioeconomic factors, allows for a broader and more comprehensive interpretation of the data. An important aspect of the study was also the comparison of different food product consumption patterns based on sex and BMI, which helped identify key differences among the analyzed groups and draw more precise conclusions about the relationship between diet and nutritional status. In addition, the use of statistical methods, including the Kruskal-Wallis analysis of variance and χ^2 test, strengthens the reliability of the results and ensures their objective interpretation. Another important aspect of the study is its practical application, as the findings can serve as a foundation for educational and preventive initiatives aimed at improving the dietary habits of children and adolescents.

This study also has several limitations. A notable limitation of the study is the absence of formal validation of the survey instrument and reliability testing. However, the researcher was present during the completion of the questionnaires and was available to respond to any inquiries. It did not account for the level of physical activity among adolescents, which is an important factor in assessing health and lifestyle. In addition, data on eating habits were collected through self-reporting, which may introduce recall bias or intentional modification of responses by participants. Certain socioeconomic aspects, such as family income or housing conditions, which could influence dietary habits, were not considered. Moreover, the study was conducted in a single region, which may limit the generalizability of the results to the broader population of children. It is crucial to acknowledge that the material used for publication was collected during the period 2016–2017. This must be taken into account when interpreting the results of the study. Another limitation is the age of the children studied. Despite these limitations, the study provides valuable insights that can contribute to international health programmers and initiatives aimed at improving the dietary quality of children and adolescents on a global scale. Moreover, the findings can be used by doctors to identify at-risk groups and implement appropriate interventions for overweight, obesity or malnutrition. Nutritionists and dieticians can use the study to develop more effective dietary strategies tailored to the needs of children and adolescents. Finally, the study is important for policymakers and public health institutions, providing a basis for prevention programmers and educational campaigns aimed at promoting healthy eating habits among young people.

5 Conclusion

Significant differences in the frequency of fast food consumption and snacking were observed between boys and girls, depending on BMI. The more frequent consumption of whole meal bread by overweight and obese adolescents, along with their lower intake of foods high in simple sugars and fast food, may suggest conscious attempts to control their diet, reflecting changing eating habits among young people. In contrast, the higher fast food consumption among malnourished girls, compared to other groups, may suggest a potential link between low body weight and a tendency to consume foods with low nutritional value.

The results of this study highlight the need for further research in this area. The application concerns the Polish teenage population. They also underscore the importance of nutrition education, particularly regarding proper meal composition and healthy snacking, tailored to specific groups based on BMI and sex. Special attention should be given to snacking habits, as they play a significant role in shaping young people's diet. This study emphasizes the importance of an interdisciplinary approach that integrates nutrition, psychology and sociology. Promoting healthy eating habits should consider not only taste preferences but also the influence of family and the broader social environment. Thanks to integrated actions and the involvement of all sectors, it will be possible to reduce the scale of obesity in Poland and improve public health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Bioethics Committee of Jagiellonian University (no. K/ZDS/007167). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

JŻ: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. EB-B: Supervision,

Visualization, Writing – review & editing. IB: Visualization, Writing – original draft, Writing – review & editing. PJ: Methodology, Supervision, Visualization, Writing – review & editing. AO-G: Writing – review & editing. PK: Supervision, Writing – review & editing.

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Trends in the prevalence of anorexia nervosa among individuals under 45 years in China, 1992–2021: an age-period-cohort analysis

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Objective: This study aims to analyze the temporal trends in the incidence and prevalence of anorexia nervosa (AN) in China from 1992 to 2021, focusing on age, period, and cohort effects, in order to provide evidence for the prevention and control of anxiety-related disorders.

Methods: Data on the incidence and prevalence of anorexia nervosa in China were obtained from the Global Burden of Disease Study 2021. Joinpoint regression analysis was employed to assess trends over time, while an age-period-cohort (APC) model was used to estimate the net effects of age, period, and cohort variables.

Results: From 1992 to 2021, the incidence and prevalence of anorexia nervosa among individuals under 45 years in China showed a general upward trend. The annual percent change (APC) for incidence was 1.29%, and for prevalence was 0.31%, with both rates consistently higher in females than in males. Age effects revealed that the highest incidence and prevalence occurred between ages 10 and 25, followed by a gradual decline. Period effects demonstrated a consistent upward trend across the total population. Cohort analysis indicated an intergenerational increase in the risk of anorexia nervosa.

Conclusion: The incidence and prevalence of anorexia nervosa among individuals under 45 years in China have increased steadily from 1992 to 2021. This growing disease burden, with marked age and gender disparities, highlights the urgent need for targeted interventions, especially among adolescents and women.

KEYWORDS

anorexia nervosa, epidemiological trends, age-period-cohort model, GBD, GBD database

Background

Anorexia nervosa (AN) is a severe psychiatric disorder characterized by extreme food restriction and pathological control of body weight, classified under eating disorders. Patients often exhibit an intense fear of weight gain, resulting in chronic malnutrition. Classic symptoms include a significantly low body mass index (BMI < 17.5), menstrual irregularities in females, and denial of the harmful consequences of being underweight (1, 2). AN is

frequently accompanied by multisystem complications, such as cardiac abnormalities (3) and increased bone fragility (2), and it is highly comorbid with other mental disorders, including depression, anxiety, and obsessive-compulsive disorder (4). Although approximately half of patients can achieve partial or full recovery with treatment, up to 5% die from organ failure or suicide, and 20% develop a chronic disease course, posing serious threats to health (2).

This disorder is especially prevalent among young individuals. Over the past three decades, the global prevalence of AN has increased significantly. According to global epidemiological data from 2017, the age-standardized prevalence rates were 7.51 per 100,000 in males and 22.46 per 100,000 in females, with adolescent girls aged 15–19 being most affected (5, 6). In China, the number of affected adolescents has also risen, with urbanized areas such as Hong Kong approaching prevalence rates comparable to those in Western developed countries (7). In addition to severely impairing quality of life, AN markedly increases the risks of substance abuse and suicide, and it has the highest mortality rate among all psychiatric conditions (8), placing a substantial burden on healthcare systems (9).

However, there remains a lack of comprehensive studies on the temporal trends of AN among individuals under the age of 45 in China. Most existing studies have only described age-specific incidence or prevalence at discrete time points, without adequately disentangling the interacting effects of age, period, and birth cohort (APC). This limitation hinders the identification of high-risk populations and key exposures. To address this gap, the present study uses data from the Global Burden of Disease Study 2021 (GBD 2021) to systematically analyze trends in the prevalence of AN in China from 1992 to 2021. By quantifying the independent effects of age, period, and cohort, this study aims to provide scientific evidence for the development of prevention and intervention strategies throughout the life course.

Methods

Data source

The data for this study were obtained from the Global Burden of Disease Study 2021 (GBD 2021) database, maintained by the Institute for Health Metrics and Evaluation (IHME). This database provides comprehensive observational epidemiological data for 369 diseases and injuries across 204 countries and territories from 1992 to 2021 (10). The AN data for China were derived from multiple sources, including disease surveillance systems, national health service surveys, and published literature. This study extracted data on the incidence and prevalence of AN among individuals aged under 45 in China from 1992 to 2021 for descriptive and analytical purposes.

Joinpoint regression analysis

Joinpoint regression analysis involves segmented linear modeling and permutation tests to objectively identify turning points in time-series data, such as critical public health intervention points. It overcomes the limitations of traditional linear regression in fitting complex non-linear patterns (e.g., fluctuating incidence rates or economic cycles). The method's strengths include automated model

selection (11), statistically validated identification of joinpoints (with Bayesian Information Criterion for overfitting control), and the ability to adjust for covariates, enabling multidimensional stratified analysis (12). Developed by the National Cancer Institute (NCI), this technique has been widely applied in cancer epidemiology (e.g., trend decomposition in survival rates) and environmental exposure assessment (e.g., climate change inflection points). Its visual outputs offer intuitive evidence to inform policy decisions (13).

Age-period-cohort analysis

Age-period-cohort (APC) analysis is a statistical approach designed to separate the independent effects of age (biological/life stage), period (contemporary historical events), and birth cohort (shared generational experiences) on a given outcome (14). This method is particularly effective in disentangling complex temporal dynamics. The age effect reflects biological or lifecycle-driven variations in risk (e.g., age-related disease vulnerability), period effects capture time-specific global influences (e.g., health policies or pandemics), and cohort effects reveal generational differences rooted in distinct social environments (e.g., shifts in health behaviors or cultural attitudes). Linear collinearity among the three dimensions is addressed via constrained estimators (e.g., the Intrinsic Estimator) or hierarchical modeling techniques (15). APC analysis is widely used in public health for identifying high-risk groups and guiding targeted interventions (e.g., cancer screening by birth cohort) and in sociology to study generational value shifts.

Statistical analysis

Key analytical indicators in this study included age-standardized incidence rates (ASIR) and age-standardized prevalence rates (ASPR) of anorexia nervosa. The study population included individuals aged 5–45 years from 1992 to 2021 in China. The population was stratified into eight 5-year age groups (5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44), six period groups (1992–1996, 1997–2001, 2002–2006, 2007–2011, 2012–2016, 2017–2021), and 13 birth cohorts (1948–1952 to 2013–2017). The 2002–2006 period and the 1982–1986 birth cohort were designated as reference categories. Joinpoint regression was performed using the JPR software (version 5.0.2) developed by the U. S. National Cancer Institute. APC analyses were conducted using the NCI's online APC analysis tool (11).

Results

Trends in Incidence and Prevalence of Anorexia Nervosa Among Individuals Under 45 Years in China (1992–2021). Table 1 and Figure 1A present the Joinpoint regression analysis of the age-standardized incidence rates (ASIR) of anorexia nervosa among individuals under 45 years in China from 1992 to 2021. The overall trend, as well as the trends in males and females, demonstrated significant segmented increases. On average, the incidence rate increased by 1.29% per year, with annual increases of 1.25% in males and 1.37% in females. Each group experienced six distinct segments of upward trends, all of which were statistically significant ($p < 0.05$). The steepest increase in the overall population occurred between 2009 and 2014, with an annual rise

TABLE 1 Joinpoint regression analysis of anorexia nervosa incidence rates by sex in China among individuals aged under 45 years (1992–2021).

Category	Indicator	Interval	Change (%)	95% CI
Overall	APC	1992–1996	0.5270*	0.2504 ~ 0.6818
		1996–1999	1.8384*	1.5831 ~ 1.9899
		1999–2009	1.2490*	1.1778 ~ 1.2882
		2009–2014	2.3251*	2.1921 ~ 2.5438
		2014–2017	1.3072*	1.0195 ~ 1.8156
		2017–2021	0.4706*	0.2264 ~ 0.6186
	AAPC	1992–2021	1.2927*	1.2721 ~ 1.3106
Male	APC	1992–1996	0.5283*	0.4866 ~ 0.5720
		1996–2002	1.2172*	1.1704 ~ 1.2456
		2002–2006	1.4033*	1.3186 ~ 1.5167
		2006–2014	1.6857*	1.6660 ~ 1.7268
		2014–2018	1.5262*	1.4614 ~ 1.5762
		2018–2021	0.5837*	0.5198 ~ 0.6442
	AAPC	1992–2021	1.2533*	1.2474 ~ 1.2591
Female	APC	1992–1996	0.5527*	0.2329 ~ 0.7414
		1996–2000	2.0285*	1.8097 ~ 2.3375
		2000–2006	1.0232*	0.7534 ~ 1.1531
		2006–2010	1.5991*	1.2745 ~ 2.2778
		2010–2015	2.7846*	2.6408 ~ 3.0261
		2015–2021	0.5308*	0.4123 ~ 0.6307
	AAPC	1992–2021	1.3749*	1.3535 ~ 1.3959

Annual percent change (APC) and average annual percent change (AAPC) are presented for each identified segment. *All APCs are statistically significant at $p < 0.05$.

of 2.32%. Among males, the fastest increase was observed from 2006 to 2014 (1.69% per year), while in females, the most pronounced growth occurred from 2010 to 2015 (2.78% per year). The differences in trend slopes between males and females were statistically significant ($p < 0.05$).

Table 2 and Figure 1B show the Joinpoint regression results for age-standardized prevalence rates (ASPR). From 1992 to 2021, the prevalence of anorexia nervosa also showed significant segmented increases in the overall population, as well as among males and females. The average annual increase in ASPR was 1.34% overall, 1.31% in males, and 1.40% in females. Both the overall population and females exhibited six periods of increasing prevalence, whereas four distinct increasing periods were identified in males, all with statistical significance ($p < 0.05$). The most substantial increases in the overall and female populations occurred between 1996 and 2000, with annual growth rates of 2.18 and 2.53%, respectively. For males, the largest increase occurred between 2004 and 2018 (1.68% annually). The differences in prevalence trends between sexes were also statistically significant ($p < 0.05$).

Temporal effects analysis: age, period, and cohort dimensions

The age-period-cohort (APC) analysis revealed distinct and interrelated contributions of age, period, and cohort effects to the

observed trends in anorexia nervosa (AN) among individuals under 45 years in China from 1992 to 2021. The age effect demonstrated a pronounced pattern (Figure 2): both incidence and prevalence peaked between the ages of 10 and 25, followed by a gradual decline. This trend was consistent in both sexes, though females exhibited higher rates across all age groups. These findings underscore adolescence and early adulthood as high-risk developmental windows, characterized by hormonal fluctuations, emerging self-identity, and heightened sensitivity to social influences—all of which may predispose individuals to disordered eating behaviors.

The period effect (Figure 3) showed a persistent upward trend in the relative risk (RR) of both incidence and prevalence over time, independent of age and cohort influences. Between 1992 and 2010, males exhibited higher incidence risks compared to females; however, by 2015–2021, the prevalence risk in males surpassed that in females. This pattern reflects broad sociocultural and technological shifts during the study period—including the proliferation of media promoting thin ideals, increased social media use, and intensified academic and workplace pressures—that likely contributed to body dissatisfaction and restrictive eating across the population.

The cohort effect (Figure 4) illustrated a generational rise in AN risk, with RR values steadily increasing among later-born cohorts. This trend suggests that individuals born more recently are more vulnerable to AN, likely due to cumulative exposure to modern stressors such as digital media, urbanization, and societal competition. Notably, the cohort effect showed no significant gender differences, indicating that these generational pressures may exert similarly adverse influences on both males and females. Together, these temporal dimensions reflect a complex interplay of biological, cultural, and environmental forces driving the increasing burden of AN in younger populations.

Discussion

To our knowledge, this study is the first to comprehensively assess the trends in incidence and prevalence of anorexia nervosa (AN) among individuals under 45 years in China using GBD 2021 data from 1992 to 2021. Over the past three decades, both the incidence and prevalence of AN in this population have steadily increased. Specifically, the incidence rate rose from 10 per 100,000 in 1992 to 14.48 per 100,000 in 2021, while the prevalence increased from 22.98 to 32.81 per 100,000. The age-period-cohort (APC) model revealed that all three temporal dimensions contributed significantly to these trends, with age emerging as a particularly influential factor.

The age effect showed a distinct gender difference, with females consistently exhibiting higher incidence and prevalence rates across all age groups. The highest burden of AN was concentrated in individuals aged 10–25, after which both incidence and prevalence declined gradually. These findings align with the results of previous studies by Li et al. (16) and Wu et al. (6). In addition, this study limited the upper age boundary to 45 years because AN predominantly affects adolescents and young adults. Epidemiological studies have demonstrated that the prevalence and incidence of AN markedly decline after age 45 (17). Moreover, the GBD 2021 dataset primarily emphasizes younger populations, especially ages 10–25, where AN risk is highest, thus focusing on this age range allows for a clearer depiction of trends in the most affected groups. It should be noted that the DSM-5 (2013) broadened the diagnostic definition

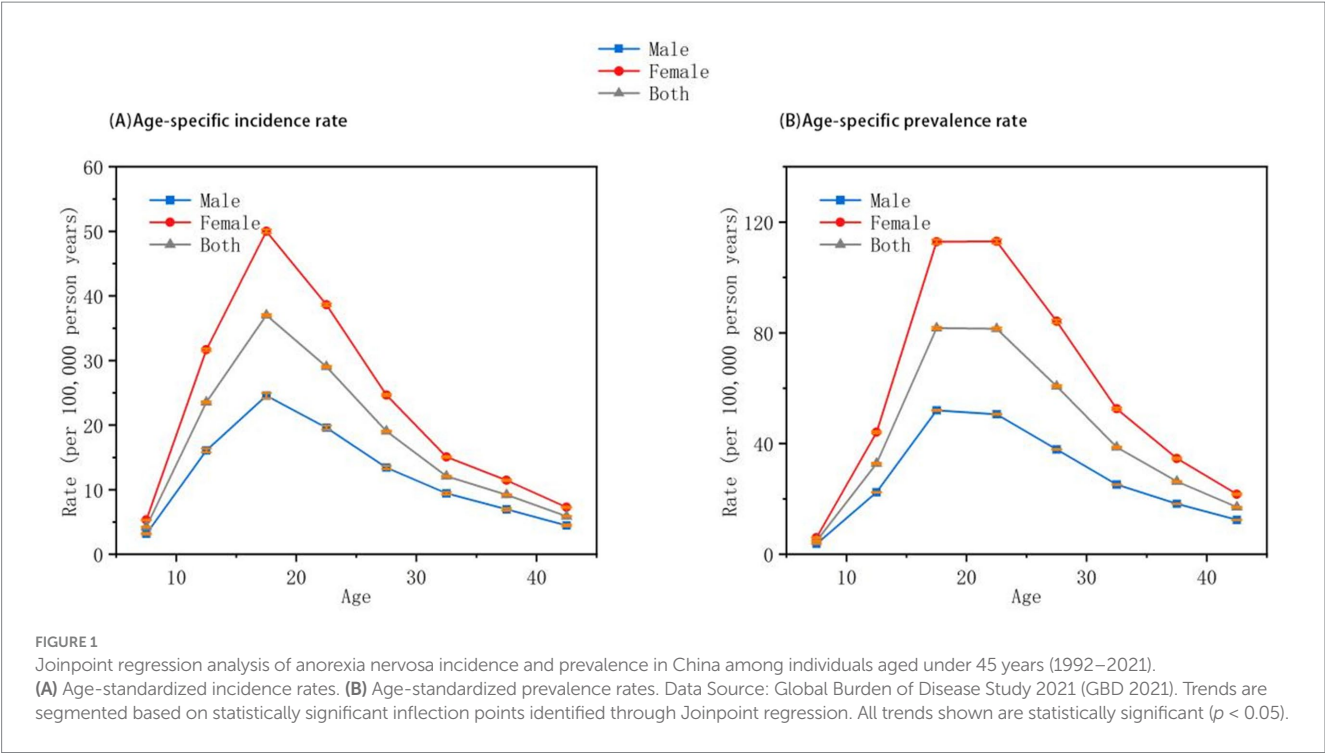


TABLE 2 Joinpoint regression analysis of anorexia nervosa prevalence rates by sex in China among individuals aged under 45 years (1992–2021).

Category	Indicator	Interval	Change (%)	95% CI
Overall	APC	1992–1996	0.5651*	0.4876 ~ 0.6432
		1996–2000	2.1761*	2.1057 ~ 2.2491
		2000–2005	1.2096*	1.1150 ~ 1.2811
		2005–2013	1.7129*	1.6719 ~ 1.7751
		2013–2018	1.3550*	1.2542 ~ 1.4347
		2018–2021	0.4548*	0.3319 ~ 0.5830
	AAPC	1992–2021	1.3384*	1.3271 ~ 1.3491
Male	APC	1992–1996	0.4590*	0.3897 ~ 0.5347
		1996–2004	1.3574*	1.3084 ~ 1.3923
		2004–2018	1.6810*	1.6653 ~ 1.7009
		2018–2021	0.6262*	0.5212 ~ 0.7126
	AAPC	1992–2021	1.3130*	1.3024 ~ 1.3233
Female	APC	1992–1996	0.5957*	0.4974 ~ 0.6957
		1996–2000	2.5337*	2.4462 ~ 2.6259
		2000 ~ 2005	1.0581*	0.9534 ~ 1.1451
		2005 ~ 2014	1.7735*	1.7319 ~ 1.8374
		2014 ~ 2018	1.3751*	1.1719 ~ 1.5303
		2018 ~ 2021	0.5094*	0.2940 ~ 0.7001
	AAPC	1992 ~ 2021	1.4048*	1.3902 ~ 1.4182

Annual percent change (APC) and average annual percent change (AAPC) are presented for each identified segment. *All APCs are statistically significant at $P < 0.05$.

of AN by removing the amenorrhea criterion, thus including males who may previously have been excluded. As GBD data span 1992–2021, crossing the DSM-IV and DSM-5 eras, this diagnostic shift

likely contributed to the observed increase in incidence and prevalence, particularly after 2013, and should be considered when interpreting these findings (18). Adolescence is a period of profound physiological and psychological change. On a biological level, hormonal fluctuations—particularly in estrogen—may disrupt normal appetite regulation and affect body image perception in females (19). Psychologically, adolescents are in the midst of forming self-identity and are highly sensitive to external influences (20). Socially, the increasing importance of peer acceptance and exposure to societal norms around body image can lead to unhealthy dieting behaviors and ultimately the development of eating disorders (21).

Our results also confirm a marked gender disparity: females exhibit significantly higher rates of AN than males, consistent with international trends (4). Compared with international studies, our reported AN incidence in China is higher. This discrepancy may stem from several factors: GBD data integrate multiple sources including surveillance, surveys, and literature, which may encompass broader definitions or self-reported cases. Additionally, China’s rapid socioeconomic changes and cultural westernization could have elevated true incidence, and differences in diagnostic rigor between studies also likely contributed (22, 23). Socioculturally, the widespread promotion of thinness as a beauty ideal in China—reinforced by fashion media and social platforms—places substantial body image pressure on women. In pursuit of this “ideal body,” women are more likely to engage in extreme dietary restrictions, thereby elevating their risk of developing AN (24, 25). Psychologically, women tend to construct self-identity more strongly around physical appearance. Dissatisfaction with one’s body or weight may lead to emotional distress and, in turn, trigger restrictive eating as a coping mechanism to alleviate anxiety and reinforce self-worth (17, 26).

China’s competitive education system imposes distinct institutional pressures on youth mental health, particularly during the

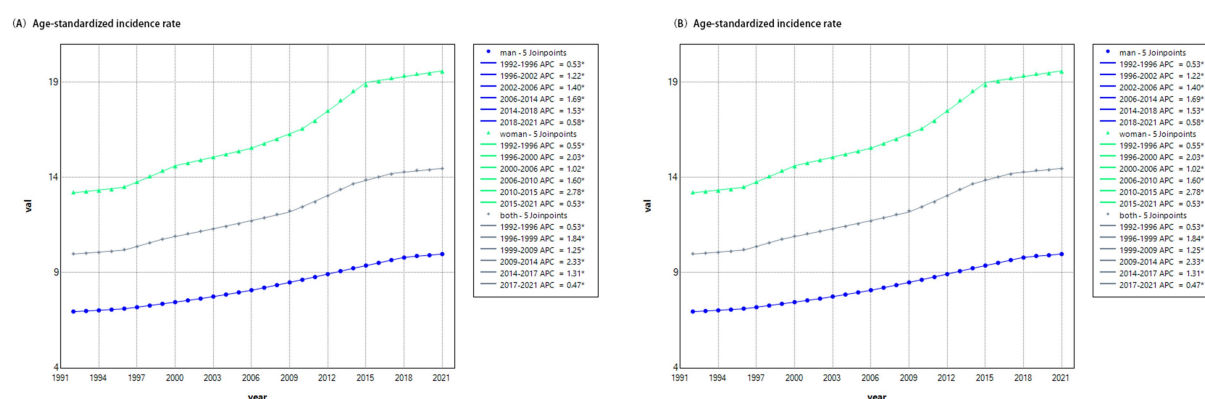


FIGURE 2

Longitudinal age effects on anorexia nervosa among individuals aged under 45 years in China (1992–2021). (A) Age-specific incidence rates. (B) Age-specific prevalence rates. Data adjusted for period effects. Both incidence and prevalence rates peak between ages 10 and 25 and decline thereafter. Females exhibit higher rates than males across all age groups.

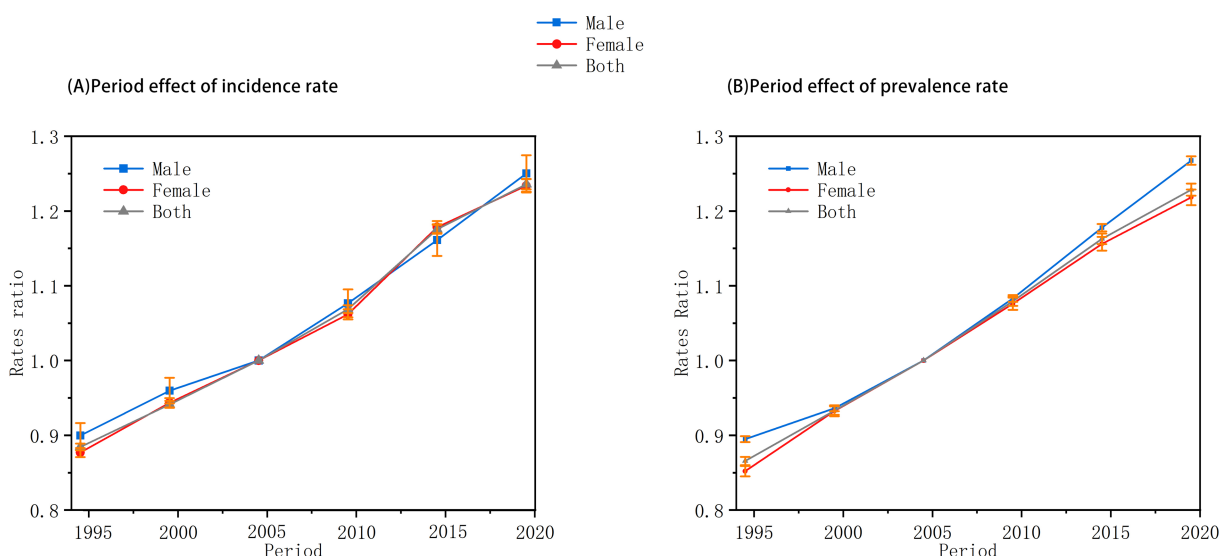


FIGURE 3

Period effects on anorexia nervosa incidence and prevalence in China among individuals aged under 45 years (1992–2021). (A) Relative risks of incidence by period. (B) Relative risks of prevalence by period. Relative risks (RRs) adjusted for age and cohort effects. Period effects demonstrate a steady increase over time. Gender differences are observed, particularly in the later periods (2015–2021).

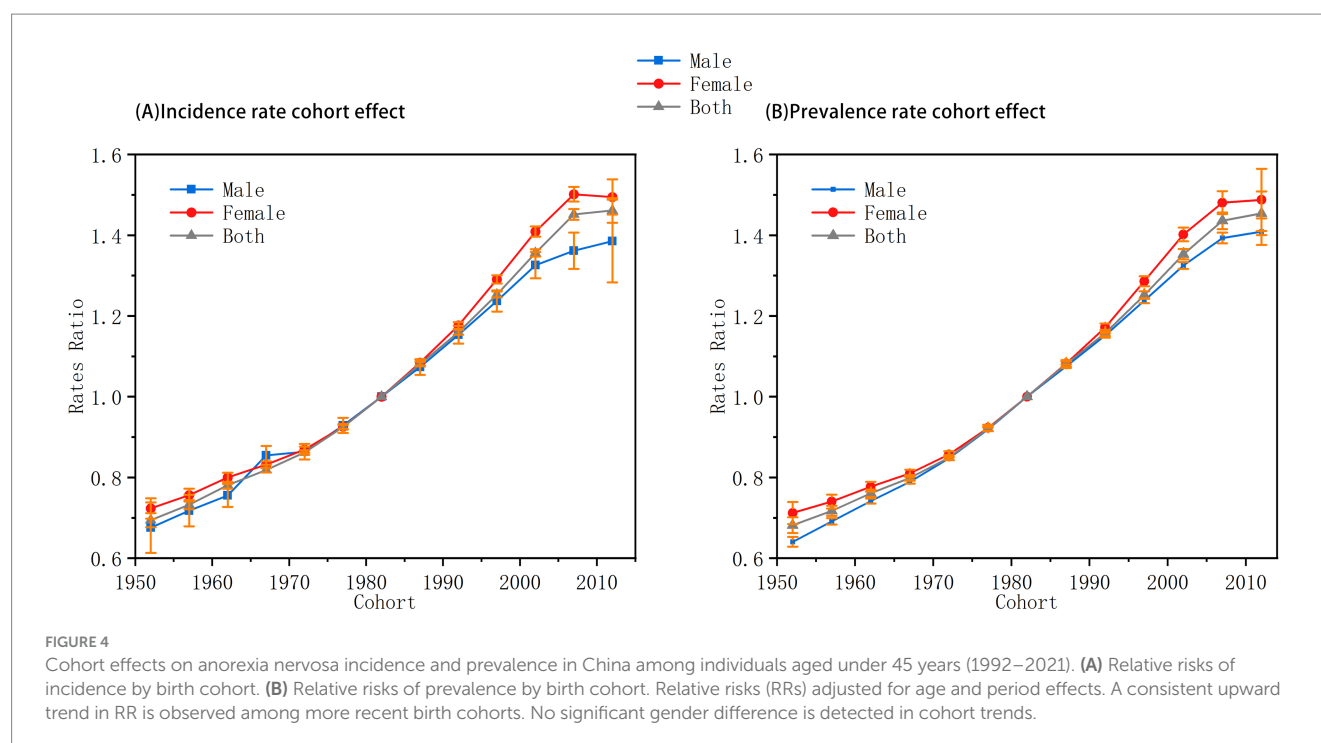
critical developmental period between ages 10 and 20. Adolescents are often subjected to academic workloads exceeding 12 h per day, significantly reducing sleep compared to international standards. Coupled with high parental expectations—where education is often seen as the family's primary investment—this dual burden can contribute to the onset of psychiatric disorders, including anorexia nervosa (27).

The period effect analysis revealed a steady increase in both incidence and prevalence ratios of AN from 1992 to 2021 across genders and in the total population. These findings reflect profound changes in China's sociocultural and media landscape during this time.

From a cultural standpoint, the proliferation of the “thin ideal” through television, fashion media, and later social media platforms has amplified body image anxiety in both genders. He et al. (28)

reported that extensive exposure to these ideals significantly elevates the risk of AN. As the internet became increasingly accessible during the study period, platforms such as Facebook and Weibo accelerated the viral spread of body-conscious norms. Notably, spending more than 3 h daily on short video platforms was associated with a 37% increase in the risk of AN.

Economically, the transition toward consumer-driven lifestyles has also contributed to this phenomenon. The rapid industrialization of fast food and the commercialization of the weight-loss industry since the 1990s created an environment of dietary paradox. Stice and Shaw (29) proposed the “affluence–restriction paradox,” whereby excessive availability of high-calorie foods coexists with pressure to maintain thinness. This paradox fosters increased dieting behavior among adolescents, a known precursor to AN. The co-occurrence of



rising obesity and AN prevalence during the same period underscores a dual-pathway model of “weight anxiety → restrictive behavior.”

Cohort analysis further suggests that sociodemographic transitions have significantly influenced AN trends. The implementation of China’s one-child policy led to a dramatic increase in nuclear family structures, wherein emotional interactions between parents and children are often diminished. Reduced familial emotional support may prompt adolescents to seek control and comfort through eating behavior regulation. Restrictive eating can become a compensatory strategy to regain psychological control. These findings are consistent with global studies linking impaired family communication patterns to elevated risk of eating disorders (30, 31).

Moreover, China’s rapid urbanization has reshaped daily life and stress exposure across generations. Younger cohorts are increasingly immersed in fast-paced urban environments characterized by intense competition, workplace stress, and ongoing economic pressure. Chronic social stress, well-documented as a risk factor for psychiatric disorders—including AN—can disrupt normal eating patterns, leading individuals to adopt disordered eating as an ineffective coping strategy.

While this study emphasizes sociocultural influences, genetic factors are equally critical in AN etiology. Twin studies estimate heritability between 48 and 74%, and female relatives of AN patients have an 11-fold higher lifetime risk than those without such family history (32, 33). Future studies should integrate genetic and environmental perspectives to better elucidate AN’s multifactorial origins. Finally, the evolving economic climate has exacerbated employment stress among younger cohorts. The high competitiveness of the labor market often generates anxiety, depression, and other negative emotional states. In the absence of effective emotional regulation strategies, these emotions can manifest as maladaptive behaviors, including extreme dietary restriction. This pattern is consistent with previous findings identifying psychological stress and

poor coping skills as major risk factors for the development of AN (34, 35).

Despite these findings, the study has several limitations. First, the GBD database provides only secondhand, aggregated data and currently includes data only up to 2021, which limits timeliness. Second, due to data availability constraints, regional analyses at the provincial or city level could not be performed. Third, the lack of individual-level disease burden data and standardized population information may lead to discrepancies between the reported estimates and the actual national situation in China. Given China’s pronounced socioeconomic and urban–rural disparities, future research should stratify by these dimensions. Urban residents’ greater exposure to social media and distinct body image norms versus rural populations could serve as an internal comparison to disentangle cultural from genetic effects. Future research should incorporate more granular, up-to-date data for enhanced accuracy and relevance.

Conclusion

From 1992 to 2021, the incidence and prevalence of anorexia nervosa among individuals under 45 years in China have exhibited a persistent upward trend. The disease burden was especially high among females aged 10–25 years. Age-period-cohort analysis demonstrated that age was a major determinant, with incidence and prevalence peaking during adolescence and declining gradually thereafter. Meanwhile, differences between males and females narrowed with increasing age. Period effects showed a steady increase across the entire population, reflecting widespread societal changes. Cohort effects revealed a progressive intergenerational increase in AN risk, with no significant gender difference. These findings highlight the urgent need for sustained attention to AN among adolescents and women, alongside timely, targeted interventions to mitigate its growing public health impact.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

JT: Writing – review & editing, Writing – original draft, Data curation. YH: Data curation, Project administration, Writing – original draft. YC: Project administration, Data curation, Writing – original draft. ZT: Methodology, Formal analysis, Writing – original draft. YZ: Writing – review & editing, Resources.

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Dietary inflammation and socioeconomic status mediate depression–constipation link: a cross-sectional analysis of NHANES 2005–2010

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Background: This study investigated the relationship between depression and constipation and examined potential mediating roles of dietary inflammatory index (DII) and socioeconomic status using data from NHANES 2005–2010.

Methods: We analyzed 12,854 adults with complete data on depression (PHQ-9), constipation (self-report/Bristol Stool Scale), DII (27 nutrients), and poverty-to-income ratio (PIR). Statistical analyses included multivariable logistic regression with appropriate reference categories, restricted cubic splines (RCS), mediation analysis, and subgroup assessments.

Results: Constipated individuals exhibited significantly higher depression severity (mean PHQ-9: 4.25 vs. 3.00), higher DII (2.00 vs. 1.37), and lower PIR (all $p < 0.0001$). After adjustments, PHQ-9 scores were independently associated with constipation risk (OR: 1.04, 95% CI: 1.03–1.06), with a non-linear relationship showing an inflection point at PHQ-9 = 10 (scores <10: OR = 1.08; scores ≥ 10 : OR = 0.98). Statistical mediation analysis revealed that DII mediated 6.03% and PIR mediated 12.46% of the depression–constipation association. Subgroup analyses demonstrated consistent associations across all demographic and clinical subgroups (OR range: 1.04–1.14).

Conclusion: This cross-sectional study demonstrates a significant non-linear relationship between depression and constipation, partially mediated by dietary inflammation and socioeconomic status. Longitudinal studies are needed to establish causality and directionality between these variables.

KEYWORDS

depression, constipation, NHANES, mediation analysis, DII, PIR

1 Introduction

Gastrointestinal disorders impose substantial burdens on global healthcare systems, with chronic constipation representing a prevalent yet mechanistically complex condition that affects approximately 10–16% of adults worldwide (64). Its bidirectional relationship with depression is increasingly recognized as a critical public health concern (1). While cross-sectional studies consistently show associations between depression and functional gastrointestinal disturbances (2, 3), longitudinal research provides stronger evidence for

causality. For instance, prospective cohort studies have shown that depression increases the risk of incident constipation [e.g., Liu et al. (4): HR = 1.72, 95% CI: 1.42–2.08] (2, 3). Conversely, constipation has also been shown to predict subsequent depression [Koloski et al. (5): OR = 2.36, 95% CI: 1.58–3.51]. Thus, neuroendocrine dysregulation and autonomic dysfunction may play a role in the relationship between depression and constipation (6, 7), while chronic distress from constipation may be linked to depression through reduced quality of life and impaired social functioning (8). The current evidence suggests a reinforcing cycle, though intervention studies indicate that depression treatment more often improves constipation than vice versa (3, 9).

Despite established correlations, mechanistic insights into the depression–constipation nexus remain fragmented. Existing research primarily implicates factors such as reduced colonic motility under stress-axis activation and disruptions in serotonergic pathways, such as pivotal elements linking these conditions (10, 11). Moreover, evidence suggests that alterations in gut microbiota and systemic inflammation may play critical roles in mediating this relationship, although further exploration is necessary to clarify their impact (7, 12). However, critical gaps persist in understanding intermediary mechanisms associated with both psychological distress and gastrointestinal pathology. The roles of lifestyle-modifiable mediators—specifically diet-driven systemic inflammation and socioeconomic disparities—are inadequately characterized within this relationship (13), limiting the development of targeted interventions aimed at addressing both conditions simultaneously.

Recent research highlights a compelling association between inflammation, depression, and gastrointestinal dysfunction, with particular focus on the role of pro-inflammatory cytokines associated with changes in gut neuromuscular coordination and visceral sensitivity (7, 10). This relationship is underscored by findings indicating that diet-derived inflammation, as operationalized by the DII, may be statistically associated with these relationships. Existing literature shows a positive correlation between higher DII scores and the incidence of depression, alongside gastrointestinal symptoms such as constipation (14). Despite these insights, studies specifically quantifying DII's potential statistical mediation in the depression–constipation context remain scarce.

Moreover, the influence of socioeconomic status (SES) on depression and gastrointestinal health is significant, yet often underexplored (15, 16). Low SES has been correlated with heightened risks of depressive symptoms and comorbid conditions such as constipation, as individuals facing economic hardships frequently have limited access to quality healthcare and nutritious food (17, 18). Recent studies indicate that SES might be associated with dietary factors, both independently and interactively, in relation to the risk of constipation (19). However, comprehensive models integrating psychological, dietary–inflammatory, and socioeconomic mediators in large-scale human studies are largely lacking, which calls for further research to fill these critical gaps.

While it is generally observed that depression severity may exhibit linear relationships with somatic outcomes, the potential for non-linear dynamics—such as threshold effects in the association with constipation—is an area ripe for exploration using flexible epidemiological tools, including restricted cubic splines (20). In light of these factors, addressing these complex interrelations is

crucial for developing targeted interventions for high-risk populations plagued by depression and gastrointestinal complications.

Leveraging NHANES data (2005–2010) from 12,854 U.S. adults, this study addresses these critical gaps by: (1) quantifying independent associations between depression severity, DII, and PIR with constipation risk; (2) identifying potential threshold effects using non-linear modeling; and (3) empirically decomposing the statistical mediation of diet-induced inflammation and socioeconomic disparities. Our findings suggest associations between depression, pro-inflammatory diets, and increased constipation risk, while also identifying a potential protective association with higher SES. Building upon established associations between individual factors and constipation risk, we provide the first formal statistical mediation analysis examining the relationships between depression, dietary inflammation, and socioeconomic status within a unified analytical framework using multi-mediator structural equation modeling.

2 Methods

2.1 Study population

The present study utilized data from the National Health and Nutrition Examination Survey (NHANES) 2005–2010 cycles because these three 2-year cycles included relevant questionnaire data on bowel health. NHANES is a comprehensive nationwide survey conducted by the National Center for Health Statistics (NCHS) to assess the health and nutritional status of the U.S. population (65, 66). It employs a complex, multistage probability sampling design to represent the non-institutionalized U.S. civilian population, with strategic oversampling of specific subgroups (elderly, African Americans, and Hispanics) to enhance estimate precision (21). Our study's participant selection workflow is depicted in Figure 1. All procedures were approved by the NCHS Ethics Review Board, and all participants provided written informed consent. Detailed methodological information is available on the NHANES website (22). From an initial sample of 31,034 participants, we excluded 13,902 individuals younger than 20 years of age, as they did not complete the bowel health questionnaire. Among the remaining 17,132 adult participants (aged 20–85 years), we further excluded those with missing data on depression ($n = 2,315$), constipation ($n = 63$), and DII ($n = 1,900$). The final analytical cohort comprised 12,854 adults with complete data on all key variables of interest.

2.2 Assessment of depression

Depression was assessed using the PHQ-9 (23, 24). This nine-item questionnaire employs a 4-point rating scale (0 = not at all; 1 = several days; 2 = more than half the days; and 3 = nearly every day), with total scores ranging from 0 to 27 (25). The PHQ-9 demonstrates high sensitivity (86%) and specificity (85%) in depression screening, with a clinical cutoff score of 10. According to validated severity classifications 21, total scores of 0–4 indicate no depression, 5–9 indicate mild depression, 10–14 indicate moderate depression, and ≥ 15 indicate moderately severe to severe depression (26).

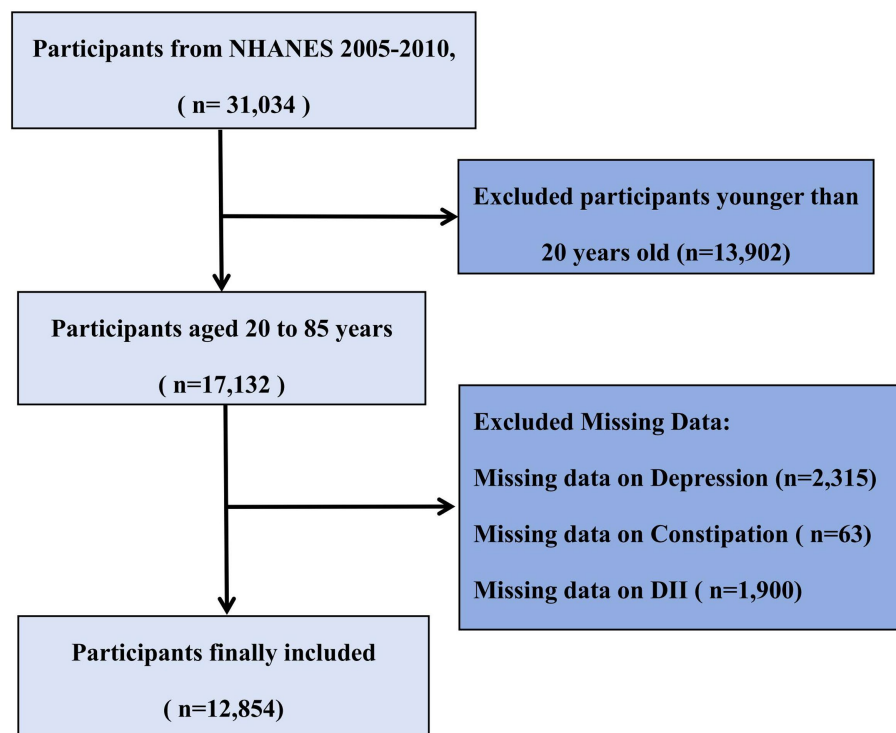


FIGURE 1
Flowchart of participant selection from NHANES 2005–2010.

2.3 Assessment of constipation

Constipation assessment was based on self-reported questionnaires and the Bristol Stool Form Scale (BSFS). Following previous studies, constipation was diagnosed based on two criteria: (1) self-reported bowel movements less than three times per week and (2) stool consistency corresponding to BSFS types 1 or 2. The BSFS classifies stools into seven types, with types 1–2 categorized as constipation, types 3–5 as normal, and types 6–7 as diarrhea (27, 28). In the NHANES database, constipation was assessed by asking, “Have you experienced constipation in the past 12 months?” For analytical purposes, frequency descriptors were operationalized as follows: “often” was defined as symptoms occurring ≥ 3 days/week but < 6 days/week, and “always” was defined as symptoms occurring ≥ 6 days/week, consistent with functional gastrointestinal disorder diagnostic criteria from Rome IV (29). Respondents who answered “always” or “often” were classified as having constipation (28, 30). This combined diagnostic approach (BSFS and self-report) has demonstrated good specificity (85%) with moderate sensitivity (72%) in previous validation studies when compared to clinical evaluations (31).

2.4 Assessment of DII

The DII was calculated based on the average dietary data obtained from two 24-h dietary recall interviews in NHANES. This index, developed by Shivappa et al. (32), assesses the inflammatory potential of diet through nutrient composition analysis, with detailed information available elsewhere (15). While the complete DII

incorporates 45 nutrients, our study utilized 27 available parameters due to data availability constraints in the NHANES database, a common limitation acknowledged in studies using secondary dietary datasets (33, 34). The 27 parameters included carbohydrates; energy; protein; fat; fiber; cholesterol; saturated fatty acids; monounsaturated fatty acids; polyunsaturated fatty acids; β -carotene; vitamins A, B1, B2, B6, B12, C, D, and E; folate; iron; magnesium (Mg); zinc; selenium; omega-3 and omega-6 polyunsaturated fatty acids; alcohol; and caffeine. Importantly, this reduced version of the DII has been validated in prior research. For instance, a study by Wirth et al. (35) demonstrated that a DII based on 28 components significantly correlated with inflammatory biomarkers (CRP and IL-6) in a similar magnitude as the full DII. Similarly, Tabung et al. (36) reported consistent associations between a reduced DII and health outcomes. Therefore, the 27-component DII used in our study is considered a valid measure of dietary inflammatory potential. Scores ≥ 0 indicate pro-inflammatory diets, while scores < 0 represent anti-inflammatory dietary patterns (37).

2.5 Assessment of PIR

PIR reflects household income relative to poverty thresholds, accounting for household size, composition, member ages, and annual inflation adjustments. These values, derived from the Department of Health and Human Services guidelines, provide precise poverty status assessments across years and states (38). For analytical purposes, income level was categorized into tertiles: low (PIR < 1.3), middle (PIR 1.3–3.5), and high (PIR ≥ 3.5) (39, 40). These cutoff points were

determined based on both policy-relevant thresholds and data distribution: the lower cutoff (1.3) approximates the Supplemental Nutrition Assistance Program (SNAP) eligibility threshold (130% of the poverty line) in many states (41), while the upper cutoff (3.5) is supported by research indicating that it represents a significant threshold in health disparities analysis (42) and aligns with prevalent income classifications used in health studies (42). This categorization is consistent with several NHANES-based studies examining health disparities across socioeconomic groups (42–44).

2.6 Covariables

NHANES-trained interviewers used a well-designed questionnaire to collect demographic, health, and biomarker data. Covariates were selected based on previous research findings and clinical expertise (45). The covariates we gathered included age, sex, ethnicity, marital status, education level, body mass index (BMI), smoking status, alcohol consumption status, hypertension, and diabetes. Ethnicity was categorized as Mexican American, non-Hispanic White, non-Hispanic Black, other Hispanic, and other ethnicities. Marital status was classified as married/living with partner, widowed/divorced/separated, and never married. Education level was divided into less than high school, high school, and above high school. BMI was categorized as <25.0, 25.0–29.9, and ≥ 30.0 kg/m². Smoking status was assessed using two questions from the NHANES questionnaire, with participants classified as never smokers, former smokers, and current smokers. Alcohol consumption status was categorized based on the average number of drinks per drinking day in the past 12 months as never drinkers, former drinkers, light drinkers, moderate drinkers, and heavy drinkers. Hypertension was defined as follows: (1) self-reported physician diagnosis; (2) mean diastolic blood pressure (DBP) ≥ 90 mmHg; (3) mean systolic blood pressure (SBP) ≥ 140 mmHg; or (4) current use of antihypertensive medication. Diabetes was defined as follows: (1) self-reported physician diagnosis; (2) laboratory indicators: glycated hemoglobin (HbA1c) $\geq 6.5\%$, fasting plasma glucose ≥ 7.0 mmol/L, random plasma glucose ≥ 11.1 mmol/L, or 2-h plasma glucose in oral glucose tolerance test (OGTT) ≥ 11.1 mmol/L; or (3) current use of diabetes medication or insulin therapy. Hyperlipidemia was determined based on self-reported medical history. Laboratory data, including total cholesterol and parameters for Fatty Liver Index (FLI) calculation, were extracted from the NHANES dataset. Total cholesterol and high-density lipoprotein cholesterol (HDL-C) were measured from fasting venous blood (≥ 9 h) according to NHANES protocols: enzymatically for cholesterol and via immunoinhibition/precipitation for HDL-C. The results were converted to mmol/L using a 0.02586 factor with strict quality control. Data, including these and FLI parameters, were extracted from the NHANES.

2.7 Statistical analysis

Between-group baseline differences were assessed using independent *t*-tests for continuous variables and chi-square tests for categorical variables. For the comparison of baseline characteristics between groups with and without constipation, we used the standard significance level ($\alpha = 0.05$) without correction for multiple comparisons, as these analyses were exploratory in nature and

intended to describe the sample characteristics rather than test formal hypotheses. Continuous variables were presented as mean $\pm$ standard deviation, and categorical variables were presented as frequencies and percentages. Missing data for key variables (<5%) were handled using multiple imputation. The associations between depression and constipation risk were evaluated using multivariable logistic regression models with three progressive models: Model 1 was unadjusted; Model 2 was adjusted for age, sex, ethnicity, and education level; and Model 3 was further adjusted for marital status, PIR, BMI, smoking status, alcohol consumption, physical activity, DII, diabetes, hyperlipidemia, hypertension, total cholesterol, HDL-C, fiber, polyunsaturated fatty acids (PUFA), vitamin D, and magnesium (Mg). The associations between DII and constipation risk and between P and constipation risk were analyzed using the same models.

To explore potential non-linear dose-response relationships between depression and constipation risk, restricted cubic spline models were applied with smooth curve fitting. A threshold effect analysis was subsequently conducted to identify the inflection point (PHQ-9 score = 10) and evaluate the presence of non-linearity, with a two-piecewise linear regression model constructed at the identified point and model fitness compared via log-likelihood ratio tests. Stratified analyses were conducted according to sex, age group (20–39, 40–59, and ≥ 60 years), ethnicity, education level, marital status, BMI categories (<25, 25–30, and ≥ 30 kg/m²), and PIR levels (<1.3, 1.3–3.5, and >3.5) to evaluate whether these factors modified the association between depression and constipation risk.

For the mediation analysis assessing the intermediary roles of DII and PIR in the depression–constipation relationship, we used R version 4.2.2 and implemented a counterfactual framework-based causal mediation analysis via the ‘mediation’ package. The existence of a significant mediation effect was defined by satisfying all of the following criteria: (1) a statistically significant indirect effect (average causal mediation effect, ACME; $p < 0.05$), (2) a statistically significant total effect ($p < 0.05$), and (3) a positive proportion mediated effect (ACME/total effect). To account for the complex survey design of the NHANES (including clustering, stratification, and sampling weights), we performed the statistical mediation analysis within the survey framework using the ‘survey’ package. Specifically, we created a survey design object incorporating sampling weights, primary sampling units, and strata. Bootstrap resampling (1,000 replicates) was applied to estimate 95% confidence intervals for mediation effects, ensuring consistent handling of the complex design features. All mediation analyses were adjusted for the same covariates included in Model 3 of the logistic regression analyses.

All analyses were conducted using the NHANES complex multistage sampling framework. Analyses were performed using R software (version 4.2.2) for primary analyses and mediation modeling, EmpowerStats (version 2.0) with the rms package for restricted cubic spline models, and Stata for supplementary analyses. Statistical significance was defined as a *p*-value of <0.05 (two-sided).

3 Results

3.1 Baseline characteristics

Table 1 presents the baseline characteristics of 12,854 participants stratified by constipation status. Participants with constipation ($n = 1,334$, 10.4% of total) were significantly younger (46.95 ± 18.59 vs. 50.28 ± 17.84 years, $p < 0.001$) and predominantly women (73.54%

vs. 49.44%, $p < 0.001$). The constipated group included a higher proportion of non-Hispanic Black (25.86% vs. 18.68%, $p < 0.001$) participants and showed lower educational attainment (41.10% vs. 49.93% above high school, $p < 0.001$), were less likely to be married (56.97% vs. 62.96%, $p < 0.001$), and had a greater proportion in the lowest family poverty-to-income ratio category (36.81% vs. 27.67%, $p < 0.001$). Regarding lifestyle and clinical factors, participants with constipation were more likely to be never-smokers (58.10% vs. 52.18%, $p < 0.001$) and never-drinkers (18.44% vs. 12.91%, $p < 0.001$) and had a lower prevalence of hypertension (37.11% vs. 42.47%, $p < 0.001$), diabetes (16.63% vs. 18.32%, $p < 0.001$), and hyperlipidemia (69.34% vs. 72.74%, $p = 0.008$). Nutritional assessments revealed that the constipation group had significantly higher dietary inflammatory index scores (2.00 ± 1.60 vs. 1.37 ± 1.81 , $p < 0.001$), fiber intake (0.32 ± 0.41 vs. 0.19 ± 0.46 , $p < 0.001$), PUFA (0.02 ± 0.25 vs. -0.04 ± 0.25 , $p < 0.001$), vitamin D (0.23 ± 0.27 vs. 0.19 ± 0.30 , $p < 0.001$), magnesium (0.15 ± 0.22 vs. 0.06 ± 0.25 , $p < 0.001$), and HDL-C (1.42 ± 0.43 vs. 1.37 ± 0.42 mmol/L, $p < 0.001$). Consistently, participants with constipation exhibited greater depression severity (mean PHQ-9 score: 4.25 ± 4.88 vs. 3.00 ± 4.10 , $p < 0.001$) and a higher percentage of severe depression (5.55% vs. 2.89%, $p < 0.001$).

3.2 Logistic regression analysis

Table 2 presents the associations between depression, DII, PIR, and constipation across three regression models. In the fully adjusted model (Model 3), higher depression scores were independently associated with increased constipation risk (OR: 1.04, 95% CI: 1.03–1.06, $p < 0.0001$). Compared to individuals without depression, those with mild, moderate, and severe depression exhibited progressively elevated odds of constipation, with odds ratios of 1.49 (95% CI: 1.23–1.82), 1.81 (95% CI: 1.37–2.40), and 1.72 (95% CI: 1.22–2.44), respectively (p for trend < 0.0001). Similarly, DII levels were positively correlated with constipation risk. Each unit increase in DII was associated with a 15% higher odds of constipation (OR: 1.15, 95% CI: 1.04–1.27, $p = 0.0064$). Participants in the second, third, and highest DII quartiles showed significantly greater risk with odds ratios of 1.45 (95% CI: 1.07–1.95), 1.47 (95% CI: 1.03–2.11), and 1.73 (95% CI: 1.13–2.64), respectively, compared to the lowest quartile (p for trend = 0.035). For PIR, individuals in the highest group (≥ 3.5) had a significantly lower constipation risk (OR: 0.77, 95% CI: 0.62–0.97, $p = 0.0292$) than those in the lowest group, with a significant inverse trend (p for trend = 0.0329). These associations remained robust after extensive adjustment for demographic factors, socioeconomic status, comorbidities, lifestyle variables, and nutritional parameters.

3.3 Dose-response relationship between depression and constipation risk

Restricted cubic spline (RCS) regression identified a non-linear dose-response relationship between depression and constipation risk (Figure 2), featuring an inflection point at a depression score of 10 (P for non-linearity = 0.001). For PHQ-9 scores below 10, increasing depression severity was significantly associated with higher constipation risk (OR: 1.08, 95% CI: 1.05–1.11, $p < 0.0001$), indicating an 8% increase in risk per one-point rise in PHQ-9 score. Importantly, the risk plateaued at scores above 10, with no significant additional risk observed with

further increases in depression severity (OR: 0.98, 95% CI: 0.93–1.02, $p = 0.3018$). The significant slope difference (OR: 0.90, 95% CI: 0.85–0.96, $p = 0.0014$) confirmed the threshold model's superior fit over linear alternatives, with the likelihood ratio test demonstrating significant improvement compared to the linear model ($p = 0.001$) (Table 3).

3.4 Statistical mediation analysis

Statistical mediation analysis revealed that DII statistically mediated 6.03% and PIR statistically mediated 12.46% of the observed association between depression and constipation after covariate adjustment (Figure 3).

3.5 Subgroup analysis

Subgroup analyses consistently demonstrated depression–constipation associations across all demographic and clinical subgroups (OR range: 1.04–1.14, all $p < 0.05$), with no significant effect modification by covariates, including age, sex, ethnicity, marital status, education level, BMI, smoking status, drinking status, hypertension, or hyperlipidemia (all interaction $p > 0.05$), highlighting robust universal applicability (Figure 4).

4 Discussion

This cross-sectional study revealed a non-linear threshold association between depression and constipation risk using restricted cubic spline models. Each 1-unit increase in PHQ-9 score was associated with a 4% increase in constipation risk (OR = 1.04, 95% CI: 1.03–1.06). Specifically, for PHQ-9 scores below 10, each unit increase conferred an 8% risk elevation (OR = 1.08, 95% CI: 1.05–1.11), while scores above this threshold showed no additional significant risk (OR = 0.98, 95% CI: 0.93–1.02, $p = 0.3018$), indicating a plateau effect. Individuals with severe depression demonstrated significantly elevated constipation odds (OR = 1.72, 95% CI: 1.22–2.44). Meanwhile, pro-inflammatory diets (highest DII quartile: OR = 1.73, 95% CI: 1.13–2.64) were positively associated with constipation, while higher socioeconomic status (highest PIR category: OR = 0.77, 95% CI: 0.62–0.97) was inversely associated. Mediation analysis further indicated that DII and PIR statistically explained 6.03 and 12.46%, respectively, of the association between depression and constipation.

Our findings of a significant positive association between depression and constipation (OR: 1.04 per PHQ-9 point) align with previous NHANES studies (OR = 2.20, 95% CI: 1.68–2.87) (46). The novel contribution of our analysis is identifying the non-linear threshold effect at PHQ-9 = 10, corresponding to moderate depression severity. This threshold likely reflects converging biological mechanisms: from a neuroendocrine perspective, it may indicate the maximum impact of cortisol's inhibitory effects on gastrointestinal motility (47, 48); from an inflammatory standpoint, moderate depression (PHQ-9 ≥ 10) is associated with significantly elevated inflammatory markers including CRP, IL-6, and TNF- α (49, 50); and from a neurophysiological perspective, PHQ-9 = 10 often marks pronounced autonomic nervous system dysfunction affecting vagal tone and gut motility (51). Additionally, individuals with moderate depression often experience substantial changes in physical activity, medication use, and dietary

TABLE 1 Baseline characteristics of participants with or without constipation.

Characteristics	Total	Constipation		
	<i>n</i> = 12,854	No	Yes	<i>p</i> -value
		<i>n</i> = 11,520	<i>n</i> = 1,334	
Age (years)	49.93 ± 17.95	50.28 ± 17.84	46.95 ± 18.59	<0.001
Sex, <i>n</i> (%)				<0.001
Male	6,178 (48.06)	5,825 (50.56)	353 (26.46)	
Female	6,676 (51.94)	5,695 (49.44)	981 (73.54)	
Ethnicity, <i>n</i> (%)				<0.001
Non-Hispanic White	6,543 (50.90)	5,947 (51.62)	596 (44.68)	
Non-Hispanic Black	2,497 (19.43)	2,152 (18.68)	345 (25.86)	
Mexican American	2,273 (17.68)	2054 (17.83)	219 (16.42)	
Other Hispanic	1,058 (8.23)	930 (8.07)	128 (9.60)	
Other ethnicities	483 (3.76)	437 (3.79)	46 (3.45)	
Education level, <i>n</i> (%)				<0.001
Below high school	1,447 (11.27)	1,277 (11.09)	170 (12.77)	
High school	5,100 (39.71)	4,486 (38.97)	614 (46.13)	
Above high school	6,295 (49.02)	5,748 (49.93)	547 (41.10)	
Marital status, <i>n</i> (%)				<0.001
Married	8,009 (62.34)	7,249 (62.96)	760 (56.97)	
Divorced	2,842 (22.12)	2,519 (21.88)	323 (24.21)	
Never married	1996 (15.54)	1745 (15.16)	251 (18.82)	
BMI (kg/m ²), <i>n</i> (%)				<0.001
<25	3,574 (28.05)	3,117 (27.29)	457 (34.65)	
≥25, <30	4,392 (34.47)	3,970 (34.76)	422 (31.99)	
≥30	4,775 (37.48)	4,335 (37.95)	440 (33.36)	
Family PIR, <i>n</i> (%)				<0.001
<1.3	3,418 (28.61)	2,966 (27.67)	452 (36.81)	
≥1.3, <3.5	4,618 (38.66)	4,134 (38.57)	484 (39.41)	
≥3.5	3,910 (32.73)	3,618 (33.76)	292 (23.78)	
Smoking status, <i>n</i> (%)				<0.001
Never	6,785 (52.79)	6,010 (52.18)	775 (58.10)	
Former	3,369 (26.21)	3,094 (26.86)	275 (20.61)	
Now	2,698 (20.99)	2,414 (20.96)	284 (21.29)	
Drinking status, <i>n</i> (%)				<0.001
Never	1731 (13.48)	1,485 (12.91)	246 (18.44)	
Former	2,637 (20.54)	2,340 (20.34)	297 (22.26)	
Mild	4,054 (31.57)	3,696 (32.12)	358 (26.84)	
Moderate	1883 (14.67)	1702 (14.79)	181 (13.57)	
Heavy	2,535 (19.74)	2,283 (19.84)	252 (18.89)	
Hypertension, <i>n</i> (%)				<0.001
No	7,465 (58.09)	6,626 (57.53)	839 (62.89)	
Yes	5,386 (41.91)	4,891 (42.47)	495 (37.11)	
Diabetes, <i>n</i> (%)				<0.001
No	9,134 (73.13)	8,157 (72.62)	977 (77.72)	
Diabetes mellitus	2,267 (18.15)	2058 (18.32)	209 (16.63)	

(Continued)

TABLE 1 (Continued)

Characteristics	Total	Constipation		
	<i>n</i> = 12,854	No	Yes	<i>p</i> -value
		<i>n</i> = 11,520	<i>n</i> = 1,334	
Impaired fasting glycemia	501 (4.01)	472 (4.20)	29 (2.31)	
Impaired glucose tolerance	588 (4.71)	546 (4.86)	42 (3.34)	
Hyperlipidemia, <i>n</i> (%)				0.008
No	3,549 (27.61)	3,140 (27.26)	409 (30.66)	
Yes	9,305 (72.39)	8,380 (72.74)	925 (69.34)	
Physical activity	926.58 ± 1485.81	932.02 ± 1499.28	874.59 ± 1349.86	0.277
Metabolic equivalent of task	3631.68 ± 5904.72	3651.18 ± 5957.17	3444.17 ± 5373.82	0.321
DII	1.44 ± 1.80	1.37 ± 1.81	2.00 ± 1.60	<0.001
Fiber	0.20 ± 0.46	0.19 ± 0.46	0.32 ± 0.41	<0.001
PUFA	−0.04 ± 0.26	−0.04 ± 0.25	0.02 ± 0.25	<0.001
Vitamin D	0.19 ± 0.29	0.19 ± 0.30	0.23 ± 0.27	<0.001
Mg	0.07 ± 0.25	0.06 ± 0.25	0.15 ± 0.22	<0.001
Total cholesterol (mmol/L)	5.11 ± 1.09	5.11 ± 1.09	5.12 ± 1.10	0.8520
HDL-C (mmol/L)	1.37 ± 0.42	1.37 ± 0.42	1.42 ± 0.43	<0.001
Depression score	3.13 ± 4.20	3.00 ± 4.10	4.25 ± 4.88	<0.001
Severity of depression, <i>n</i> (%)				<0.001
No depression	9,787 (76.14)	8,906 (77.31)	881 (66.04)	
Mild depression	1969 (15.32)	1713 (14.87)	256 (19.19)	
Moderate depression	691 (5.38)	568 (4.93)	123 (9.22)	
Severe depression	407 (3.17)	333 (2.89)	74 (5.55)	

Data are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables. *p*-values were calculated using t-tests for continuous variables and chi-square tests for categorical variables; *p*-values are presented for descriptive purposes and were not adjusted for multiple comparisons. Physical activity represents total minutes per week; MET, metabolic equivalent of task (total minutes per week). Depression categories based on PHQ-9 scores: none (0–4), mild (5–9), moderate (10–14), severe (≥15). Family PIR categories: low (<1.3), middle (≥1.3 to <3.5), high (≥3.5). BMI, body mass index; PIR, poverty-to-income ratio; DII, dietary inflammatory index; PUFA, polyunsaturated fatty acids; HDL-C, high-density lipoprotein cholesterol; MET, metabolic equivalent of task.

habits that collectively contribute to constipation without proportional increases at higher severity levels (52).

The depression–constipation relationship appears to operate through multiple interconnected pathways, with our mediation analysis revealing partial roles for both dietary inflammation (DII: 6.03%) and socioeconomic factors (PIR: 12.46%). These “modest” mediation proportions highlight the multifactorial nature of this relationship. Mechanistically, depression and constipation are linked through the central nervous system–gut axis: depression modulates vagal tone and serotonin balance, affecting intestinal motility (53), while dysregulated corticotropin-releasing factor and disrupted gut microbiota alter short-chain fatty acid production and gut health (54). Inflammatory pathways further connect these conditions, with DII influencing both depression (through inflammatory markers affecting neurotransmitter metabolism and neuroplasticity) (55, 56) and constipation (by reducing beneficial gut bacteria, increasing intestinal permeability, and inhibiting motility) (57, 58). This creates a bidirectional cycle where gut microbiota alterations affect neurotransmitters and inflammatory mediators, exacerbating depressive symptoms, while depression further aggravates constipation through altered intestinal autonomic function (67, 68). Socioeconomic factors compound these effects, with low-income

individuals facing nutritional inequity and limited access to anti-inflammatory foods (59, 60) while experiencing chronic stress-induced glucocorticoid resistance and heightened inflammatory responses (61, 62). Our observed DII mediation proportion (6.03%) is lower than the 71.43% reported for specific saturated fatty acids in depression models (63), likely reflecting methodological differences between controlled nutrient studies versus our population-based approach capturing holistic dietary patterns.

This study has several methodological strengths that enhance result reliability. We utilized a large nationally representative sample (NHANES 2005–2010; *n* = 12,854), employed restricted cubic spline modeling to identify non-linear relationships, and used mediation analysis to examine the potential mediating relationships involving DII and PIR, elucidating the relative contributions of dual mediation mechanisms within a single study for the first time. Furthermore, we implemented progressive multivariable adjustment strategies controlling for an extensive array of potential confounders across demographic (age, sex, and ethnicity), socioeconomic (education, marital status, and PIR), lifestyle (smoking, alcohol consumption, and physical activity), clinical (BMI, diabetes, hypertension, and hyperlipidemia), and nutritional (total cholesterol, HDL-C, fiber, polyunsaturated fatty acids, vitamin D, and magnesium) factors and

TABLE 2 Association between depression, DII, PIR, and constipation.

Characteristics	Model 1		Model 2		Model 3	
	OR (95% CI)	<i>p</i> -value	OR (95% CI)	<i>p</i> -value	OR (95% CI)	<i>p</i> -value
Depression score						
Continues	1.06 (1.05, 1.07)	<0.0001	1.05 (1.03, 1.06)	<0.0001	1.04 (1.03, 1.06)	<0.0001
Severity of depression						
No depression	Ref		Ref		Ref	
Mild depression	1.51 (1.30, 1.75)	<0.0001	1.36 (1.17, 1.58)	<0.0001	1.49 (1.23, 1.82)	<0.0001
Moderate depression	2.19 (1.78, 2.69)	<0.0001	1.92 (1.56, 2.37)	<0.0001	1.81 (1.37, 2.40)	<0.0001
Severe depression	2.25 (1.73, 2.92)	<0.0001	1.87 (1.43, 2.44)	<0.0001	1.72 (1.22, 2.44)	0.0022
P for trend	<0.0001		<0.0001		<0.0001	
DII						
Continues	1.24 (1.20, 1.29)	<0.0001	1.17 (1.13, 1.21)	<0.0001	1.15 (1.04, 1.27)	0.0064
Q1	Ref		Ref		Ref	
Q2	1.70 (1.41, 2.05)	<0.0001	1.56 (1.29, 1.88)	<0.0001	1.45 (1.07, 1.95)	0.0156
Q3	2.11 (1.76, 2.53)	<0.0001	1.73 (1.44, 2.08)	<0.0001	1.47 (1.03, 2.11)	0.0353
Q4	2.74 (2.29, 3.27)	<0.0001	2.10 (1.75, 2.52)	<0.0001	1.73 (1.13, 2.64)	0.011
P for trend	<0.0001		<0.0001		0.0350	
PIR						
Continues	0.86 (0.83, 0.89)	<0.0001	0.87 (0.84, 0.91)	<0.0001	0.95 (0.90, 1.01)	0.0852
<1.3	Ref		Ref		Ref	
≥1.3 and <3.5	0.77 (0.67, 0.88)	0.0002	0.79 (0.69, 0.91)	0.0012	0.93 (0.77, 1.11)	0.4155
≥3.5	0.53 (0.45, 0.62)	<0.0001	0.56 (0.48, 0.66)	<0.0001	0.77 (0.62, 0.97)	0.0292
P for trend	<0.0001		<0.0001		0.0329	

Model 1: unadjusted; Model 2: adjusted for age, sex, and ethnicity; Model 3: additionally adjusted for marital status, PIR, depression score, education level, smoking status, alcohol consumption, BMI, hypertension, diabetes, hyperlipidemia, DII, total cholesterol, HDL-C, fiber, PUFA, vitamin D, and Mg; DII dietary inflammatory index; PIR, poverty-to-income ratio; OR, odds ratio; CI, confidence interval.

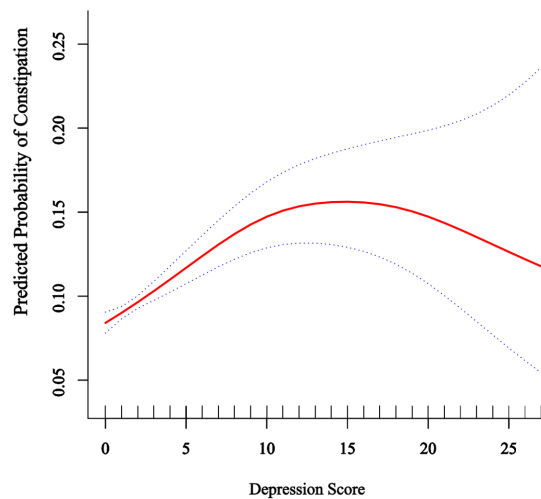
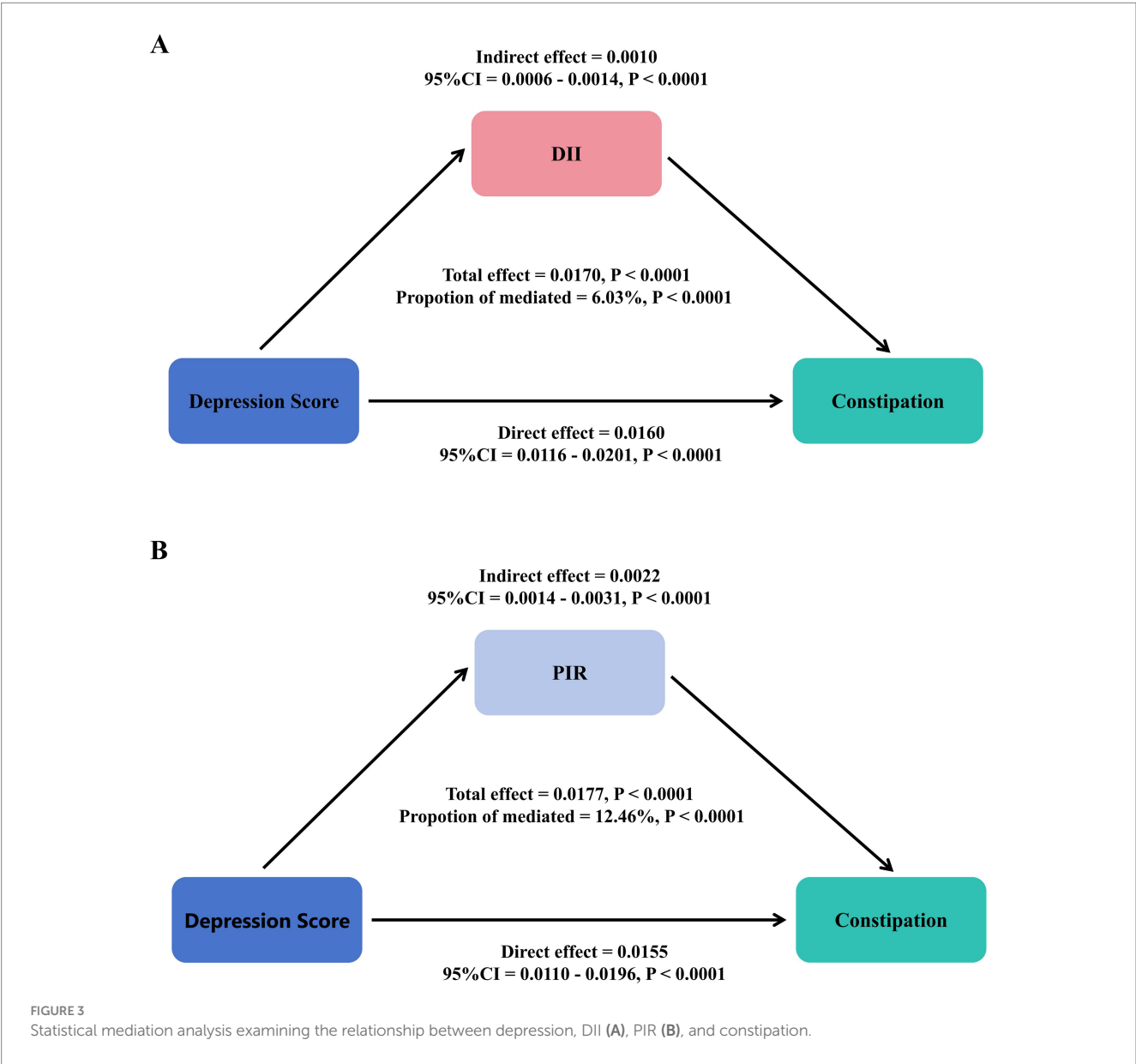


FIGURE 2 Association between depression score and predicted probability of constipation. The solid red line represents the predicted probability of constipation across the range of depression scores (0–27) based on a restricted cubic spline model with four knots. The dotted lines represent the 95% confidence intervals. The model was adjusted for age, sex, ethnicity, marital status, poverty income ratio, education level, smoking status, alcohol consumption, BMI, hypertension, diabetes mellitus, hyperlipidemia, DII, total cholesterol, HDL-C, fiber, PUFA, vitamin D, and Mg.

TABLE 3 Threshold effect analysis of depression score on constipation risk.

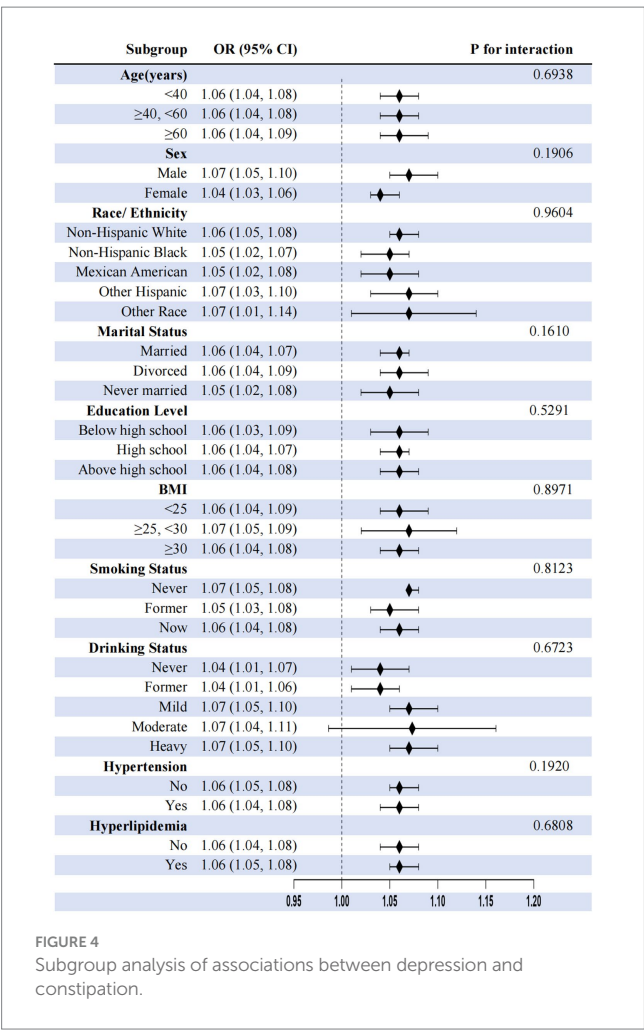
Variable	OR (95% CI)	p-value
Model I		
Linear effect of depression score	1.04 (1.03, 1.06)	<0.0001
Model II		
Depression score <10	1.08 (1.05, 1.11)	<0.0001
Depression score <10	0.98 (0.93, 1.02)	0.3018
Slope difference (≥ 10 vs. < 10)	0.90 (0.85, 0.96)	0.0014

The breakpoint (K) was 10 in Model II; the predicted value of the equation at the breakpoint was -1.58 (95% CI: -1.70, -1.34); the *p*-value for the log likelihood ratio test comparing Model I and Model II was 0.001. All models were adjusted for age, sex, ethnicity, marital status, poverty income ratio, education level, smoking status, alcohol consumption, BMI, hypertension, diabetes mellitus, hyperlipidemia, DII, total cholesterol, HDL-C, fiber, PUFA, vitamin D, and Mg.



performed comprehensive subgroup analyses verifying result robustness across different populations.

While this study makes significant contributions, several limitations should be acknowledged: (1) the cross-sectional design precludes establishing causality between depression and constipation; (2) results based on U.S. adults may not generalize to populations from other regions; (3) constipation and dietary data obtained from questionnaires could be affected by recall bias, with our operational definitions of frequency terms representing reasonable but arbitrary thresholds that influence case identification; (4) despite adjusting for numerous



confounders, unmeasured factors (particularly antidepressant use and comorbid irritable bowel syndrome) may influence the observed associations; (5) depression assessment using PHQ-9 at a single time point may not capture symptom fluctuations; and (6) the absence of objective inflammatory biomarkers (such as C-reactive protein, interleukin-6, or tumor necrosis factor- α) limits our ability to validate the biological relevance of DII scores and may introduce measurement error in assessing dietary inflammatory potential.

In conclusion, this study identified a non-linear threshold association between depression and constipation, with a significant inflection point at a PHQ-9 score of 10. Below this threshold, each unit increase in depression score conferred an 8% elevation in constipation risk, while scores above 10 demonstrated a plateau effect with no additional significant risk increase. Dietary inflammation and socioeconomic factors partially mediated this relationship, suggesting potential intervention targets. These findings emphasize the importance of constipation risk screening in patients with depression, particularly those with moderate depression symptoms (PHQ-9 ≥ 10), as this represents the threshold where maximal risk is achieved. As our findings are derived from a cross-sectional design, we cannot establish temporal ordering or causality between depression and constipation. Future research should explore causal relationships through longitudinal designs; implement methodological approaches to address unmeasured confounding,

such as collecting comprehensive medication data and conducting sensitivity analyses; and incorporate objective inflammatory biomarkers and gastrointestinal function measures to reduce measurement bias and validate self-reported assessments.

5 Conclusion

Higher depression severity was linked to greater constipation risk (particularly for PHQ-9 ≥ 10), partially mediated by DII and PIR.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: <https://www.cdc.gov/nchs/nhanes/default.aspx>.

Ethics statement

This study utilized publicly available, de-identified data from the National Health and Nutrition Examination Survey (NHANES). The NHANES protocol was approved by the National Center for Health Statistics Research Ethics Review Board. As this analysis used de-identified, publicly available data, additional institutional review board approval was not required.

Author contributions

QH: Data curation, Conceptualization, Writing – review & editing, Funding acquisition, Writing – original draft. HZ: Writing – review & editing, Project administration. MY: Validation, Writing – review & editing, Supervision. YM: Writing – review & editing, Data curation, Methodology. LW: Visualization, Formal analysis, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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Parents of children and adolescents knowledge, attitude, and practice toward metabolically healthy obesity: a cross-sectional survey

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Introduction: Understanding parental knowledge, attitudes, and practices (KAP) regarding metabolically healthy obesity (MHO) in children and adolescents is crucial. This study aimed to assess the KAP levels of parents concerning MHO and identify factors influencing these levels.

Methods: A cross-sectional study was conducted at Jiangsu Provincial People's Hospital (June 28, 2023–August 3, 2023). 534 valid questionnaires were collected. Data analysis included descriptive statistics, univariable/multivariable regression, and Spearman correlation to determine KAP levels and influencing factors. Cronbach's α was 0.890.

Results: Median scores were 11 (IQR: 7–13; maximum 18) for knowledge, 32 (IQR: 30–35; maximum 40) for attitude, and 32 (IQR: 27–35; maximum 40) for practice. Significant positive correlations were found between knowledge and attitude ($r = 0.407$, $p < 0.001$), knowledge and practice ($r = 0.357$, $p < 0.001$), and attitude and practice ($r = 0.456$, $p < 0.001$). Non-medical occupations (OR = 0.658, $p = 0.037$) and income 8,000–12,000 (OR = 2.796, $p = 0.001$) were linked to knowledge. Income 5,000–8,000 (OR = 2.864, $p = 0.001$) and 8,000–12,000 (OR = 2.392, $p = 0.013$) related to attitude, while income 8,000–12,000 (OR = 2.798, $p = 0.001$) and >12,000 (OR = 2.340, $p = 0.013$) related to practice.

Conclusion: Parents showed moderate knowledge but good attitudes/practices toward MHO. KAP dimensions were positively correlated. Socioeconomic status, particularly income, significantly associated with knowledge/practice.

KEYWORDS

children, adolescents, obesity, metabolically, obesity, health knowledge, attitude, practice, cross-sectional studies

Introduction

Overweight and obesity are emerging as a global public health crisis and are related to the rapid economic growth and changes in lifestyles (1, 2). Obesity and overweight have more than doubled in the past 30 years, with obesity alone affecting over 1 billion people globally as of 2024 (3). China has the largest number of overweight and obese individuals worldwide, and

approximately 20% of Chinese children and adolescents have excess weight (4). Obesity not only impacts the normal growth and development of children and adolescents but also stands as a primary risk factor for non-communicable diseases in this age group, including cardiovascular diseases, type 2 diabetes mellitus (T2DM), musculoskeletal disorders, cancer, and mental health issues, leading to an increased likelihood of premature death and disability in adulthood (5, 6).

Still, not all overweight/obese individuals are equal, and research has revealed that individuals with obesity who have unhealthy metabolic profiles are more prone to cardiovascular diseases and overall mortality than those with a healthier metabolic profile (7, 8). Hence, it has been recommended to classify obesity into distinct phenotypes based on body mass index (BMI) and metabolic status, including metabolically healthy obesity (MHO) and metabolically unhealthy obesity (MUO), and to adopt different management strategies (9, 10). People with MHO do not appear to have cardiometabolic abnormalities despite a BMI in the obesity range, while patients with MUO display T2DM, fatty liver disease, hypertension, dyslipidemia, and cardiovascular diseases (10). In 2019, China issued an expert consensus that clearly defines MHO as individuals whose BMI qualifies as obese but does not exhibit metabolic abnormalities such as high blood pressure, high blood glucose, lipid disorders, or insulin resistance (11). Still, the data regarding the overall prevalence of MHO and MUO in Chinese children and adolescents according to the criteria mentioned above is poorly known.

“The ‘Healthy China 2030’ Blueprint,” the “Healthy Children Action Enhancement Plan (2021–2025),” and the “China Children’s Development Program (2021–2030)” all emphasize the need to address and control childhood obesity from a national strategic perspective (12). Identifying the risk factors for childhood and adolescent obesity is a crucial approach to preventing and managing obesity, and the concept of MHO brings new insights to the treatment and management of childhood obesity (13). Currently, the principles of treating childhood and adolescent obesity involve reducing energy intake and increasing energy expenditure to reduce body fat while promoting normal growth and health in the affected children (14–16). Treatment methods primarily encompass (1) lifestyle interventions, (2) psychological and behavioral interventions, (3) medication, and (4) metabolic weight reduction surgery. Lifestyle interventions, which include diet, exercise, and sleep management, should be family-based, integrated into daily life, and involve the active participation of children, parents, teachers, and healthcare professionals, with a duration of at least 1 year (14–16). Previous studies commonly acknowledge that genetic and environmental factors contribute to obesity (17–19). Therefore, the World Health Organization (WHO) specifically urges improvements in children’s and adolescents’ obesity through parental behaviors, early life conditions, individual diet, and physical activity (20, 21). Parents play a crucial role in recognizing and managing childhood and adolescent obesity, through early recognition and health monitoring, modeling and shaping healthy behaviors, engagement in behavior change interventions, and long-term maintenance (22, 23). Even among children with MHO, parents should ensure the maintenance of protective behaviors (high physical activity, healthy diet, reduced sedentary time). Regular health check-ups are needed to detect any changes in metabolic profile. Encouraging healthy habits, such as high fruit/vegetable intake and low screen time, directly relates to a more favorable metabolic profile and slower progression to metabolic syndrome (24).

There is currently limited direct research specifically focused on parental awareness, attitudes, and behaviors regarding metabolically healthy obesity (MHO) in children and adolescents. Most existing studies address parental perceptions, knowledge, and practices concerning childhood obesity more broadly, with only indirect relevance to the MHO phenotype (25–27). Therefore, this study aims to explore the levels of parental awareness, attitudes, and behaviors regarding MHO in children and adolescents, which holds significant implications for preventing and managing obesity-related health issues. Particularly in the context of the escalating obesity epidemic, understanding parental perceptions and actions toward MHO provides valuable insights for devising effective health education and intervention strategies. Moreover, the study can unveil factors influencing parental awareness and behavioral practices, including socioeconomic status, thereby offering more targeted recommendations for future health promotion initiatives. This research holds crucial practical and policy implications for fostering the health development of children and adolescents, as well as preventing and managing obesity-related health problems.

Materials and methods

The study was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist (28).

Study design and participants

This cross-sectional study was conducted at Jiangsu Provincial People’s Hospital from June 28, 2023, to August 3, 2023. Established in 1936 as the affiliated clinic to Jiangsu Provincial Medical College, Jiangsu Provincial People’s Hospital is the largest comprehensive hospital in Jiangsu Province. It is designated as a Grade 3A hospital, representing the highest tier in China’s hospital classification system for comprehensive service and advanced medical capabilities. It houses approximately 4,200 beds with a daily patient volume approaching 9,000. The staff exceeds 6,800 employees, including specialists in multiple nationally and provincially recognized key clinical disciplines. The hospital serves the population of Nanjing municipality and the wider Jiangsu Province, regions that include both highly urbanized areas and vast rural communities. Jiangsu itself is one of China’s most economically developed provinces, but it exhibits strong urban–rural socioeconomic diversity and health inequality. Over 95% of the population has basic medical security, but out-of-pocket health spending remains a significant burden for the lowest-SES and high-cost families, especially those with chronic diseases and older adults.

The participants were the parents of children and adolescents, enrolled at the General outpatient clinic of child health department (i.e., obese/overweight patients found in general physical examination screening), the pediatric nutrition clinic, and the pediatric child weight management clinic (i.e., patients who are seen for obesity). The study was approved by the Medical Ethics Committee of Jiangsu Provincial People’s Hospital. Each participant provided written informed consent before completing the questionnaire.

The inclusion criteria were (1) parents of children or adolescents who could be encountered in routine outpatient work, (2) individuals with clear consciousness, normal cognitive

function, and the ability to complete the questionnaire (in Chinese) without communication barriers, and (3) participants who provided informed consent for this study and voluntarily agreed to participate. The exclusion criteria were (1) participants who did not consent to participate in the study, (2) respondents with completion time >1,800 s or <150 s (the minimum time to answer the questionnaire was calculated as 2 s for a single-choice question and 3 s for a multiple-choice question; the maximum was set arbitrarily to exclude those who might be checking for answers on the internet or other sources), (3) incomplete or duplicate questionnaire responses, or (4) questionnaires with logical errors in the responses.

Questionnaires and data collection

Since no questionnaire was available to answer the research question in the specific study population, a new KAP questionnaire was designed based on the literature (10, 29, 30) and the Expert Consensus on the Definition and Screening of Metabolically Healthy Obesity in Chinese Children (11). The questionnaire was refined based on the feedback of 15 experts in pediatric endocrinology, child growth and development, and the child healthcare field. A pilot study was conducted with 49 participants, and the Cronbach's α coefficient was 0.872.

The questionnaire consisted of four sections (Supplementary materials): demographic characteristics (11 items), knowledge (15 items), attitudes (eight items), and practices (eight items) related to MHO. The scores were computed individually for each subcategory. In the knowledge section, the responses were coded as 1 = correct, 0 = incorrect, and 0 = uncertain. The attitude section used a five-point Likert scale, ranging from "totally agree" (5 points) to "totally disagree" (1 point). The scores for negative topics were reverse-coded before calculation. The practice section also used a five-point Likert scale, ranging from "always" (5 points) to "never" (1 point). Hence, the total scores for the knowledge, attitude, and practice dimensions were 0–15, 8–40, and 8–40, respectively.

Data was collected through an online questionnaire using a QR code generated with the WeChat-based Questionnaire Star applet. The parents were approached for participation when they visited the hospital. Data are collected using the Questionnaire Star applet. The participants accessed the questionnaire by scanning the QR code via WeChat and completing it. The questionnaire took 2–30 min to complete. The research assistants were available to provide guidance and answer questions when the questionnaire was completed on-site. Once enrolled and the QR code was scanned, the participants could complete the questionnaire at their leisure. All items were mandatory. A given IP address could be used only once to submit a questionnaire.

Sample size

The sample size calculation was performed using the Open Epi calculator tool, using the following formula (31, 32):

$$n = \frac{p \times (1-p) \times z^2}{e^2}$$

where n is the required sample size, z is the Z statistic for the confidence level (e.g., 1.96 for a 95% confidence level or 2.58 for a 99% confidence level), p is the estimated proportion (generally set at 0.5), and e is the margin of error (typically set at 5%). A smaller margin of error increases the reliability of the conclusions. Hence, using the formula.

$$n = \frac{0.5 \times (1-0.5) \times 1.96^2}{0.05^2} = 384.16$$

a minimum of 384 valid questionnaires were needed to be collected to ensure the required level of confidence in the research findings.

Statistical analysis

The data were analyzed using SPSS 22.0 (IBM, Armonk, NY, USA). The continuous data were tested for normal distribution using the Kolmogorov–Smirnov test. The continuous data following the normal distribution were presented as means $\pm$ standard deviations and analyzed using Student's t -test or ANOVA. Those with a non-normal distribution were presented as medians [interquartile ranges (IQRs)] and analyzed using the Mann–Whitney U -test or Wilcoxon's test. Categorical data were presented as n (%) and analyzed using the chi-squared test. Correlations between scores were analyzed using Pearson correlation coefficients (normal distribution) or Spearman correlation coefficients (non-normal distribution). Univariate logistic regression analyses were performed to determine the factors associated with the KAP scores. Variables with p -values < 0.10 were included in the multivariable logistic regression analyses. In this study, the p -values were reported with three decimals, and p -values < 0.05 were considered statistically significant.

Results

Demographics characteristics

This study collected 632 questionnaires, but three participants did not agree to the use of the collected data for scientific research, and 95 questionnaires took less than 150 s or more than 1,800 s to fill in. Therefore, 534 questionnaires were included in the analysis. The results confirmed the questionnaire's good reliability and validity, with a Cronbach's α coefficient of 0.890 and a Kaiser–Meyer–Olkin (KMO) value of 0.893. The Cronbach's α coefficients for knowledge, attitudes, and practices were 0.868, 0.723, and 0.882, respectively. The knowledge, attitude, and practice scores did not meet the normal distribution (Supplementary Table S1).

The characteristics of the participants are shown in Table 1. Most participants were female (75.5%), aged 31–39 years (68.0%), had a college/undergraduate education (72.5%), were living in urban areas (94.4%), were working in non-medical occupations (65.2%), had a monthly income of 5,000–8,000 RMB (33.5%), were married (96.4%), had one child or adolescent in the household (68.7%), and showed no family history of obesity (79.8%). The primary caregiver of the child or adolescent was the mother (65.5%).

TABLE 1 Characteristics of the participants.

Variables	n (%)	Knowledge		Attitude		Practice	
		Median (25th, 75th percentile)	p	Median (25th, 75th percentile)	p	Median (25th, 75th percentile)	p
Total	534	11 (7, 13)		32 (30, 35)		32 (27, 35)	
Gender			0.076		0.271		0.548
Male	131 (24.5)	11 (7, 14)		32 (29, 34)		31 (26, 35)	
Female	403 (75.5)	11 (6, 13)		32 (30, 35)		32 (27, 36)	
Age (years)			0.282		0.188		0.663
30 and below	44 (8.2)	10 (7, 12)		31.5 (27, 34)		32 (24.5, 35.5)	
31–39	363 (68.0)	11 (6, 14)		32 (30, 35)		32 (27, 36)	
41–49	104 (19.5)	11 (8, 14)		32 (30, 35.5)		32 (26, 34.5)	
50 and above	23 (4.3)	10 (7, 13)		31 (28, 35)		31 (24, 34)	
Education level			< 0.001		< 0.001		< 0.001
Junior high school or below	18 (3.4)	3 (0, 10)		31 (28, 34)		28 (24, 34)	
High school/ technical school	51 (9.6)	8 (1, 11)		30 (27, 33)		27 (23, 32)	
College/ undergraduate	387 (72.5)	11 (7, 13)		32 (29, 34)		32 (27, 35)	
Graduate and above	78 (14.6)	13 (9, 15)		34 (31, 37)		33 (29, 39)	
Residence			0.001		0.032		0.013
Urban	504 (94.4)	11 (7, 14)		32 (30, 35)		32 (27, 35)	
Rural	30 (5.6)	8 (4, 10)		30.5 (28, 34)		28.5 (24, 32)	
Occupation			< 0.001		< 0.001		0.001
Medical field-related	178 (33.3)	12 (9, 14)		33 (31, 37)		32 (28, 37)	
Other occupations	348 (65.2)	10 (5, 13)		32 (29, 34)		31 (26, 35)	
Retired	8 (1.5)	9 (4.5, 11.5)		28.5 (26.5, 33.5)		25.5 (22.5, 30.5)	
Monthly income (RMB)			< 0.001		< 0.001		< 0.001
< 5,000	80 (15.0)	7 (2.5, 11)		30.5 (27, 33)		27.5 (23.5, 33)	
5,000–8,000	179 (33.5)	10 (7, 13)		32 (29, 34)		30 (26, 34)	
8,000–12,000	164 (30.7)	12 (9, 14)		33 (30, 36)		32 (28.5, 37)	
> 12,000	111 (20.8)	12 (8, 14)		33 (30, 36)		33 (28, 36)	
Marital status			0.306		0.517		0.492
Unmarried	14 (2.6)	8.5 (2, 13)		31 (27, 34)		32 (25, 36)	
Married	515 (96.4)	11 (7, 14)		32 (30, 35)		31 (27, 35)	
Divorced/widowed	5 (0.9)	9 (7, 11)		30 (29, 32)		37 (32, 40)	
Number of children and adolescents in the household			0.042		0.276		0.904
1	367 (68.7)	11 (7, 14)		32 (29, 34)		32 (27, 35)	
2	158 (29.6)	10 (5, 13)		32 (30, 36)		31 (26, 36)	
3 or more	9 (1.7)	6 (0, 13)		32 (27, 34)		32 (21, 37)	
Primary caregiver for the children and adolescents			0.821		0.405		0.638
Father	126 (23.6)	10 (6, 14)		31.5 (29, 34)		31 (27, 35)	

(Continued)

TABLE 1 (Continued)

Variables	n (%)	Knowledge		Attitude		Practice	
		Median (25th, 75th percentile)	<i>p</i>	Median (25th, 75th percentile)	<i>p</i>	Median (25th, 75th percentile)	<i>p</i>
Mother	350 (65.5)	11 (7, 13)		32 (30, 35)		32 (27, 35)	
Grandfather/ grandmother	40 (7.5)	10 (6, 14)		33 (29.5, 34)		32 (24, 35.5)	
Maternal/paternal grandparents	17 (3.2)	7 (2, 15)		32 (29, 34)		32 (27, 36)	
Nanny	1 (0.2)	9 (9, 9)		36 (36, 36)		40 (40, 40)	
Relationship with household children			0.068		0.053		0.382
Father	128 (24.0)	11.5 (7.5, 14)		32 (29, 34)		31.5 (27, 35)	
Mother	393 (73.6)	11 (6, 13)		32 (30, 35)		32 (27, 36)	
Grandfather/ grandmother	11 (2.1)	7 (3, 12)		29 (26, 33)		29 (22, 32)	
Maternal/paternal grandparents	2 (0.4)	11.5 (9, 14)		34 (31, 37)		34.5 (34, 35)	
Family history of obesity			0.053		0.467		0.835
Yes	108 (20.2)	11 (8, 14)		32 (30, 35)		32 (27, 35)	
No	426 (79.8)	11 (6, 13)		32 (29, 35)		31 (26, 35)	

Knowledge

The median knowledge score was 11 (61.1%; IQR: 7–13; range: 0–18) ([Supplementary Table S2](#)). Higher knowledge scores were observed with higher education ($p < 0.001$), urban residence ($p = 0.001$), medical occupation ($p < 0.001$), higher income ($p < 0.001$), and only one child or adolescent in the household ($p = 0.042$) ([Table 1](#)). The item with the highest score was K1 (88.0%; “Overweight and obesity are defined as the excessive or abnormal accumulation of fat that poses health risks, and they are chronic metabolic diseases caused by the interaction of various factors, including genetics and the environment.”), while the item with the lowest score was K7 (13.9%; “MHO, as a form of obesity with normal metabolism, is no different from other health states”) ([Supplementary Table S3](#)).

Attitudes

The median attitude score was 32 (80.0%; IQR: 30–35; range: 16–40) ([Supplementary Table S2](#)). Higher attitude scores were observed with higher education level ($p < 0.001$), urban residence ($p = 0.032$), medical occupation ($p < 0.001$), and higher income ($p < 0.001$) ([Table 1](#)). The item with the highest score was A3 (87.0%; “I believe it is necessary to control and improve the diet of children and adolescents to manage MHO.”), while the lowest score was seen for A6 (46.7%; “I believe MHO will resolve naturally or transform into metabolically healthy normal-weight individuals as children and adolescents develop.”) ([Supplementary Table S4](#)).

Practices

The median practice score was 32 (80.0%; IQR: 27–35; range: 8–40) ([Supplementary Table S2](#)). Higher practice scores were seen with higher education level ($p < 0.001$), urban residents ($p = 0.013$), medical occupation ($p = 0.001$), and a higher income ($p < 0.001$) ([Table 1](#)). The highest practice score was observed with P5 (79.2%; “I will educate MHO children and adolescents to develop healthy sleep hygiene habits, such as maintaining a regular sleep schedule and avoiding stimulating activities before bedtime.”) and the lowest score was seen with P8 (53.3%; “I will collaborate with teachers and healthcare professionals to participate in intervention programs for MHO children and adolescents.”) ([Supplementary Table S5](#)).

Correlations

The knowledge scores were positively correlated with the attitude ($r = 0.407$, $p < 0.001$) and practice ($r = 0.357$, $p < 0.001$) scores, while the attitude scores were positively correlated to the practice scores ($r = 0.456$, $p < 0.001$) ([Table 2](#)).

Multivariable analyses

All multivariable analyses used the median score as the cutoff value. Non-medical occupations (OR = 0.658, 95%CI: 0.442–0.976, $p = 0.037$) and income 8,000–12,000 (OR = 2.796, 95%CI: 1.487–6.355, $p = 0.001$) were independently associated with the knowledge scores ([Table 3](#)). Income 5,000–8,000 (OR = 2.864, 95%CI:

TABLE 2 Correlation analysis.

Dimensions	Knowledge	Attitude	Practice
Knowledge	1.000		
Attitude	0.407 ($p < 0.001$)	1.000	
Practice	0.357 ($p < 0.001$)	0.456 ($p < 0.001$)	1.000

1.388–24.830, $p = 0.001$) and income 8,000–12,000 (OR = 2.392, 95%CI: 1.421–11.962, $p = 0.013$) were independently associated with the attitude scores (Table 4). Income 8,000–12,000 (OR = 2.798, 95%CI: 1.498–5.336, $p = 0.001$) and income >12,000 (OR = 2.340, 95%CI: 1.195–4.666, $p = 0.013$) were independently associated with the practice scores (Table 5).

Discussion

This cross-sectional study analyzed the KAP levels of parents of children and adolescents regarding MHO. The KAP dimensions were positively correlated to each other. Socioeconomic status was associated with knowledge and practice scores.

The present study showed moderate parental knowledge (61.1%) toward MHO but positive attitudes and proactive practice (both 80.0%). No previous studies examined the KAP of parents toward MHO specifically. Available studies mostly examined obesity in general and only brushed the subject of MHO (25–27). Previous studies among Chinese university students showed poor knowledge of obesity and its complications (33, 34). Straughan and Xu showed that the parental KAP toward childhood obesity was moderate in Singapore (35). Similar results were observed in Congo (36) and even in developed countries like the United States of America (37). In the present study, participants with non-medical occupations had lower knowledge of MHO. Indeed, medical workers are more likely to have learnt about MHO in the course of their occupation or continuing education. Healthcare providers are primary sources of medical and health information for patients and the general population. Studies showed that the KAP toward obesity can be low or moderate among healthcare providers in specific parts of the world (38). The KAP of healthcare providers was not examined in the present study, and future studies should involve such professionals. Indeed, improving the parental KAP could involve improving the KAP upstream, especially given that parent-physician communication plays an important role in KAP toward obesity and its prevention/management (39).

Socioeconomic conditions are well-known to be related to health literacy, health risk behaviors, and health status (40). Accordingly, in the present study, parents with a higher income had higher knowledge scores, as did those involved in medical professions. Only a higher income was associated with better attitude and practice scores. In the study area, an income of < 5,000 yuan is a lower income level, covering some graduates, grassroots service workers, or part-time workers who have just joined the workforce. An income of 5,000–8,000 yuan is a lower middle/mainstream wage, which is the typical income range of white-collar workers and ordinary employees in many cities, and is the backbone of society, but life pressure may be greater. An income of 8,000–12,000 yuan is a middle/upper middle income, usually for more experienced

professionals, grassroots managers, or technical backbones with relatively affordable lives. An income of > 12,000 yuan represents the high-income group, including senior managers, senior experts, business owners, etc., with strong consumption and savings ability. Those results are globally supported by Straughan and Xu (35), who showed that parents with higher KAP scores toward obesity were younger, had a higher income, were not working full-time, and were living in a separate household from the children's grandparents. Similar results were also reported in various countries (41–43). Nevertheless, all three dimensions were positively correlated to each other. Based on the KAP theory, knowledge is the basis for practice, but attitude is the force driving practice (44, 45). Hence, improving knowledge and attitudes through educational and motivational interventions could also improve practice (46, 47). Future studies should also examine such interventions.

This study had limitations. The study met the calculated sample size, but it was performed at a single center and thus represents only a small proportion of the parents in China, limiting generalizability. The study was cross-sectional and, therefore, represents a single point in time, preventing causality analysis and the changes over time. Nevertheless, the results could serve as a historical baseline to evaluate the effect of future educational activities on MHO. All KAP studies are at risk of social desirability bias, i.e., the participants might be tempted to answer what they know they should think/do instead of what they are actually thinking/doing (48, 49). Considering the high attitude and practice scores, that bias is a possibility. Future studies should involve multiple centers and cover larger areas of the country. Finally, the sparse effect raises the odds ratio's confidence interval. It refers to the phenomenon that when the sample size is small, and there are many variables, the parameter estimation in the so-called "separated data" tends to be infinite (50–52). We acknowledge that the statistical analysis may have resulted in some inflation of the Type I error rate. However, given the exploratory nature of this study, the primary aim was hypothesis generation rather than definitive hypothesis testing. Accordingly, the acceptance of a slightly elevated risk of false-positive findings was considered justifiable, with the understanding that these results require confirmation in future, adequately powered confirmatory studies (53, 54). Therefore, pending confirmation, the results should be interpreted with caution.

Conclusion

In conclusion, this study showed that the parents of children and adolescents had moderate knowledge but good attitudes and practices toward MHO. The KAP dimensions were positively correlated to each other. The socioeconomic status (living in an urban area, income, and working in a medical profession) was generally associated with the KAP scores. The results could be used to optimize educational

TABLE 3 Univariable and multivariable regression analysis of knowledge.

Cut-off value: ≥11/<11	No.	Univariable		Multivariable (enter method)	
		OR (95%CI)	<i>p</i>	OR (95%CI)	<i>p</i>
Gender					
Male	73/131	ref.			
Female	202/403	0.798 (0.537, 1.187)	0.266		
Age (years) (comparison method = difference)					
30 and below	19/44	ref.			
31–39	187/363	1.398 (0.744, 2.628)	0.298		
41–49	59/104	1.459 (0.885, 2.406)	0.139		
50 and above	10/23	0.755 (0.319, 1.785)	0.522		
Education level (comparison method = difference)					
Junior high school or below	4/18	ref.		ref.	
High school/technical school	15/51	1.458 (0.412, 5.162)	0.599	1.067 (0.318, 4.072)	0.919
College/undergraduate	206/387	3.299 (1.700, 6.400)	< 0.001	1.538 (0.510, 5.423)	0.456
Graduate and above	50/78	3.477 (1.853, 6.523)	< 0.001	1.933 (0.566, 7.520)	0.300
Residence					
Urban	269/504	ref.		ref.	
Rural	6/30	0.218 (0.088, 0.543)	0.001	0.413 (0.151, 1.005)	0.051
Occupation					
Medical field-related	111/178	ref.		ref.	
Other occupations	164/356	0.506 (0.353, 0.730)	< 0.001	0.658 (0.442, 0.976)	0.037
Monthly income (RMB) (comparison method = difference)					
< 5,000	22/80	ref.		ref.	
5,000–8,000	86/179	2.438 (1.376, 4.318)	0.002	1.808 (0.999, 3.334)	0.051
8,000–12,000	104/164	2.927 (1.909, 4.487)	< 0.001	2.796 (1.487, 5.355)	0.001
> 12,000	63/111	1.549 (1.004, 2.392)	0.048	1.958 (0.990, 3.929)	0.054
Marital status					
Unmarried	7/19	0.584 (0.213, 1.515)	0.278		
Married	268/515	ref.			
Number of children and adolescents in the household (comparison method = difference)					
1	197/367	ref.			
2	75/158	0.780 (0.537, 1.133)	0.192		
3 or more	3/9	0.489 (0.121, 1.978)	0.316		
Primary caregiver for the children and adolescents					
Father	62/126	ref.			
Mother	187/350	1.184 (0.788, 1.780)	0.416		
Grandfather/grandmother	19/40	0.934 (0.458, 1.904)	0.851		
Maternal/paternal grandparents	7/17	0.723 (0.259, 2.018)	0.535		
Relationship with household children					
Father	73/128	ref.		ref.	
Mother	198/393	0.765 (0.512, 1.144)	0.192	0.826 (0.540, 1.260)	0.376
Grandfather/grandmother	4/13	0.333 (0.092, 1.094)	0.081	0.610 (0.161, 2.070)	0.433
Family history of obesity					
Yes	60/108	ref.			
No	215/426	0.815 (0.533, 1.246)	0.345		

TABLE 4 Univariable and multivariable regression analysis of attitude.

Cut-off value: ≥32 /<32	No.	Univariable		Multivariable (enter method)	
		OR (95%CI)	<i>p</i>	OR (95%CI)	<i>p</i>
Gender					
Male	68/131	ref.			
Female	232/403	1.257 (0.846, 1.867)	0.257		
Age (years) (comparison method = difference)					
30 and below	22/44	ref.			
31–39	210/363	1.373 (0.734, 2.568)	0.322		
41–49	58/104	1.076 (0.654, 1.771)	0.772		
50 and above	10/23	0.641 (0.271, 1.514)	0.310		
Education level (comparison method = difference)					
Junior high school or below	8/18	ref.		ref.	
High school/technical school	17/51	0.625 (0.209, 1.872)	0.401	0.820 (1.880, 0.730)	0.753
College/undergraduate	217/387	2.018 (1.125, 3.619)	0.018	1.365 (1.783, 1.713)	0.591
Graduate and above	58/78	3.628 (1.933, 6.810)	< 0.001	1.934 (1.899, 2.798)	0.304
Residence					
Urban	289/504	ref.		ref.	
Rural	11/30	0.431 (0.201, 0.924)	0.031	0.628 (1.575, 0.359)	0.306
Occupation					
Medical field-related	119/178	ref.		ref.	
Other occupations	181/356	0.519 (0.356, 0.756)	0.001	0.752 (1.222, 0.241)	0.155
Monthly income (RMB) (comparison method = difference)					
< 5,000	33/80	ref.		ref.	
5,000–8,000	93/179	1.540 (0.904, 2.625)	0.112	1.765 (1.363, 6.280)	0.066
8,000–12,000	103/164	1.938 (1.281, 2.931)	0.002	2.864 (1.388, 24.830)	0.001
> 12,000	71/111	1.634 (1.053, 2.535)	0.028	2.392 (1.421, 11.962)	0.013
Marital status					
Unmarried	9/19	0.617 (0.231, 1.587)	0.315		
Married	291/515	ref.			
Number of children and adolescents in the household (comparison method = difference)					
1	205/367	ref.			
2	90/158	1.046 (0.718, 1.524)	0.815		
3 or more	5/9	0.966 (0.256, 3.645)	0.959		
Primary caregiver for the children and adolescents					
Father	63/126	ref.			
Mother	203/350	1.381 (0.918, 2.078)	0.122		
Grandfather/grandmother	23/40	1.353 (0.660, 2.773)	0.409		
Maternal/paternal grandparents	10/17	1.429 (0.512, 3.990)	0.496		
Relationship with household children					
Father	67/128	ref.			
Mother	229/393	1.271 (0.852, 1.898)	0.240		
Grandfather/grandmother	4/13	0.401 (0.107, 1.306)	0.249		
Family history of obesity					
Yes	62/108	ref.			
No	238/426	0.939 (0.613, 1.439)	0.773		

TABLE 5 Univariable and multivariable regression analysis of practice.

Cut-off value: ≥32 /<32	No.	Univariable		Multivariable (enter method)	
		OR (95%CI)	<i>p</i>	OR (95%CI)	<i>p</i>
Gender					
Male	65/131	ref.			
Female	204/403	1.041 (0.702, 1.544)	0.842		
Age (years) (comparison method = difference)					
30 and below	23/44	ref.			
31–39	182/363	0.918 (0.491, 1.717)	0.789		
41–49	53/104	0.990 (0.603, 1.626)	0.969		
50 and above	11/23	0.876 (0.373, 2.059)	0.762		
Education level (comparison method = difference)					
Junior high school or below	5/18	ref.		ref.	
High school/technical school	14/51	0.984 (0.296, 3.269)	0.979	0.799 (0.248, 2.783)	0.713
College/undergraduate	198/387	2.746 (1.459, 5.170)	0.002	1.303 (0.454, 4.158)	0.630
Graduate and above	52/78	3.744 (2.011, 6.970)	<0.001	1.829 (0.559, 6.525)	0.322
Residence					
Urban	261/504	ref.		ref.	
Rural	8/30	0.339 (0.148, 0.775)	0.010	0.652 (0.263, 1.508)	0.323
Occupation					
Medical field-related	107/178	ref.		ref.	
Other occupations	162/356	0.565 (0.391, 0.815)	0.002	0.755 (0.511, 1.114)	0.157
Monthly income (RMB) (comparison method = difference)					
< 5,000	22/80	ref.		ref.	
5,000–8,000	81/179	2.179 (1.230, 3.862)	0.008	1.734 (0.961, 3.187)	0.068
8,000–12,000	101/164	2.863 (1.871, 4.381)	<0.001	2.798 (1.498, 5.336)	0.001
> 12,000	65/111	1.777 (1.149, 2.748)	0.010	2.340 (1.195, 4.666)	0.013
Marital status					
Unmarried	12/19	1.587 (0.610, 4.348)	0.354		
Married	257/515	ref.			
Number of children and adolescents in the household (comparison method = difference)					
1	186/367	ref.			
2	77/158	0.925 (0.637, 1.343)	0.682		
3 or more	6/9	2.024 (0.500, 8.193)	0.323		
Primary caregiver for the children and adolescents					
Father					
Mother	58/126	ref.			
Grandfather/grandmother	176/350	1.186 (0.788, 1.784)	0.413		
Maternal/paternal grandparents	24/40	1.759 (0.853, 3.624)	0.126		
Relationship with household children					
Father	64/128	ref.			
Mother	199/393	1.026 (0.688, 1.529)	0.901		
Grandfather/grandmother	6/13	0.861 (0.259, 2.718)	0.792		
Family history of obesity					
Yes	60/108	ref.			
No	209/426	0.771 (0.504, 1.178)	0.229		

strategies for parents and provide guidance and references for preventing and managing childhood and adolescent obesity. Policymakers should be made aware of the results and participate in the development of an intervention to improve the KAP of the parents toward MHO. Better practice could translate into patient outcomes.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Ethics statement

The study was carried out after the protocol was approved by the Medical Ethics Committee of Jiangsu Provincial People's Hospital (2023-SR-514). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

FZ: Writing – original draft. JF: Writing – original draft. LZ: Writing – original draft. LL: Writing – original draft. HY: Writing – original draft. JL: Writing – original draft. TT: Writing – original draft. YH: Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2025.1591300/full#supplementary-material>

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Diet quality and its associated factors among adolescents in high schools of Rawalpindi and Islamabad

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Introduction: Adolescence is a critical developmental stage during which dietary behaviors have profound impacts on physical health, mental well-being, and academic performance.

Objective: The objective of this study was to examine the associations between diet quality and academic performance, body image perceptions, and demographic factors.

Methods: $n = 281$ adolescents aged 15–18 years from public and private high schools in Rawalpindi and Islamabad were selected for the study. A cross-sectional study design was incorporated and the data were gathered through the Diet Quality Questionnaire (DQQ), Kuppusswamy Socioeconomic Scale and Body Satisfaction and Image Questionnaire.

Results: The analysis showed that 42.7 of % students possess a moderate diet and 57.3% possessed a poor diet. Diet quality was significantly associated with class grade, age, gender, socioeconomic status, body image and academic performance ($p < 0.001$). Students with a lower socioeconomic status, girls, senior grade students, and younger students were more likely to have poor eating habits.

Conclusion: The findings present an urgent need for specific nutritional education and interventions in schools, in particular, among high-risk and vulnerable groups. Enhancing teenage diets can impact their psychological conditions, intellectual growth, and overall school performance.

KEYWORDS

adolescents, diet quality, diet quality questionnaire, socioeconomic status, body image, academic performance, high school students

1 Introduction

Adolescence is a period of rapid physical and mental development. Maintaining a healthy and adopting a balanced diet needs to be prioritized. It is essential for overall health as it affects the cognitive function and academic performance (1). The eating habits developed during this period can have a profound impact on future health-related conditions, such as the development of chronic diseases, including obesity, diabetes, and cardiovascular diseases (2). Additionally, teenagers go through various emotional and mental transformations, which can increase their vulnerability to unhealthy food choices. Their eating habits may be further complicated by peer influence, media influence, and the desire to act independently when it comes to food choice (3). Therefore, the factors that influence diet quality in adolescence are critical to understand, prevent, and manage, the emergence of diet-related issues in adulthood (4). Moreover, the period of adolescence is the onset of greater freedom in terms of food choices, because adolescents begin to make decisions beyond their family influence. Advertisements, social media, and peer influence tend to promote poor diets, especially those that are high in sugars, fats, and sodium (5).

The socioeconomic status has a great influence on the dietary habits of adolescents. Those living below the poverty line exhibit a higher risk of limited access to nutritious foods, resulting in a low-quality diet. Such a difference not only affects their physical wellbeing but may also negatively affect their cognitive growth and academic achievements (6). Young people with low-income families have limited purchasing power to buy fresh produce, low-calorie proteins, and other healthy alternatives, and instead prefer using cheaper, highly processed ones that contain high amounts of calories and lower nutritional value (7). Moreover, the economic pressure of these families can also act as a hindrance toward finding educational materials about nutrition, which only continues to promote poor eating habits (8). This is faced by the increased price of fresh and healthy foods over the processed, energy giving foods, and thus it is harder to ensure that low-income level families comply with the prescribed dietary requirements.

Another factor that has an impact on dietary behavior among adolescents is perceived body image. Individuals with poor body image perceptions are also more likely to engage in unhealthy eating habits, including restrictive diets or skipping meals, which further worsen their nutritional body conditions and academic performance (9). Media illustrations of the best type of body, which is unrealistic and not attainable by a lot of adolescents, tend to worsen body image dissatisfaction (10). Low body image may also result in emotional distress on the part of the adolescents who may decide to cope with this by either eating more or eating less. On the other hand, teenagers who have a more favorable body image will tend to consider food as a source of nutrition and not a way to change their appearance (9). Body positivity and self-acceptance promotion, as well as nutritional education, could be essential to enhancing food preferences and a healthy life in teenagers (11). Besides the psychological factor, the peer pressures exerted on adolescents to fit into a certain body shape might result in dieting habits and the adoption of weight control practices, including fasting or the use of diet pills. These practices not only affect the regular eating habits but may also cause severe long-term health effects, such as eating disorders, nutritional deficiency, and metabolic imbalances (12).

Adolescence is a developmental period in which the individual faces increased stress, peer pressure and social pressure. All these can predispose the individual to develop unhealthy eating patterns. Across 61 different countries, 17.9% of students were affected psychologically. The percentage was higher among girls compared to boys (20.8 vs. 14.9) (13). The lower consumption of vegetables and fruits, regular use of soft drinks and fast food were significantly related to stress, which shows the direct influence of the emotional strain on the food preferences. Similarly, the national statistics of Pakistan indicated that 38.8 percent of college students who suffered anxiety and 70 percent of those who suffered depression were associated with unhealthy eating habits that include a high level of saturated fats and refined carbohydrates (14). Such results highlight the impact of psychological distress and low-quality food on worsening mental health and physical conditions.

Another critical reason why adolescents are making poor dietary decisions is the prevalent advertisement of unhealthy foodstuffs across traditional and social media. Studies have shown that among children and teenagers, there is a constant exposure to commercials and advertisements about fast foods, highly processed foods and sugar-sweetened beverages, which subsequently greatly influence their eating habits and tastes. The most promoted ones were fast food restaurants and sugary drinks, and 83% of food and beverage ads by social media popular people in Canada were classified as less healthy (15). In the same manner, a narrative review that summarized 25 years of studies found that more than 90 percent corroborated the positive relationship between exposure to unhealthy food marketing and increased consumption of marketed products (16). All these, along with the high impact of multi-platform and influencer-led marketing, make unhealthy foods an ordinary good and lead to diet-related non-communicable diseases, indicating that it is high time to implement regulatory measures to safeguard the youth who are at risk. The rates of adolescents aged 13–15 years who eat fruits and vegetables at least five times per day are very low, as shown by data from the Global School-based Student Health Survey (GSHS): 12.6% in Libya and up to 38.1% in Djibouti. On the other hand, the percentage of adolescents who consume carbonated soft drinks daily was high, and it was reported as between 30.8 and 66.6 percent in the age group of 13–14 years and 31.5 to 56.9 years, respectively (17). These statistics show that there is a significant inclination toward processed and sugary types of food rather than whole foods. Consumption of carbonated soft drinks is a matter of great concern mainly because such drinks are associated with a higher risk of obesity, diabetes, and tooth decay. There can be many reasons that might lead to such a low intake of fruits and vegetables, such as the poor availability of fresh products, the absence of education about the value of such products, and the tendency to use more energy-dense and processed foods influenced by culture (18). Besides these external factors, there exists another issue of concern that is connected to the marketing efforts of food and beverage companies that tend to target youth in advertising their sugary snacks and beverages (19). The popularity of such advertisements in the numerous media networks, such as social media, television, and billboards, also contributes to the poor choice of food. Addressing the problem of low consumption of healthy foods and promoting healthy eating among adolescents it is possible with the help of effective policy interventions, including stricter regulations on food advertising and promotion of healthier options (20).

Studies throughout the EMR also indicate the poor dietary practices of the adolescents. Research has revealed that there is a range

of 11 to 33.5 percent daily consumption of fruits among adolescents in most countries, with the exception of Iraq and Palestine which were reported to have higher rates. The consumption of vegetable diets is also different, with Bahrain, Jordan, Kuwait, Morocco, Qatar and Saudi Arabia recording 20 to 43 percent per day and Egypt (78.2), Iraq (46–62), Palestine (73) and Sudan (70) recording higher percentages. The difference in the consumption of fruits and vegetables between such countries highlights that the culturally-focused interventions should consider the local dietary preferences and socioeconomic determinants (21). Moreover, the dietary habits and cultural standards have an important influence on the adolescent eating habits in a region. In other regions, traditional food might not contain adequate amounts of fruits and vegetables, and others might be exposed to modernized food that is highly dependent on fast food and processed food (22). Consequently, health leadership bodies in the regions need to come up with nutrition education programs that are within the local setting to take cover of traditional and modern day eating issues so as to enhance the nutritional status of adolescents in different cultures.

As compared to the national level of 13.5, the Minimum Dietary Diversity (MDD) is also low and is reported at 11.7 in Pakistan. The percentage of underweight adolescents is equal to the country (11.4 vs. 12.1), but the level of anemia is lower (56.6 vs. the national level of 43.8). These percentages show the continuous problem of poor nutrition in rural areas of Pakistan and the urgent need for specific interventions to enhance nutrition diversity and intake levels of micronutrients among teenagers (23). In Islamabad, 68.6% of the adolescents like the food available in the canteens during the break time, and 49% reported dissatisfaction with the food options present in canteens (24). The emphasis on food choice in schools suggests the importance of the change of school meal programs, which might be a key factor in the nutritional conditions of adolescents. It can be effective to change the dietary patterns of adolescents by improving the quality and the range of food sold in school canteens and raising the level of nutrition awareness (25). Also, the school is a setting where healthy eating practices are critical to be promoted. Since adolescents spend a large percentage of their day at school, they should be able to have healthy food choices. Healthy eating could be supported by policy interventions, which require the delivery of healthy foods and snacks, among other elements, and the implementation of nutrition education programs (26). When adequately put into practice, school-based nutrition interventions can reach many adolescents and promote the adoption of healthy eating habits throughout their lives.

The study investigates the relationship between the dietary quality, socioeconomic status, perceived body image, and academic success among high school adolescents in Rawalpindi and Islamabad. Given the fact that the impact of the diet quality on health outcomes is widely-reported, there is no coherent research on the relationship of diet patterns with socioeconomic factors and their overall influence on academic achievement and self-esteem. Researching the impact of socioeconomic status on dietary behavior and its consequential effects on academic performance and body image, in turn, will offer valuable information to policymakers and teachers. It assists in creating particular interventions that address the nutritional deficiency in the diet, improving performance in school, and developing a positive body image. Consequently, it will affect the creation of more appropriate policies and the development of education on public health which can be adopted in this respect and applied to meet the needs of adolescents.

2 Materials and methods

2.1 Study settings

The research was carried out in both the public and private high schools of Rawalpindi and Islamabad, Pakistan. These cities have been chosen because they represent different socioeconomic and educational statuses. It provides a good sample for assessing the diet quality of adolescents.

2.2 Study population

The targeted population was adolescents aged between 15 and 18 years. This represents late adolescence, the stage where socioeconomic status and body image are important in determining nutritional practices.

2.3 Study period

The study period was 6 months, starting from January 2025 to June 2025. The planning stage involved ethical approvals in January 2025. After that school permissions were obtained from school authorities, in the period between February and April 2025. Then data entry, data cleaning, and data analysis were carried out in May and June 2025.

2.4 Study design

The study design was a cross-sectional in order to measure the quality of the diet, the socioeconomic status, and body image satisfaction of the respondents at a single time. The data collection instrument was a structured questionnaire. This design permitted determining the correlations between variables without controlling the study environment.

2.5 Sample size calculation

The size of the sample was calculated with the help of the World Health Organization (WHO) sample size calculator and it was assumed that the confidence interval is 95 percent ($Z = 1.96$), the margin of error is 5 percent, and the prevalence is 0.788 according to past studies (27). The size of the sample needed was 255. The sample size of 281 students was used to take into consideration 10% of non-response or attrition that was expected in the study to make the statistical analysis robust.

$$n^0 = \frac{z^2 pq}{e^2}$$

Where:

- n^0 = required sample size
- z = standard normal deviate corresponding to the desired confidence level (1.96 at 95% CI)
- p = estimated prevalence (0.788 based on (27))
- $q = (1 - p) = 0.212$

- e = margin of error (0.05)

Substituting values:

$$n^0 = (1.96)^2 \cdot (0.788)(0.212) / (0.05)^2.$$

$$n^0 = 3.8416 \cdot 0.1669 / 0.0025.$$

$$n^0 = 0.641 / 0.0025 = 256.4.$$

Thus, the minimum required sample size was ≈ 255 participants.

To account for a potential 10% non-response or attrition rate:

$$n^0 = 256.4 + 25.6 = 282.$$

The final sample size was set at 281 adolescents, which adequately met the requirement for statistical robustness.

2.6 Sampling technique

As shown in [Figure 1](#), this study employed a two-stage purposive sampling technique. In the first stage, schools were purposively selected based on accessibility and willingness to participate. As shown in [Table 1](#), a total of 10 schools were included: five public and five private, distributed across Rawalpindi and Islamabad to capture both urban and suburban representation. In the second stage, a convenience sampling approach was applied within each selected school ([28](#)). Students aged 15–18 years who were present on data collection days, gave informed consent (and parental consent), and met the study criteria were included.

2.7 Inclusion criteria

- Adolescents aged 15–18 years enrolled in public or private schools of Rawalpindi and Islamabad.
- Students able to read and understand Urdu and/or English.
- Participants present during the data collection period (February to April 2025) and who provided informed consent.
- Adolescents not enrolled in any structured weight loss or diet program at the time of the study.
- Students who had not received a formal nutritional education program within the past year, to avoid bias in dietary knowledge and behavior.

2.8 Exclusion criteria

- Adolescents with chronic health conditions such as diabetes, cardiovascular disease, celiac disease, or severe allergies that could significantly affect dietary patterns.
- Students who had relocated to Rawalpindi or Islamabad within the last 6 months, as environmental and cultural exposure may differ from long-term residents.
- Participants who declined to provide consent or were absent during data collection days.
- Adolescents currently under a medically prescribed diet or specialized nutritional intervention.

2.9 Data collection procedures

Prior to data collection, ethical approval was obtained from the Institutional Review Board (IRB), ensuring adherence to ethical standards

for human subject research. Formal permission was also obtained from school authorities. The schools were contacted via phone and email, shared study information, and conducted meetings with principals to clarify study goals. Once approval was granted, students and their guardians (where applicable) were informed about the study's purpose and provided written consent. Data collection was conducted onsite. Students first filled out a demographic information sheet, followed by the study instruments. Participants were provided with clear verbal and written instructions, and all questionnaires were completed and collected during the same session to ensure completeness and data integrity.

2.10 Data collection tools

2.10.1 Diet quality questionnaire

The Diet Quality Questionnaire (DQQ) was used to assess dietary patterns of adolescents. It is a valid tool developed by the Global Diet Quality Project to standardize the assessment of diet quality across populations ([29](#)). It consists of 29 yes/no questions regarding food and drink consumption during the previous 24 h, covering core food groups (grains, pulses, fruits, vegetables, and animal-based foods), discretionary foods (fried foods, sweets, and snacks), and beverages (milk, tea, juices, and carbonated drinks). The tool provides dietary diversity indicators and allows estimation of diet quality by categorizing participants into poor, moderate, or good dietary intake based on the number of food groups consumed ([30](#)). Responses were coded as “1” for consumption and “0” for non-consumption, and scores were summed to reflect overall dietary diversity.

2.10.2 Kuppuswamy's socioeconomic status scale

Socioeconomic status was assessed using the modified Kuppuswamy's Socioeconomic Scale, which classifies households based on three domains:

- 1) Education of the head of family (illiterate to professional degree, score 1–7),
- 2) Occupation of the head of family (unemployed to legislators/senior officials, score 1–10), and
- 3) Monthly family income updated to 2023 Pakistani Rupees (score 1–12).

The total score ranges from 3 to 29 and categorizes families into five socioeconomic classes: Upper (26–29), Upper Middle (16–25), Lower Middle (11–15), Upper Lower (5–10), and Lower (<5). This tool is validated and widely used in South Asian populations for socioeconomic stratification ([31](#)).

2.10.3 Body self-image questionnaire

Body image perception and satisfaction were assessed using the Body Self-Image Questionnaire (BSIQ), which includes 27 items rated on a Likert scale. The tool was developed by Rowe and his colleagues in 1999 ([32](#)). It was shortened by Rowe in 2015 for further development.

The tool comprises nine subscales:

- Overall Appearance Evaluation (OAE)—satisfaction with body appearance,
- Health Fitness Influence (HFI)—effect of health/fitness on self-image,

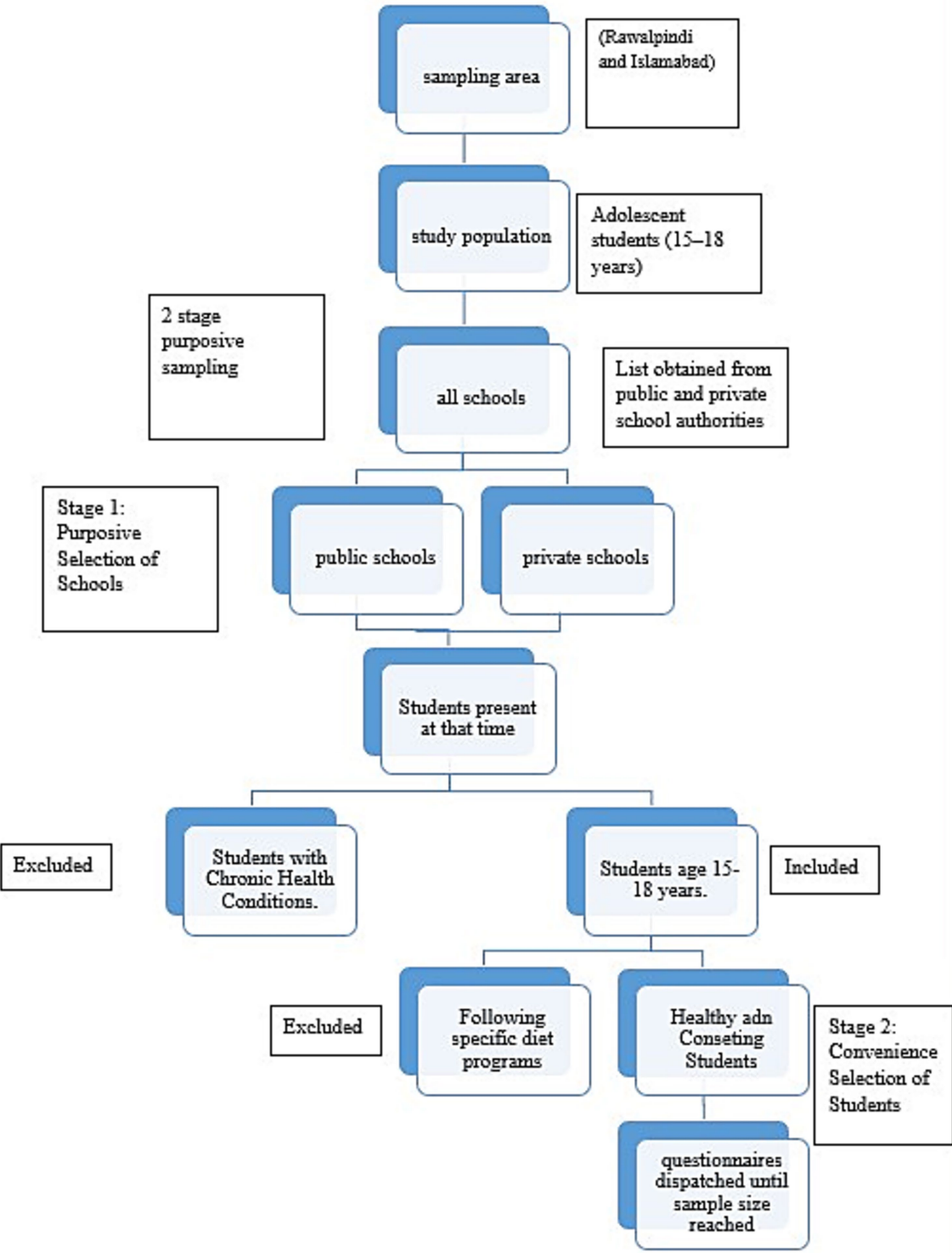


FIGURE 1
School selection process. The flowchart illustrates the sampling procedure, beginning with the selection of the study area (Rawalpindi and Islamabad) and the identification of the study population (adolescents aged 15–18 years). From this population, public and private schools were purposively selected, followed by the convenience selection of students who met the inclusion criteria. The final step shows that questionnaires were administered until the required sample size of 281 participants was achieved.

- Investment in Ideals (II)—importance of achieving ideal body standards,
 - Health-Fitness Evaluation (HFE)—perceptions of health and fitness levels,
- Attention to Grooming (AG)—emphasis on grooming and appearance,
 - Height Dissatisfaction (HD)—concerns about height,
 - Fatness Evaluation (FE)—perception of fatness,

TABLE 1 Participants' distribution among selected schools.

School code	City	Type	Boys (N)	Girls (N)	Total (N)
A	Rawalpindi	Public	12	18	30
B	Rawalpindi	Public	10	15	25
C	Rawalpindi	Private	14	21	35
D	Rawalpindi	Private	11	14	25
E	Islamabad	Public	13	17	30
F	Islamabad	Public	16	19	35
G	Islamabad	Private	15	20	35
H	Islamabad	Private	12	18	30
I	Rawalpindi	Public	14	16	30
J	Islamabad	Private	11	25	36
Total			128	183	281

- Negative Affect (NA)—negative emotions about body image, and
- Social Dependence (SD)—influence of social comparisons on body image.

Each item is scored according to its response category, and subscale scores are summed to reflect the psychological and perceptual domains of body self-image. Higher scores on negative domains (e.g., FE, NA, HD, and SD) indicate greater dissatisfaction, whereas higher scores on positive domains (e.g., OAE, HFE, and AG) reflect a more favorable body image (33).

2.11 Statistical analysis

All collected data were coded and entered into SPSS version 27 for analysis. Descriptive statistics were generated to summarize demographic data, socioeconomic status, dietary quality indicators, and body image perceptions. To assess associations between variables such as dietary quality, socioeconomic status, body image satisfaction, and academic performance, chi-square tests were conducted. Prior to analysis, the dataset was checked for completeness, missing values, and coding consistency. Categorical responses (e.g., DQQ and BSIQ items) were numerically coded, and ordinal responses from Likert scales were appropriately handled. A significance level of $p < 0.05$ was used for inferential testing.

3 Results

The results include demographic characteristics such as gender, age, class level, academic performance, and socioeconomic status. These variables were assessed to explore their potential associations with diet quality.

As shown in Table 2, out of the total 281 participants, 117 (41.6%) were male and 164 (58.4%) were female. The age distribution indicated that the majority, 197 (70.1%), were in the 17–18-year age group. Regarding academic level, 131 (46.6%) participants were enrolled in 2nd year or A-Level programs. In terms of academic performance, 92 (32.7%) students scored an A grade ($\geq 85\%$), while 114 (40.6%) achieved a B grade ($\geq 75\%$). The majority of participants, 151 (53.7%),

belonged to the Upper Middle (II) socioeconomic class, whereas 9 (3.2%) and 7 (2.5%) were classified under the Lower Middle (III) and Upper Lower (IV) categories, respectively.

Table 3 provides a detailed report on the frequency distribution of dietary quality indicators. The Non-Communicable Disease (NCD)-Risk score was 1.8, indicating that, on average, each adolescent consumed nearly two unhealthy food items such as sugary drinks, sweet snacks, or fried foods. Conversely, the NCD-Protect score stood at 3.1, which suggests the presence of three positive dietary behaviors, including the intake of legumes, fruits, and animal-source foods. One of the essential DQQ indicators, known as *All-5*, assesses whether individuals consumed at least one item from all five core food groups within the last 24 h. In this sample, 101 (36.0%) adolescents met this criterion. Furthermore, 121 (43.1%) consumed at least one vegetable, and 104 (37.0%) consumed at least one fruit. A high proportion, 261 (92.9%), reported intake of at least one item from the pulses, nuts, or seeds group, while 200 (71.2%) consumed an animal-source food. In contrast, only 101 (36.0%) reported intake of starchy staples. Alarming, 160 (57.0%) adolescents reported zero vegetable or fruit consumption on the assessed day. Additionally, 138 (49.1%) consumed sweet foods, 84 (29.9%) consumed salty or fried snacks, 84 (29.9%) consumed deep-fried items, and 76 (27.0%) reported whole grain consumption.

Figure 2 reports the distribution of diet quality among a sample of 281 school-going adolescents from Rawalpindi and Islamabad. According to the results, 42.7% of the adolescents ($n = 120$) fell into the “moderate” diet quality category, 57.3% ($n = 161$) were identified as having a “poor” diet quality.

Figure 3 displays the frequency distribution of body image satisfaction. Among 281 adolescents surveyed in this study, 165 (58.7%) reported dissatisfaction with their body image, while 99 (35.2%) expressed partial satisfaction. Only 17 (6.1%) of the respondents, after merging the “High Satisfaction” and unclassified responses, expressed high satisfaction with their body image.

Table 4 summarizes the associations between various demographic factors and diet quality among 281 participants, categorized into moderate and poor diet quality groups. A significant relationship was found between age group and diet quality ($\chi^2 = 13.45$, $p = 0.000$). Participants aged 15–16 years (50 out of 84; 59.5%) had a higher proportion of poor diet quality compared to those aged 17–18 years (111 out of 197; 56.3%), indicating that younger adolescents were more likely to exhibit poorer dietary habits. Gender was also significantly associated with diet quality ($\chi^2 = 13.93$, $p = 0.0003$). Females were more represented in the poor diet quality category, with 107 out of 164 (65.2%) experiencing poor diet quality compared to 54 out of 117 (46.2%) males. Class grade was another demographic variable significantly associated with diet quality ($\chi^2 = 13.55$, $p = 0.000$). Students in the 2nd Year/A Levels class (77 out of 131; 58.8%) had the highest number of participants with poor diet quality, whereas 9th grade students (17 out of 42; 40.5%) showed relatively fewer cases of poor diet quality. This suggests that as students' progress to higher academic levels, their risk of developing poorer dietary habits increases. Socioeconomic status also showed a strong and significant association with diet quality ($\chi^2 = 30.99$, $p = 0.0002$). Participants from lower socioeconomic groups, particularly those in the Lower (V) category (26 out of 34; 76.5%) and Upper Lower (IV) category (58 out of 85; 68.2%), had a higher prevalence of poor diet quality compared to those in higher socioeconomic brackets.

TABLE 2 Descriptive statistics of the participants.

Variable	Category	Frequency (n)	Percentage (%)
Gender	Female	164	58.4
	Male	117	41.6
Age group	15–16 years	84	29.9
	17–18 years	197	70.1
Class	9th	24	8.5
	10th / O Levels	44	15.7
	1st Year	82	29.2
	2nd Year / A Levels	131	46.6
Academic grades	A (Above 85%)	92	32.7
	B (Above 75%)	114	40.6
	C (Above 65%)	52	18.5
	D (Above 55%)	23	8.2
Socioeconomic status	Upper (I)	111	39.5
	Upper Middle (II)	151	53.7
	Lower Middle (III)	9	3.2
	Upper Lower (IV)	7	2.5
	Lower (V)	3	1.1

Table 5 displays the association between diet quality and academic performance among the 281 participants. Of the total, 122 (43.4%) students reported moderate diet quality, while 159 (56.6%) reported poor diet quality. A chi-squared test of independence was conducted to examine whether an association exists between academic performance and diet quality. The results revealed a statistically significant relationship between the two variables ($\chi^2 = 56.06$, $df = 3$, $p < 0.001$).

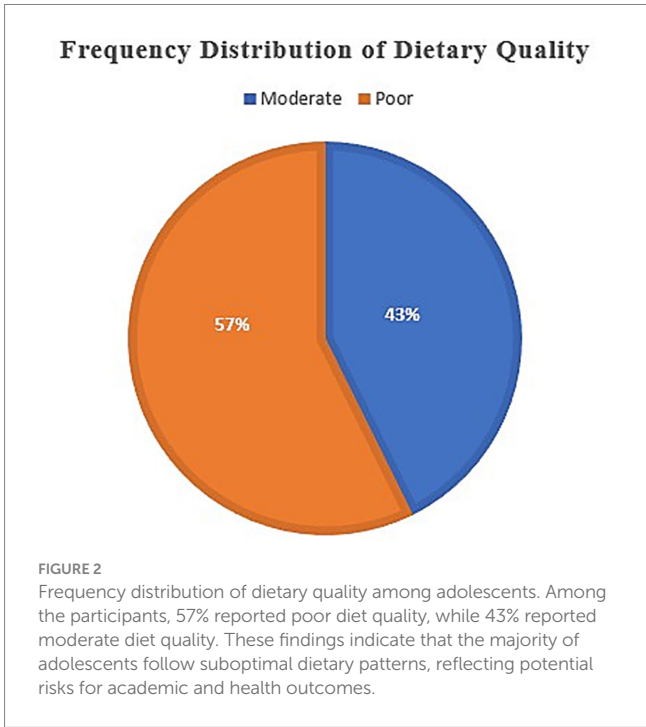
Table 6 illustrates the relationship between diet quality and satisfaction levels among 281 participants. A chi-squared test of independence was performed to explore the association between diet quality and satisfaction levels among 281 students. The Chi-Square statistic was 22.46, with 2 degrees of freedom, and the p -value was 0.0007.

4 Discussion

This study aimed to evaluate the association between diet quality and academic performance among adolescents aged 15–18 in Rawalpindi and Islamabad, Pakistan. The sample size of 281 participants was chosen using a convenience sampling method in both the public and private schools. The study investigated the relationship between diet quality and academic achievement, body image satisfaction, and socioeconomic status (SES). The Diet Quality Questionnaire (DQQ), the Body Satisfaction and Image Questionnaire (BSIQ) and the Kuppuswamy Socioeconomic Scale were used to gather self-reported measures. Following the data analysis based on chi-square tests of independence, the statistically significant association of diet quality with all three major variables was observed, which indicates that eating habits contribute to the multidimensional influences on the development of cognitive, emotional, and social outcomes during the adolescent stage.

TABLE 3 Frequency distribution of dietary quality indicators overall.

Indicator	Scores/ Percentages
GDR (Global Dietary Recommendations) Score	10.4
NCD-Risk Score (Negative dietary behaviors)	1.8
NCD-Protect Score (Positive dietary behaviors)	3.1
All-5 (Minimum consumption of all five core food groups)	36%
At least one vegetable	43%
At least one fruit	37%
At least one pulse, nut, or seed	93%
At least one animal-source food	71%
At least one starchy staple	36%
MDD-W (Minimum Dietary Diversity for Women)	–
Dietary Diversity Score (DDS)	4
Zero vegetable or fruit consumption (–)	57%
At least one vegetable or fruit	43%
Pulse consumption	69%
Nuts or seeds consumption	54%
Whole grain consumption	27%
Processed meat consumption (–)	19%
Salty or fried snack consumption (–)	30%
Deep fried food (–)	30%
Sweet foods consumption (–)	49%
Soft drinks (sodas, energy drinks, sports drinks) (–)	11%



In our research, the demographic variables showed significant trends. The adolescents who were younger (15–16 years old) reported lower-quality diets than older individuals, which is contrary to another

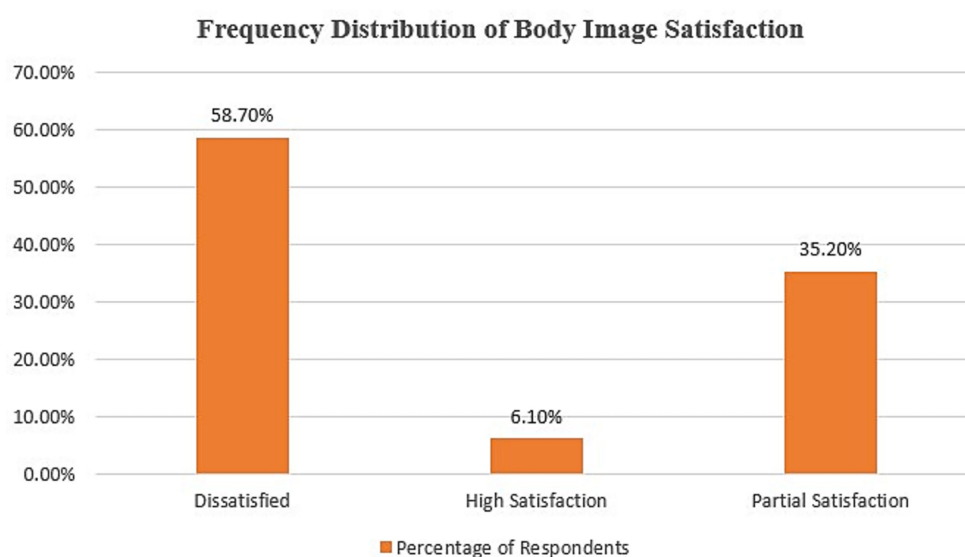


FIGURE 3

Frequency distribution of body image satisfaction among adolescents. The majority of participants (58.7%) reported dissatisfaction with their body image, while 35.2% expressed partial satisfaction. Only a small proportion (6.1%) indicated high satisfaction, highlighting overall concerns with body image in this population.

TABLE 4 Association between demographic variables and diet.

Demographic variable	Category	Moderate diet quality	Poor diet quality	Total	Chi-square (df)	p-value
Age group (years)	15–16	34	50	84	$\chi^2 = 13.45$ (1)	0.000*
	17–18	86	111	197		
	Total	120	161	281		
Gender	Female	57	107	164	$\chi^2 = 13.93$ (1)	0.0003*
	Male	63	54	117		
	Total	120	161	281		
Class grade	9 th	13	11	24	$\chi^2 = 13.55$ (3)	0.000*
	10 th / O Levels	21	23	44		
	1 st Year	32	50	82		
	2 nd Year / A Levels	54	77	131		
	Total	120	161	281		
Socioeconomic status	Lower (V)	24	60	84	$\chi^2 = 30.99$ (4)	0.0002*
	Lower Middle (III)	7	11	18		
	Upper (I)	8	13	21		
	Upper Lower (IV)	72	83	155		
	Upper Middle (II)	9	14	23		
	Total	120	161	281		

*Means statistically significant values.

study which discovered that older adolescents were more likely to eat conveniently (34). Such a difference can be attributed to regional and cultural differences in autonomy, peer pressure and parental interferences in food preferences. There were also gender differences and females reported a low quality of diet as compared to males. On the same note, another report observed that restrictive eating habits in

adolescent girls can be promoted because of sociocultural pressures which could be the explanation of the differences found in this study (35). According to another evidence, results of the Health Behavior in School-aged Children (HBSC) survey in 45 European countries found that the prevalence of meal skipping and dieting is higher in girls than in boys (36). In addition, another study demonstrated that body image

TABLE 5 Association between diet quality and academic performance.

Academic performance	Moderate diet quality	Poor diet quality	Total	Chi-square (df)	p-value
A (Above 85%)	44	48	92	$\chi^2 = 56.06$ (3)	0.000*
B (Above 75%)	50	63	113		
C (Above 65%)	20	34	54		
D (Above 55%)	8	14	22		
Total	122	159	281		

*Means statistically significant values.

TABLE 6 Association between body self-image and diet quality.

Body self-image	Moderate diet quality	Poor diet quality	Total	Chi-square (df)	p-value
Dissatisfied	25	38	63	$\chi^2 = 22.46$ (2)	0.0007*
High satisfaction	62	91	153		
Partial satisfaction	33	32	65		
Total	120	161	281		

*Means statistically significant values.

strongly influences the dietary choices in adolescent girls, reinforced by evidence of gender-specific concerns (9).

Academic grade was the other determinant, where higher grades (2nd Year/A levels) were associated with greater likelihood of poor diet quality. This observation is consistent with the fact that higher grade levels are linked with increased academic workload and stress, which results in poor eating habits (37). In the same way, the socioeconomic inequality to a large extent influenced the quality of food, with the poor population exhibiting a greater percentage of unhealthy food habits that contributed to poor nutrition. This correlates with the evidence that continuously associates economic reasons and a lack of access to nutritious food with unhealthy diets (18, 38). Such results indicate the necessity of a systemic intervention with the basis of affordability, accessibility, and food literacy.

Equally, it has been pointed out that the socioeconomic disparities in adolescence is associated with reduced dietary diversity and increased intake of energy-dense, nutrient-dense foods (39). Moreover, it is demonstrated that healthier diets are systematically more costly, and affordability is one of the critical obstacles of low-income families (40). Lastly, there was a strong correlation between the quality of the diet and academic performance. Students who had higher grades were more likely to eat healthier, which is also consistent with previous research that nutrient-rich foods improve memory, attention, and cognitive flexibility (41, 42). Poor diet quality, in turn, was associated with lower academic performance which could be explained by a decrease in concentration, fatigue, and less energy. This observation is also reinforced by the fact that the healthier the diet of adolescents, the better they performed in standardized literacy tests (43). Similarly, dietary patterns that are rich in fruits, vegetables, and whole grains have been observed to positively correlate with academic achievement, and intake of processed foods has been observed to predict poor performance in school (44). These results support the advantages of educating students about healthy eating in schools.

The quality of the dietary intake revealed that over 50% of the adolescents had poor dietary habits, involving less intake of fruits,

vegetables, and whole grains along with excessive intake of unhealthy food. This tendency is consistent with the previous research in South Asia and other countries that has reported about a nutrition transition with a rise in the use of processed food (34). Likewise, one of the studies emphasized that limited access to healthy foods during adolescence could impede educational achievement and future wellness (41). There is another study that supports these findings, whereby more intakes of fast food and sugary beverages were associated with lower intakes of micronutrients and higher chances of overweight or obesity (45). Moreover, one study demonstrated that low nutritional quality was among the primary risk factors of untimely mortality, and adolescents are particularly vulnerable to it since they develop lifetime eating patterns (46). These findings highlight the necessity of immediate school-based nutritional programs to promote eating healthier foods.

Body image satisfaction was greatly related to the quality of diet. The healthier the diet was among adolescents, the more they were likely to report more body satisfaction, and the poorer the dietary practices, the more dissatisfaction. This result does not contradict a study where researchers proved that bad eating habits tend to support the negative view of body image (47). On the contrary, the balanced diets have been associated with improved mood, enhanced energy and enhanced self-perception. Likewise, one study in Spain discovered that emotional distress and problematic social media mediation mediated the association between unhealthy eating habits and increased body dissatisfaction, especially in females (48). Furthermore, another study mentioned that poor eating habits are also caused by stress, which, besides disrupting physical health, influences the perception of negative body images (49). Those findings demonstrate the psychosocial implications of eating habits and the need to incorporate body positivity into food-related educational practices.

In addition, it has been established that body dissatisfaction is associated with mental distress, particularly tension and anxiety, and problematic social media use is the mediator of this relationship (Monton, Diego, and Estevez, 2024). A meta-analysis

states that stress can adversely affect eating behavior by raising consumption of harmful foods and reducing consumption of good foods (49). The implication of these results is that body dissatisfaction not only undermines mental health, but it can also indirectly result in the poor quality of the diet by triggering eating behaviors that are associated with stress. Moreover, the tastes of teens toward food are largely shaped by their exposure to social media, and celebrities and other influencers often push high-energy and nutrient-dense food, which strengthens unhealthy eating patterns (50). Strengths of the study include addressing a gap in the literature by investigating the nature of the relationship between the quality of diet and the outcome of academic performance among teenagers in South Asian countries. It also provides useful insights to a region and a very critical problem at a global level. The sample ($n = 281$) was sufficiently large to render the results strong, and the method of dietary assessment was followed by the utilization of the validated tools, such as the DQQ. In addition, the research study looks into the demographic and socioeconomic inequities in the quality of the diet that can be employed to set up school and community-based interventions. There are also few limitations. The causal interpretation was not that great, as the study design was cross-sectional. One of the limitations is the recall or reporting bias that could have been caused by the use of self-reported questionnaires. The research was limited to Rawalpindi and Islamabad, and thus the generalization to other areas is not possible. Moreover, other determinants like exercise, peer pressure, and mental status were not evaluated, which can also define dietary habits and academic performance.

5 Conclusion

This paper analyzed the relationship between the quality of diets, academic achievement, body self-image and socioeconomic status of adolescents in Rawalpindi and Islamabad. The results show that there are very strong correlations between these factors, indicating that the quality of the diet is a very important factor in academic performance and emotional health. The overall effect of low quality of diet on poor performance in schools helps to support the hypothesis that nutritional habits can have a direct or indirect impact on cognitive capabilities like concentration, memory retention, and general classroom performance. Moreover, the body self-image was also largely connected to the quality of diet, and students who had a moderate diet had a higher level of satisfaction with their body image. Nutrition education programs should be incorporated in the school's curriculum so as to sensitize them on the advantages of eating healthy food. Such programs can be especially productive when it comes to reaching students who belong to the lower SES group and might lack access to healthy diets and food options at home. The gap can be closed by ensuring that such meals are accessible and affordable to students whose families have low incomes. Involvement of parents in nutritional education can assist in supporting the idea of healthy eating at home. This may involve collaboration with local communities, non-governmental organizations and government schemes that pay attention to food aid. There is a need for further research in the areas of long-term quality of diet in academic and mental health outcomes. Longitudinal studies that track the impact of dietary changes over time could provide deeper insights into how

nutrition influences adolescents' cognitive and emotional development.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethical Review Committee of the Armed Forces Postgraduate Medical Institute (AFPGMI), Rawalpindi, Pakistan. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

FF: Conceptualization, Data curation, Methodology, Writing – original draft. AA: Conceptualization, Methodology, Supervision, Writing – review & editing. HM: Conceptualization, Methodology, Supervision, Writing – review & editing. ZM: Formal analysis, Writing – review & editing. SS: Formal analysis, Writing – original draft. JA: Methodology, Writing – review & editing. MI: Data curation, Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The effect of dietary carbohydrate quality on depression and anxiety levels in adolescents

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Background: Given that the quality of carbohydrate intake, rather than quantity alone, may influence psychological health, particularly during adolescence, this study aimed to evaluate the relationship between dietary carbohydrate quality and depression and anxiety levels in adolescents.

Methods: This cross-sectional study was conducted with a sample of 192 second-year high school students from Bolu (Turkey). Participants' 24-h retrospective food consumption records were collected, and the data were analyzed through the Nutrition Information System to calculate the energy, macro, and micronutrient content of their diets. Dietary carbohydrate quality was evaluated using a quintile-based scoring system created according to criteria such as glycemic index, total fiber intake, the ratio of whole grains to total grains, and the ratio of solid carbohydrates to total carbohydrates, with total scores ranging from 4 to 20 points. Depression and anxiety levels were assessed using the Beck Depression Inventory and the Beck Anxiety Inventory.

Results: The analysis results revealed a statistically significant decrease in depression and anxiety levels as dietary carbohydrate quality increased ($p < 0.05$). The group with the lowest carbohydrate quality had the highest levels of depression and anxiety, and these individuals were found to have higher energy/fiber and carbohydrate/fiber ratios ($p < 0.001$). Moreover, adolescents with a habit of skipping main meals were found to have significantly higher anxiety scores ($p < 0.05$). Sodium, phosphorus, and vitamin A intakes exceeded recommended levels among male adolescents, whereas both sexes demonstrated generally insufficient intake of dietary fiber and various micronutrients, including vitamins E and C, riboflavin, pyridoxine, folate, potassium, calcium, magnesium, iron, and zinc.

Conclusion: The results indicate that adolescents with low carbohydrate quality and irregular meal patterns are at risk of depression and anxiety. Nutritional interventions aimed at addressing imbalances in the intake of macro and micronutrients and improving carbohydrate quality are thought to play an important role not only in preventing metabolic diseases but also in supporting psychological well-being.

KEYWORDS

carbohydrate quality, glycemic index, depression, anxiety, adolescent

1 Introduction

Although total carbohydrate intake has not exhibited substantial variation over the past 70 years, it is well recognized that notable differences exist in the types of carbohydrates consumed across various regions of the world. It has been observed that the consumption of low-quality carbohydrate foods has become increasingly prevalent, particularly in economically less developed countries (1). Adolescents represent the population group most affected by this situation. In a study examining how dietary carbohydrate intake and carbohydrate quality changed among adolescents over the 20-year period spanning the late 20th and early 21st centuries, it was found that total carbohydrate and added simple sugar intake increased over time, whereas whole grain and dietary fiber intake declined (2). This situation is considered one of the contributing factors to the recent increase in the prevalence of nutrition-related diseases among adolescents, such as prediabetes, type 2 diabetes, obesity, and metabolic syndrome (3).

Apart from metabolic disorders, a significant increase in the prevalence of depression and anxiety is observed during the transition from childhood to adolescence, and this situation triggers adverse dietary behaviors (4). On the other hand, unhealthy dietary behaviors and an imbalanced diet pattern influence depression and anxiety in adolescents (5). In other words, there exists a bidirectional relationship between dietary patterns and depression and anxiety. Mood disorders characterized by depression and anxiety can influence individuals' food choices, as well as the consumption of certain foods that may impact symptoms related to these conditions (6, 7). Although several prospective and epidemiological studies have provided strong evidence for the relationship between dietary patterns and depression and anxiety (8, 9), the impact of dietary carbohydrate quality on these mood disorders in adolescents has yet to be fully elucidated. The results of the limited number of studies evaluating the relationship between dietary carbohydrate quality and depression and anxiety, however, are inconsistent (10, 11). Nevertheless, recent advances in nutritional neuroscience have begun to explore the potential physiological mechanisms underlying these associations.

Emerging evidence suggests that the association between dietary carbohydrate quality and mood disorders may be mediated through several interconnected physiological mechanisms. Diets with a high glycemic index and load can cause rapid fluctuations in blood glucose, influencing serotonin and dopamine synthesis through altered tryptophan transport and insulin dynamics (12). Recurrent glycemic variability may activate the hypothalamic–pituitary–adrenal axis and elevate cortisol levels, contributing to anxiety and mood instability (13). Moreover, excessive intake of refined carbohydrates promotes systemic inflammation and oxidative stress, both implicated in the pathophysiology of depression and anxiety (14). Another mechanism involves the gut–brain axis, where fiber-rich and low-glycemic diets enhance microbial diversity and short-chain fatty acid production, exerting anti-inflammatory and neuroprotective effects (15). Conversely, low-quality carbohydrate diets may disrupt gut microbiota balance and increase neuroinflammatory responses (16). These mechanisms collectively highlight the biological pathways through

which carbohydrate quality may influence psychological well-being.

The literature indicates that refined foods with high added simple sugar content and low fiber content have a high risk of leading to food addiction, and that the prevalence of food addiction is higher among adolescents compared to other age groups (17, 18). These foods, with a high potential for food addiction, are also characterized by low carbohydrate quality due to their high simple sugar content and low fiber content. It is believed that these types of foods may contribute to the increase in the prevalence of depression and anxiety in this age group by reducing dietary diversity in adolescents' daily diets and promoting the consumption of foods with low carbohydrate quality.

In conclusion, while carbohydrate quality is recognized as an important risk factor in the etiology of metabolic diseases, it is likely also a significant determinant of psychological well-being. One possible reason for the high prevalence of depression and anxiety in adolescents may be the low dietary carbohydrate quality in this population. This study aims to assess adolescents' dietary patterns based on the Turkish Nutrition Guide (TNG) reference data (19) and determine the impact of dietary carbohydrate quality on depression and anxiety levels.

2 Materials and methods

2.1 Study setting, duration, and participants

The study was conducted with adolescent students attending high school in Bolu (Turkey), aged within the adolescent range, and without any chronic illnesses that could affect food choices. To ensure homogeneity within the sample group, data was collected solely from second-year high school students (mean age 16). The sample size was calculated using the G-Power program (version 3.1.9.7), with an effect size of 0.5, a significance level of 0.05, and 90% power, resulting in a minimum of 132 participants. Data were collected through face-to-face surveys between December 15, 2024, and February 15, 2025.

2.2 Anthropometric measurements

The students' body weight, height, waist circumference, and neck circumference measurements were performed by the researchers on the study team in environments designated by the school where the data were collected. Height was measured with the individual barefoot, with feet together and the head in the Frankfurt plane. Body weight was also measured without shoes and in light clothing. For waist circumference measurement, the midpoint between the lowest rib and the iliac crest was identified, and the measurement was taken at this level. Neck circumference was measured with the individual standing upright and the head in a natural position; the measurement was taken just below the thyroid cartilage (Adam's apple) using a flexible, non-stretchable tape. For body composition analysis, a Tanita BC 545 N digital scale was used. All anthropometric measurements were performed by a single evaluator to ensure consistency and minimize measurement variability. The measurement procedures for height, weight, waist, and neck circumference were conducted in accordance with the standardized anthropometric techniques described by Lohman et al. (20).

2.3 Determination of nutrient intake levels and calculation of dietary carbohydrate quality

Dietary intake data were obtained from the adolescents participating in the study using the 24-h recall method, and a total of three 24-h recalls were collected for each participant on non-consecutive days, including two weekdays and one weekend day, to better represent usual dietary intake and account for variations between weekdays and weekends. The mean of the 3 days was calculated to estimate participants' average daily nutrient intakes. The mean of the 3 days was calculated to estimate participants' average daily nutrient intakes, and the collected data were evaluated using the Nutrition Information System (BeBİS) program to determine the nutrient intake levels of the adolescents. The dietary carbohydrate quality of the adolescents was determined according to the method of Sawicki et al. (21) (Table 1). In this method, dietary carbohydrate quality is calculated by considering the total fiber intake level, the ratio of whole grains to total grains, glycemic index, solid carbohydrates, and the ratio of total carbohydrates. All parameters to be used in the calculation were considered using BeBİS data, and only the glycemic index assessment was based on the international glycemic index value table by Foster-Powell et al. (22).

2.4 Determination of depression and anxiety levels

To assess the levels of depression and anxiety, the Beck Depression Inventory (BDI) and the Beck Anxiety Inventory (BAI), developed by Aaron T. Beck, were used. Both scales consist of 21 items, with each item being rated on a scale from 0 to 3, and the total score reflects the level of the respective psychological condition. The Turkish validity and reliability of the BDI were established by Hisli (23), and the BAI by Ulusoy (24). In both the BDI and BAI, higher total scores indicate higher levels or severity of depression and anxiety.

TABLE 1 Carbohydrate quality index (CQI) calculation criteria.

CQI component	Score range	Minimum score criterion	Maximum score criterion
Glycemic index	1–5	Highest quintile of glycemic index	Lowest quintile of glycemic index
Dietary fiber intake (g/day)	1–5	Lowest quintile of dietary fiber intake	Highest quintile of dietary fiber intake
Whole grain / total grain ratio	1–5	Lowest quintile of the ratio	Highest quintile of the ratio
Ratio of solid carbohydrates to total (solid + liquid) carbohydrates	1–5	Lowest quintile of the ratio	Highest quintile of the ratio
Total CQI score	4–20		

CQI, Carbohydrate Quality Index.

2.5 Statistical analysis of the data

IBM SPSS Statistics (Version 22) software was used for data analysis. The normality of continuous variables was assessed using the Kolmogorov–Smirnov test, along with examination of skewness and kurtosis values and visual inspection of histograms and Q–Q plots. Variables showing a normal distribution were analyzed using parametric tests, whereas categorical variables were evaluated using the chi-square test. Descriptive statistics were reported as mean $\pm$ standard deviation for numerical variables and as percentages and frequencies for categorical variables. Independent Samples t-test was used to compare the means between two groups, while One-Way ANOVA was applied to determine if there were differences among more than two groups. For variables that showed significant differences in ANOVA, the Tukey post-hoc test was used to identify the differences between groups. Chi-Square test was used to examine the relationship between categorical variables. A significance level of $p < 0.05$ was considered statistically significant.

2.6 Ethics

Ethical approval for the study was obtained from the Ethics Committee for Social Science Human Researches at Bolu Abant İzzet Baysal University (Protocol No. 2024/215). After receiving ethical approval, institutional permission was obtained from the Ministry of National Education (Application No: MEB.TT.2024.005721). Permissions for the use of the scales, which ensured their Turkish validity and reliability, were obtained from the authors, and all stages of the study were conducted in accordance with the Helsinki Declaration.

3 Results

The study was conducted with a total of 192 adolescents, including 108 females and 84 males, and the characteristics of the adolescents are presented in Table 2. The mean age of female adolescents was 15.52 ± 0.58 years, while the mean age for males was 15.57 ± 0.50 years. The gender-specific difference in the mean age of adolescents was not statistically significant ($p > 0.05$). Regarding the anthropometric findings of the participants, the mean BMI of female adolescents was 22.53 ± 4.43 kg/m², height was 160.63 ± 5.42 cm, body weight was 58.15 ± 11.89 kg, waist circumference was 71.54 ± 8.94 cm, and neck circumference was 31.67 ± 2.26 cm. In male adolescents, the mean BMI was found to be 22.9 ± 4.96 kg/m², height 172.67 ± 7.6 cm, body weight 68.8 ± 17.77 kg, waist circumference 79.34 ± 10.6 cm, and neck circumference 35.55 ± 2.67 cm. While the difference in BMI values between sexes was not statistically significant ($p > 0.05$), male adolescents had significantly higher mean values for height, body weight, waist circumference, and neck circumference ($p < 0.001$). Regarding body fat percentage, the mean value was significantly higher in female adolescents (24.52 ± 8.98) compared to male adolescents (14.63 ± 9.28 ; $p < 0.001$).

According to the findings on adolescents' daily energy and macronutrient intake, female adolescents consumed an average of 1150.46 ± 464.87 kcal of energy, 41.28 ± 18.01 g of protein, 48.02 ± 22.47 g of fat, and 135.68 ± 66.98 g of carbohydrates. The

TABLE 2 Dietary pattern data and anthropometric findings for adolescents.

Variable	Women (n = 108)		Men (n = 84)		p
	Mean	SD	Mean	SD	
Age (year)	15.52	0.58	15.57	0.5	>0.05
BMI (kg/m ²)	22.53	4.43	22.9	4.96	>0.05
Height (cm)	160.63	5.42	172.67	7.6	<0.001
Weight (kg)	58.15	11.89	68.8	17.77	<0.001
Waist Circumference (cm)	71.54	8.94	79.34	10.6	<0.001
Neck Circumference (cm)	31.67	2.26	35.55	2.67	<0.001
Body Fat Percentage (%)	24.52	8.98	14.63	9.28	<0.001
Anxiety Score	14.62	9.07	10.32	6.66	<0.001
Depression Score	12.77	6.83	11.51	6.04	>0.05
CQI	10.35	2.94	10.42	2.57	>0.05
Energy	1,150.46	464.87	1,554.69	766.85	<0.001
Protein (g)	41.28	18.01	65.63	43.91	<0.001
Protein (Energy %)	15.3	5.01	17.5	5.87	=0.005
Protein (g/kg)	0.74	0.37	0.98	0.56	<0.001
Lipid (g)	48.02	22.47	66.18	39.94	<0.001
Lipid (Energy %)	37.4	10.03	37.4	11.97	>0.05
Carbohydrate (g)	135.68	66.98	171.46	91.16	=0.002
Carbohydrate (Energy %)	47.3	11.45	45.1	12.61	>0.05
Fiber (g)	11.10	5.8	13.93	7.77	=0.004
PUFA (g)	9.13	6.56	13.42	10.21	=0.001
Cholesterol (mg)	196.6	150.8	381.37	388.7	<0.001
Number of main meals (n)					<0.001*
≥3	43		57		
<3	65		27		
Number of snacks	1.39	0.83	1.24	0.92	>0.05

#Chi square test; other analyses were conducted using the independent samples *t*-test. CQI, Carbohydrate Quality Index; BMI, Body Mass Index; PUFA, Polyunsaturated Fatty Acids. Bold values denote statistical significance ($p < 0.05$).

average values for male adolescents were determined as 1554.69 ± 766.85 kcal for energy, 65.63 ± 43.91 g for protein, 66.18 ± 39.94 g for fat, and 171.46 ± 91.16 g for carbohydrates. The differences in these values between genders were statistically significant ($p < 0.05$).

In terms of the macronutrient source of daily dietary energy, it was determined that for female adolescents, $15.3 \pm 5.01\%$ of the energy came from proteins, $37.4 \pm 10.03\%$ from fats, and $47.3 \pm 11.45\%$ from carbohydrates. For male adolescents, the percentage of dietary energy from fats was the same as females ($37.4 \pm 11.97\%$), while the percentage from proteins and carbohydrates was $17.5 \pm 5.87\%$ and $45.1 \pm 12.61\%$, respectively. In the specified ratios, although there were no statistically significant differences in the carbohydrate and fat percentages between genders ($p > 0.05$), the percentage of daily energy derived from protein was significantly higher in male adolescents ($p = 0.005$). Additionally, the protein intake per body weight for male adolescents (0.98 ± 0.56 g) was significantly higher than that of female adolescents (0.74 ± 0.37 g).

In terms of daily intake of fiber, polyunsaturated fatty acids (PUFAs), and cholesterol, male adolescents had significantly higher intake levels

compared to females ($p < 0.05$). The average daily fiber intake for males was 13.93 ± 7.77 g, PUFA intake was 11.10 ± 5.8 g, and cholesterol intake was 381.37 ± 388.7 mg. For female adolescents, these values were 11.10 ± 5.8 g, 9.13 ± 6.56 g, and 196.6 ± 150.8 mg, respectively.

The results related to depression and anxiety scores revealed that the anxiety score of female adolescents (14.62 ± 9.07) was significantly higher than that of male adolescents (10.32 ± 6.66 ; $p < 0.001$). However, no statistically significant difference was observed between genders regarding the depression score (female: 12.77 ± 6.83 ; male: 11.51 ± 6.04 ; $p > 0.05$). As for dietary carbohydrate quality, it was found to be 10.35 ± 2.94 in female adolescents and 10.42 ± 2.57 in male adolescents, with no statistically significant gender-specific difference ($p > 0.05$).

The findings regarding main meal consumption indicated that 100 adolescents consumed three or more main meals per day, while 92 consumed fewer than three. The difference in main meal consumption frequency between female and male adolescents was statistically significant ($p < 0.001$). Furthermore, a higher proportion of female adolescents (60.2%) skipped meals compared to their male counterparts (32.1%). However, the average number of snacks

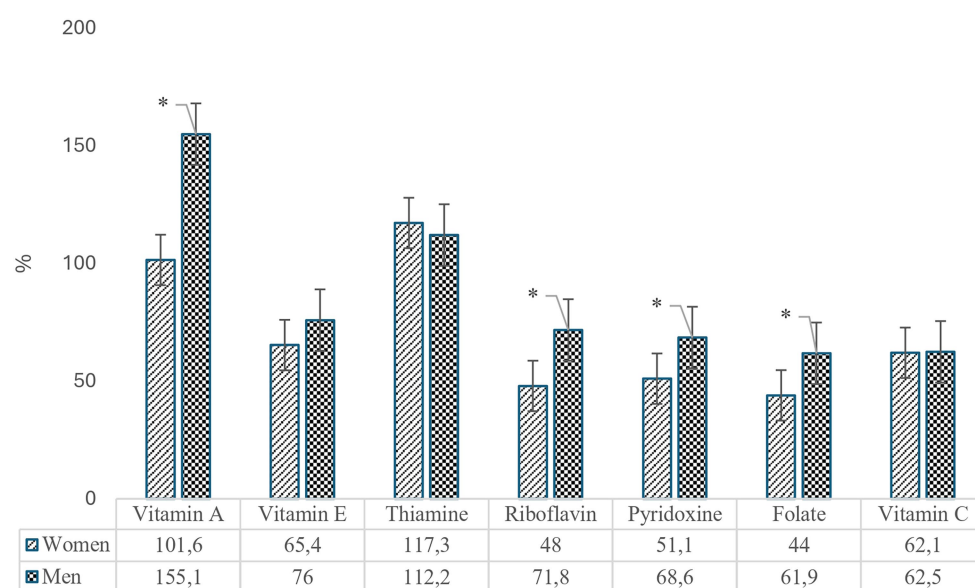


FIGURE 1

Vitamin intake rates of adolescents according to TNG recommendations (*Indicates statistically significant difference).

consumed by female adolescents (1.39 ± 0.83) was slightly higher than that of male adolescents (1.24 ± 0.92), but this difference was not statistically significant ($p > 0.05$).

The daily vitamin intakes of adolescents were compared with the recommended daily intake levels for vitamins as outlined in the 2022 Turkish Nutrition Guide (TNG), with the corresponding ratios presented in Figure 1. The findings indicated that both female and male adolescents had average intakes of vitamin A and thiamine above the recommended daily levels. The ratio of daily vitamin A intake to the TNG reference value was 155.1% for male adolescents and 101.6% for female adolescents. The gender difference in vitamin A intake was statistically significant ($p < 0.05$). While the average thiamine intake for both genders exceeded the reference level (female: 117%, male: 112%), the gender difference in thiamine intake was not statistically significant ($p > 0.05$).

The average intake levels of riboflavin, pyridoxine, folate, vitamin E, and vitamin C were found to be below the reference values specified in the TNG for both genders. Folate was identified as the vitamin with the lowest intake relative to the reference values among adolescents. Female adolescents consumed 44% of the recommended daily intake of folate, while male adolescents consumed 61.9%. The difference between genders in the percentages of recommended intake fulfillment for folate was statistically significant ($p < 0.001$). Gender-specific differences in the percentage of requirements met for riboflavin and pyridoxine were also statistically significant ($p < 0.01$), with male adolescents having higher intake levels (riboflavin: 71.8%; pyridoxine: 68.6%) compared to female adolescents, whose intake levels were 48% for riboflavin and 51.1% for pyridoxine. For vitamins E and C, the average intake levels as a percentage of the recommended daily intake were 65.4 and 62.1% in female adolescents, respectively, while in male adolescents, these percentages were 76 and 62.5%. No statistically significant gender differences were found for the intake of vitamins E and C ($p > 0.05$).

The daily mineral intakes of adolescents were compared with the recommended daily intake levels for minerals, as specified in the

Turkish Nutrition Guide (TNG), and the corresponding ratios are presented in Figure 2. The results indicated that the average daily sodium intake of male adolescents exceeded the recommended level by 25.4%, with a statistically significant gender-specific difference in sodium intake ($p < 0.001$). Both female and male adolescents had average phosphorus intakes exceeding the reference values (female: 101.2%; male: 141.3%), and the gender-based difference was statistically significant ($p < 0.001$). In contrast, calcium was identified as the mineral with the lowest intake relative to the reference values for both genders (female: 32.7%; male: 38.3%). However, the gender-specific difference in calcium intake was not statistically significant ($p > 0.05$).

The intake levels of potassium, iron, and zinc among female adolescents were found to be approximately half or below the reference values. Specifically, the intake levels for female adolescents were 40.1% for potassium, 48.5% for iron, and 50.5% for zinc. In contrast, male adolescents exhibited intake levels of 49.7% for potassium, 76.6% for iron, and 60% for zinc. The intake of magnesium was similar across genders, with female adolescents at 64.5% and male adolescents at 67.9%. Of these minerals, only iron intake demonstrated a statistically significant gender difference ($p < 0.001$), while the differences in magnesium, potassium, and zinc intake were not statistically significant ($p > 0.05$).

The quintiles based on adolescents' dietary carbohydrate quality, along with corresponding data on general depression and anxiety scores, energy-to-fiber ratio (kcal/g), carbohydrate-to-fiber ratio (g/g), and anthropometric measurements, are presented in Table 3. The findings revealed that the group with the lowest carbohydrate quality exhibited the highest anxiety (15.08 ± 7.37) and depression (13.98 ± 5.24) scores. Conversely, the lowest anxiety score was observed in the Q4 quintile (10.21 ± 7.94), while the lowest depression score was found in the Q5 quintile (9.8 ± 4.42). Statistically significant differences were noted between the quintiles for both anxiety and depression scores ($p = 0.033$ and $p = 0.039$), with a near-linear decrease in both parameters as dietary carbohydrate quality improved.

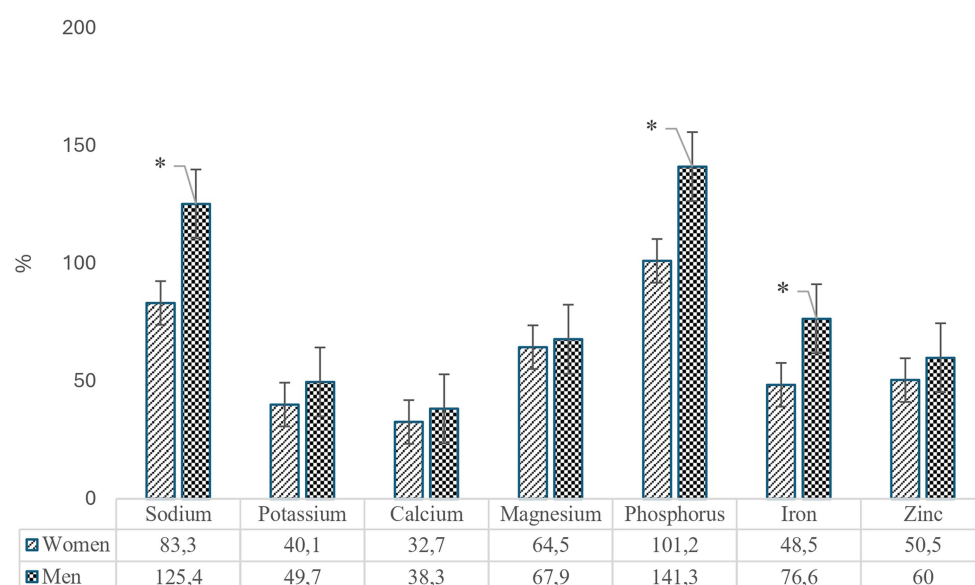


FIGURE 2

Mineral intake rates of adolescents according to TNG recommendations (*Indicates statistically significant difference).

TABLE 3 Depression and anxiety scores, dietary fiber patterns, and anthropometric findings according to dietary carbohydrate quality.

Variable	CQI										p
	Q1		Q2		Q3		Q4		Q5		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Anxiety score	15.08	7.37	13.93	9.45	11.48	8.32	10.21	7.94	10.48	6.92	0.033
Depression score	13.98	5.24	13.09	6.29	11.33	8.42	10.85	7.23	9.8	4.42	0.039
Energy-to-fiber ratio (kcal/g)	156.1	85.5	119.7	56.6	131.9	64.9	103.2	42.2	102.6	61.3	0.001
Carbohydrate-to-fiber ratio (g/g)	17.32	10.8	12.92	4.86	14.06	5.3	11.4	4.6	10.15	3.54	<0.001
Body fat percentage (%)	20.05	10.55	21.22	10.83	20.82	10.7	17.1	9.01	21.56	9.87	0.39
Waist circumference (cm)	74.95	10.97	74.98	12.16	76.23	10.96	74.54	7.63	73.96	8.2	0.949
BMI (kg/m²)	22.93	5.43	22.76	4.85	22.98	4.86	22.16	3.02	22.48	4.45	0.947
Height (cm)	165.2	8.3	164.8	9.27	167.4	9.7	167.6	8.8	165.4	7.5	0.522
Weight (kg)	63	17.2	62.6	18.6	64.36	14.38	62.48	11.3	61.3	11.8	0.970

BMI, Body Mass Index, All analyses were performed using one-way ANOVA. Bold values denote statistical significance ($p < 0.05$).

The findings regarding the energy-to-fiber and carbohydrate-to-fiber ratios, which are commonly used methods for evaluating dietary carbohydrate quality in the literature, revealed that as dietary carbohydrate quality increased, both ratios decreased. The highest energy-to-fiber ratio was observed in the Q1 quintile, while the lowest ratio was found in the Q5 quintile. The difference in energy-to-fiber ratios between the quintiles was statistically significant ($p = 0.001$). Similarly, the highest carbohydrate-to-fiber ratio was found in the Q1 quintile, and the lowest in the Q5 quintile, with a statistically significant difference between the quintiles ($p < 0.001$).

The findings related to dietary carbohydrate quality and anthropometric parameters (body fat percentage, waist circumference, BMI, height, and body weight) revealed no statistically significant differences between the quintiles for any of the anthropometric measures ($p > 0.05$).

The findings suggest that skipping main meals may be a significant predictor of anxiety scores in adolescents (Figure 3). Adolescents who regularly skipped main meals ($n = 92$) had higher anxiety scores (14.3 ± 8.9), which were significantly higher compared to those who did not skip meals (11.75 ± 7.64 ; $p = 0.039$). However, no statistically significant difference was observed in depression scores between

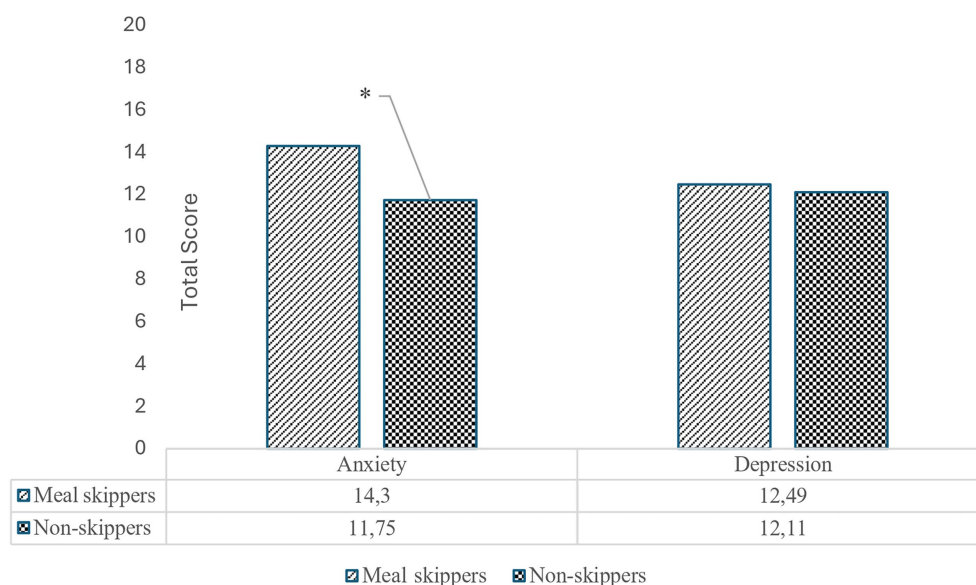


FIGURE 3

Anxiety and depression levels of adolescents with and without the habit of skipping main meals.

adolescents with (12.49 ± 6.31) and without (12.11 ± 6.70) the habit of skipping main meals ($p > 0.05$).

4 Discussion

4.1 Main findings of this study

Findings from the present study indicate that, the average BMI, body weight, and height values of the adolescents were within the age- and sex-specific reference ranges established for the Turkish population (25). The proportion of dietary energy derived from fat exceeded the reference values set by the TNG (19), representing a potential risk factor with regard to healthy eating principles for children and adolescents. Psychological assessment results indicated that participants' mean depression and anxiety scores were at a mild level. Furthermore, the intake of key micronutrients including riboflavin, pyridoxine, folate, vitamins E and C, calcium, iron, potassium, zinc, and magnesium was found to be inadequate. Conversely, intakes of sodium, phosphorus, vitamin A, and thiamine among male adolescents exceeded recommended levels. Notably, a decline in dietary carbohydrate quality was associated with higher depression and anxiety scores, underscoring the potential influence of carbohydrate quality on mental health.

4.2 Anthropometric and energy intake characteristics, underreporting tendencies

Based on the dietary intake records of the participants, the average energy intake was found to be significantly lower than the energy requirements established by the TNG, which are based on physical activity levels (sedentary, moderately active, active, very active). This

discrepancy is believed to stem from common behavioral tendencies in adolescents, such as underreporting or concealing actual food intake. Such tendencies are especially pronounced in those with prevalent fast-food dietary habits or who eat in unstructured environments during social gatherings (26). When self-reporting methods (e.g., food diaries or 24-h dietary recalls) are employed, adolescents often struggle to accurately estimate portion sizes or fail to report foods consumed outside the home, which may compromise the accuracy of the data (27). Furthermore, mood and social acceptance pressures particularly among female adolescents who experience societal pressure regarding body image and diet compliance can lead to the concealment of unhealthy food choices (28, 29).

The literature indicates that food intake is systematically underreported among adolescents, with estimates suggesting that energy intake may be underreported by as much as 41% (30). The use of various dietary assessment methods, such as food frequency questionnaires, tends to result in higher reported food intake compared to food diaries or retrospective recalls. This suggests that individuals are more likely to underreport their intake when shorter-term assessment methods are employed (31). Repeated evidence of underreporting, combined with adolescents' limited knowledge about food content and preparation methods, further compromises dietary data accuracy (26, 32). Consequently, these findings raise concerns about the reliability of diet data obtained through self-reporting in adolescents. Therefore, employing multifaceted dietary assessment approaches that consider adolescents' developmental and psychological characteristics is essential to improve reporting accuracy and willingness to disclose actual consumption (33, 34).

No evidence of chronic energy deficiency or insufficiency was found in the anthropometric measurements of height and body weight among the adolescents. The average height values for both female and male adolescents were found to be very close to the age-specific

median values established in the TNG (for females, 15 years: 162 cm, 16 years: 163 cm; for males, 15 years: 169 cm, 16 years: 173 cm). In contrast, the average body weight values were >10% higher than the corresponding age group median values (for females, 15 years: 52.8 kg, 16 years: 54.7 kg; for males, 15 years: 56.6 kg, 16 years: 61.3 kg). Taken together, the consistency between dietary intake records and anthropometric measurements highlights the importance of using multiple complementary methods to accurately assess adolescents' food consumption. This issue also has implications for interpreting nutrient adequacy and psychological associations discussed in the following sections.

4.3 Macronutrient intake and dietary patterns in adolescents

Studies evaluating adolescents' daily dietary patterns indicate that these patterns are often inadequate both quantitatively and qualitatively, which may negatively impact long-term health outcomes (35, 36). Additionally, the distribution and sources of macronutrients in the daily diet are a cause for concern. Adolescents typically consume an imbalanced diet high in sugar and fat, which may lead to long-term health issues such as obesity and cardiovascular diseases. For example, saturated fats contribute approximately 11.6% of the energy intake in adolescents aged 12–15 years, while monounsaturated and polyunsaturated fats account for 12.7 and 6.8%, respectively (37). For instance, during the COVID-19 pandemic, several studies have reported that foods high in energy and saturated fats were frequently consumed, whereas fruit and vegetable intake showed only limited improvement, indicating a deterioration in overall dietary quality (38). The findings of this study also revealed a high proportion of energy derived from fat in adolescents' daily diets, with notably elevated daily cholesterol intake observed among male adolescents.

The findings indicate that adolescents' protein intake is within the normal range; however, the literature highlights that the insufficient consumption of high-quality protein sources, such as lean meats, legumes, and dairy products, often results in protein quality being below optimal levels (39, 40). While many adolescents meet the minimum protein requirements through their diet, emerging evidence suggests that the protein consumed primarily originates from sources with significantly lower nutritional value (39, 40). For instance, high-quality protein sources like lean meats, legumes, and low-fat dairy products provide a well-balanced profile of essential amino acids with minimal unwanted fat content. In contrast, many adolescent diets rely on protein sources high in fat, cholesterol, or added sugars, which could contribute to adverse health outcomes over time (41). Furthermore, excessive intake of certain types of animal protein has been linked to abdominal obesity and other metabolic disorders. Studies have established a relationship between animal protein consumption and overall body fat accumulation in adolescents (42). This mismatch between the quantity and quality of protein intake suggests that, even if adolescents adhere to the recommended protein intake guidelines, they may still be at risk of inadequate nutrition in terms of optimal growth, lean body mass development, and long-term metabolic health.

4.4 Micronutrient deficiencies and excesses

The present study found that adolescents' intake of essential micronutrients, including riboflavin, pyridoxine, folate, vitamins E and C, as well as calcium, iron, potassium, zinc, and magnesium, was below the recommended levels. In contrast, particularly among male adolescents, the intake of sodium, phosphorus, vitamin A, and thiamine exceeded the reference values. These findings are consistent with the reported micronutrient deficiencies and imbalances documented in the literature. Studies on adolescent micronutrient intake indicate that deficiencies in folate and B-complex vitamins, particularly riboflavin and pyridoxine, are common (43). Ayal et al. (44) found that general micronutrient deficiencies are widespread among adolescents and that current dietary habits increase the risk of such deficiencies. Despite the importance of riboflavin and pyridoxine in various metabolic processes, many adolescent groups consume these nutrients in insufficient amounts. Kawade (45) emphasized that the average intake levels of several micronutrients, including zinc, are inadequate among adolescents, and noted that micronutrient deficiencies are prevalent across different geographic regions. Additionally, multiple studies have reported insufficient intake of calcium, zinc, and vitamins E and C among adolescents, and these findings align with those obtained in this study (46, 47).

On the other hand, studies have shown that adolescents living in urban areas often consume excessive amounts of processed, refined foods, fast food, and sugary beverages, resulting in sodium and phosphorus intakes that exceed the recommended levels. These findings are consistent with the existing literature (48, 49). While the literature also notes that some adolescents consume certain micronutrients, such as vitamin A and thiamine, at levels above the recommended intake, these findings have not yet been widely generalized (50).

In summary, the pattern of excessive consumption of processed foods and fast food, combined with a low intake of vegetables, fruits, and dairy products, as reflected in the data, may increase adolescents' vulnerability to future health issues, including cardiovascular diseases, diabetes, and cancer.

4.5 Dietary habits and mental health outcomes

Adolescence is a developmental phase marked by heightened susceptibility to mental health disorders such as depression, stress, and anxiety, which arise from the complex interplay of biological, psychological, and social changes. During this critical period, meal patterns play a significant role in regulating psychological and mental well-being.

The practice of skipping main meals, particularly breakfast and lunch, during adolescence has been significantly associated with mental health problems such as depression and anxiety. The literature emphasizes that regular meal consumption, especially family meals, serves as a protective factor against depressive symptoms in adolescents (51, 52). Additionally, a structured meal routine has been shown to support coping mechanisms for stress, particularly for adolescents facing academic and social pressures (53, 54).

When evaluated at the metabolic level, skipping meals can lead to fluctuations in blood glucose levels, which may contribute to the onset

of mood disorders (55). Such fluctuations in glucose homeostasis are known to influence the secretion of neuroendocrine regulators, including insulin and cortisol, thereby exacerbating emotional instability. This disruption in metabolic balance can facilitate the development of unhealthy eating habits, often accompanied by symptoms such as fatigue, irritability, and difficulty concentrating (56). Conversely, existing research indicates that current levels of depression and anxiety negatively influence eating behaviors, leading to an increase in irregular eating patterns, such as meal skipping, thus creating a bidirectional relationship between mood and dietary behavior (55). The findings of this study align with the literature, revealing that adolescents who skipped main meals exhibited significantly higher levels of anxiety.

4.6 Carbohydrate quality and mental health

An important determinant of adolescent health is the composition of carbohydrates in their diet. Carbohydrate quality refers to the nutritional and physiological value of carbohydrate-containing foods, influenced by factors such as fiber content, degree of processing, and glycemic response. Literature suggests that, rather than the quantity of carbohydrate intake, its quality plays a crucial role in regulating mood and emotional well-being (57). In academic studies, the quality of dietary carbohydrates is typically assessed using factors such as glycemic index, glycemic load, fiber content, and degree of processing. High glycemic index foods have been identified as risk factors in the pathophysiology of mood disorders, due to their potential to induce glycemic variability, systemic inflammation, and neurochemical imbalances. In contrast, low glycemic index foods have been associated with more favorable neuropsychological outcomes (58). These findings highlight that carbohydrate quality not only influences metabolic balance but may also play a pivotal role in maintaining emotional stability during adolescence. The findings of this study further support this notion, as an increase in the quality of dietary carbohydrates was associated with lower depression and anxiety scores.

A growing body of observational and interventional research has begun to clarify the potential mechanisms linking high-glycemic-index diets to adverse mental health outcomes. In this context, clinical and case-based evidence further supports the association between glycemic regulation and mood symptoms. For example, a case report indicated that reducing the intake of refined carbohydrates was associated with improvements in symptoms of generalized anxiety disorder and hypoglycemia (59). Moreover, a study involving adolescents with type 1 diabetes found a relationship between poor glycemic control and elevated psychological distress (60). Although this association is primarily related to diabetes management, it suggests that glycemic variability may have broader implications for psychological well-being in both diabetic and non-diabetic populations.

The literature has also proposed a mechanistic explanation for the relationship between glycemic index and psychological well-being. Meals composed of high-glycemic-index foods can lead to marked postprandial elevations in blood glucose levels, which may subsequently be followed by reactive hypoglycemia. Such glycemic fluctuations are thought to influence neuroendocrine regulators including insulin and cortisol that play key roles in modulating mood and stress responses. Research on glycemic variability has identified a correlation between acute spikes in blood glucose and heightened anxiety-related traits,

suggesting that blood glucose stability may be linked to improved psychological well-being (61). Moreover, a systematic review by Rahimlou et al. (61) found that diets characterized by a low glycemic index may reduce the risk of depression, reinforcing the notion that glycemic stability represents a potentially modifiable factor in mood regulation. While these findings highlight the biological mechanisms linking diet and mental health, it should be acknowledged that several behavioral and contextual factors may also play an important role.

In addition to dietary factors, several external variables may influence both eating behavior and psychological outcomes in adolescents. Physical activity level plays a critical role in regulating energy balance, neuroendocrine function and mood, with lower activity frequently associated with higher depressive and anxiety symptoms (62, 63). Irregular or insufficient sleep can disrupt circadian rhythms and neurotransmitter homeostasis, thereby contributing to emotional dysregulation and heightened anxiety (64). Socioeconomic status affects access to nutrient-dense foods and exposure to psychosocial stressors, both of which may confound the relationship between carbohydrate quality and mental health (65). Cultural and familial dietary practices also shape food preferences and meal patterns and may therefore modify the associations observed across different populations (66). Although these factors were not measured in the present study, acknowledging their potential influence underscores the need to include such variables in future prospective and interventional research to disentangle causal pathways.

Dietary fiber content is a key determinant of carbohydrate quality. A growing body of research indicates that higher fiber intake is inversely associated with symptoms of depression and anxiety. For instance, a systematic review by Aslam et al. (67) demonstrated that increased fiber consumption is linked to a lower risk of these mental health disorders. Similarly, Oddy et al. (68) highlighted that high-fiber, nutrient-dense diets may enhance mental health by mitigating systemic inflammation. Conversely, evidence also suggests a U-shaped relationship between fiber intake and mental health, indicating that both insufficient and excessive fiber consumption may have detrimental effects (69). Mao et al. (70) further emphasized that the protective effects of fiber against depression may differ across demographic groups, and that both the type and source of fiber play a critical role.

In line with this literature, the findings of the present study revealed that as the dietary carbohydrate quality index increased, the carbohydrate-to-fiber and energy-to-fiber ratios declined, while depression and anxiety scores significantly decreased. These results support the notion that adequate fiber intake may serve as a protective factor against the development of depression and anxiety, particularly during adolescence.

Overall, the results of this study are consistent with the growing evidence linking carbohydrate quality to psychological well-being. Dietary interventions aimed at reducing the glycemic index or ensuring adequate fiber intake in adolescents have demonstrated potential for alleviating anxiety symptoms, suggesting that lifestyle changes may serve as complementary tools in the management of mental health. Although no studies in the literature specifically assess the relationship between dietary carbohydrate quality and depression or anxiety in adolescents, the concept of carbohydrate quality is increasingly recognized as a key determinant of health. It is proposed as a more comprehensive measure that extends beyond glycemic index and fiber content alone (71–73). The carbohydrate quality index considers the differential physiological effects of solid and liquid carbohydrates, underscoring the advantages

of a holistic approach rather than reliance on isolated metrics such as glycemic index or fiber content. This multidimensional approach provides a broader understanding of the health impact of carbohydrate consumption, offering a more precise method for predicting health outcomes. In line with recent developments in this area, incorporating carbohydrate quality as a central element in dietary guidelines could play a significant role in reducing the risk of chronic diseases and improving overall health outcomes.

4.7 Strengths, limitations, and future directions

This study has several notable strengths. It specifically targets an adolescent population, a developmental period in which dietary behaviors and emotional regulation undergo significant change. The comprehensive evaluation of dietary carbohydrate quality through multiple indicators, together with validated measures of depression and anxiety, provides valuable insight into the relationship between diet and psychological health. This multifactorial assessment strengthens the study's contribution to the growing field of nutritional psychiatry, particularly within adolescent populations. Furthermore, the use of multiple 24-h dietary recalls that included both weekdays and weekends strengthened the representativeness of usual intake and enhanced the reliability of dietary assessment.

However, certain limitations should be acknowledged. The cross-sectional design precludes any inference of causality between dietary carbohydrate quality and mental health outcomes. The use of self-reported dietary data and psychological assessments introduces the possibility of recall and reporting bias. In addition, some potentially influential variables such as physical activity, sleep quality, socioeconomic status, and cultural eating habits were not assessed in detail. These unmeasured factors could partially account for the associations observed in the present study.

Future research should build upon these findings through well-designed longitudinal and interventional studies to elucidate causal mechanisms underlying the relationship between carbohydrate quality and mental health in adolescents. Experimental designs incorporating controlled dietary interventions could help clarify the directionality and magnitude of these effects. Additionally, integrating objective measures such as accelerometry for physical activity, actigraphy for sleep patterns, and biomarkers for dietary intake would improve the accuracy of data collection. Cross-cultural comparisons may also shed light on how sociocultural dietary patterns interact with mental health outcomes. Such approaches will contribute to a more comprehensive understanding of how carbohydrate quality can be leveraged in nutritional strategies aimed at promoting adolescent psychological well-being. Ultimately, integrating these findings into public health and educational strategies could help shape healthier dietary behaviors and improve mental well-being during adolescence.

5 Conclusion

The findings of this study suggest that low carbohydrate quality in adolescents' diets may be associated with increased levels of depression and anxiety. Dietary patterns dominated by refined carbohydrates characterized by a high glycemic index and low fiber content appear to

have a detrimental impact on mental well-being. Additionally, the results indicate widespread inadequacies in micronutrient intake among adolescents, particularly in essential nutrients such as folate, riboflavin, and vitamins C and E. These findings underscore the critical importance of enhancing overall dietary quality, not only to support metabolic health but also to promote psychological well-being. Nutritional interventions focused on improving carbohydrate quality may offer a promising approach to supporting adolescent mental health. Accordingly, incorporating carbohydrate quality as a key component in national nutrition strategies targeting this age group is warranted.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethical approval for the study was obtained from the Ethics Committee for Social Science Human Researches at Bolu Abant İzzet Baysal University (Protocol No. 2024/215). After receiving ethical approval, institutional permission was obtained from the Ministry of National Education (Application No: MEB.TT.2024.005721). Permissions for the use of the scales, which ensured their Turkish validity and reliability, were obtained from the authors, and all stages of the study were conducted in accordance with the Helsinki Declaration. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

TÜ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. BS: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. AM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. YÇ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. ŞF: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. Bİ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Parents' nutrition knowledge, perceived barriers and enablers, and healthy-eating attitudes associated with children's adherence to the Mediterranean diet: the DELICIOUS project

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Objective: Children's dietary choices are influenced by several factors, including parents' modeling. The relation between parents' psychosocial factors and their children's level of adherence to the Mediterranean diet were explored.

Methods: Food literacy, perceived barriers and enablers, and healthy-eating attitude following the Capability, Opportunity and Motivation (COM-B) model for behavioral change were evaluated in 2,011 participants in the DELICIOUS (UnDerstanding consumer food choices & promotion of healthy and sustainable Mediterranean Diet and Lifestyle in Children and adolescents through behavIOUral change actionS) project. Adherence to the Mediterranean diet was

assessed through the KIDMED questionnaire. Beta coefficients and standard errors (SEs) were calculated through linear regression analyses.

Results: Post-adjustment for potential confounding factors, results showed significant positive correlation between children's adherence to the Mediterranean diet and parental food literacy [β (SE) = 0.180 (0.011)], perceived barriers and enablers [β (SE) = 0.135 (0.009)], and healthy-eating attitudes (divided into five constructs) [β (SE) = 0.069 (0.030), β (SE) = 0.037 (0.029), β (SE) = 0.162 (0.017), β (SE) = 0.147 (0.010), β (SE) = 0.158 (0.011)]. Individual dietary components of the Mediterranean diet were also associated with various psychosocial factors.

Conclusion: These results confirm the importance of parental food literacy, perceived enablers and barriers to healthy-eating, health-eating attitude in their children's adherence to the Mediterranean diet.

KEYWORDS

Mediterranean diet, children, adolescents, parents, food literacy, nutrition knowledge

1 Introduction

Over the last decades, current trends of food choice and diet quality in children's and adolescents have led to the gradual displacement of traditional dietary patterns in favor of unhealthy alternatives (1, 2). One traditional dietary pattern recognised for its health benefits that has been documented to have lost popularity is the Mediterranean diet (3): such a model refers to the traditional eating habits of people in countries bordering the Mediterranean Sea characterized by richness in plant-based foods and moderation in animal ones, with a variety of specific foods, culinary and cultural features that reflect the millenary history of the populations inhabiting such places (4). At its core, the Mediterranean diet emphasizes whole, unprocessed foods that are rich in nutrients, flavor, and cultural significance (5). The Mediterranean diet is based on some key principles. Firstly, an abundance of plant-based foods such as fruits, vegetables, herbs, legumes (e.g., chickpeas and beans), nuts, seeds, and whole grains: these foods are loaded with vitamins, minerals, fiber, and antioxidants (6). Secondly, healthy fats (i.e., monounsaturated fat), such as those from olive oil, a hallmark of the Mediterranean diet (7). Thirdly, moderate consumption of animal-based proteins: the Mediterranean diet advocates for the consumption of fish and seafood over red meat while poultry, eggs, and dairy products are also recommended to be consumed in moderation (8). Next, to enhance the flavor of the food, herbs and spices are preferred sources over salt, sugar, and other ultra-processed condiments; common seasonings observed in the Mediterranean diet are garlic, basil, oregano, and rosemary (9, 10). Lastly, food and beverage aside, an active lifestyle was characteristic alongside the aforementioned features (5). In fact, the Mediterranean diet transcends the limited concept of diet, while it embraces an overall lifestyle that is shaped by culture and tradition passed down from generations before altogether with preference for locally produced foods promoting low environmental impact and health (11, 12). Notably, comprehensive evidence from the scientific literature supports the rationale that higher adherence to the Mediterranean diet would lead to better physical and mental health in both adults and young individuals (13, 14).

Cultivating healthy dietary habits from a young age is crucial as they often persist into adulthood (15, 16). As children are also undergoing rapid growth, a healthy and balanced diet will provide the

necessary macronutrients, vitamins, and minerals for proper bone, cognitive, and immune development (17, 18). Several factors, such as family, peers, education, community, television and social media are thought to all play some role in shaping eating behaviors, and they could be perceived as barriers or enablers to the adoption of a healthy diet (19, 20). As home is where children develop their initial knowledge of food, eating attitudes and dietary patterns, parents are thereby examined with the greatest scrutiny as their food literacy and healthy-eating attitude determines the home food environment (including choice of ingredients, food preparation methods and feeding routine) (19). Furthermore, tailored dietary and lifestyle interventions targeting both parents and children have been proven to improve their habits (21).

To influence children's behavior, there is a need to understand why behavior is as it is and identify what is needed to motivate a change for the desired behavior (22). In this context, a wide range of comprehensive theoretical frameworks encompassing theoretical domains and constructs categorized in various behavior change theories have been applied to investigate psychosocial and behavioral predictors of healthy eating (23). Among the most studied, the Theory of Planned Behavior (TPB) framework posits that the intention to change is the greatest proponent of behavior change (24). The TPB model aims to forecast an individual's inclination to undertake a specific behavior subject to self-regulation (24). There is therefore a great emphasis on behavioral intent in this model, which evaluates one's attitude towards the anticipated consequences of the behavior and subjective assessment of the associated risks and benefits (24). However, TPB hinges heavily on the rationality of behavior which may deviate from reality (25). In addition, TPB can be subjective or circumstantial and may not accurately predict behavior (25). The Capability, Opportunity and Motivation Behavior (COM-B) model is another theoretical framework used in the context of behavioral change in nutrition science that has been previously used to identify key determinants of dietary choices and, eventually, for behavioral change (22). The COM-B model suggests that individuals will need the requisite psychological and physical capability (i.e., knowledge and skill to carry out a task), an opportunity defined by social and physical environment enablers (e.g., access to requisite resources and a conducive environment), and the right motivation (e.g., environmental triggers and cultural norms) to engage in a behavior (22). In essence,

the COM-B model provides a structured roadmap to break down the various factors that influence human behavior (physical, psychological, social and cognitive) as well as how they work together to elicit and sustain a behavior change (22).

The DELICIOUS (understanding consumer food choices & promotion of healthy and sustainable Mediterranean diet and lifestyle in children and adolescents through behavioral change actions) project is an European project that aims to promote and enable good eating habits among children and adolescents through improving adherence to the Mediterranean diet (26). DELICIOUS is a project involving five different countries in the Mediterranean region – Portugal, Spain, Italy, Egypt, and Lebanon. Recent reports showed that adherence to the Mediterranean diet and diet quality in the participating countries is average (27, 28) and potentially associated with children's lifestyle factors (29). While prior studies have suggested an association between parental attitudes and the dietary choices of their children, no previous harmonized evaluation has been performed across Mediterranean countries concerning parents' capability, opportunity, and motivation to ensure adherence to the Mediterranean diet in children and adolescents. Therefore, as part of the DELICIOUS project, this study aims to investigate whether parents' food literacy, their perceived barriers and enablers, and healthy-eating attitude do influence children's and adolescents' dietary choices and adherence to the Mediterranean diet in five Mediterranean countries leveraging on the COM-B model as a guiding framework.

2 Methods

2.1 Study design and participants

For the purposes of this cross-sectional study, a consumer electronic survey was conducted in 2023 among parents of children and adolescents aged between 6 and 17 years old from the five Mediterranean countries involved in the DELICIOUS project. Participants were shortlisted from the consumer database of AIJU Technical Institute for Children's Products and Leisure and recruited based on their voluntary agreement in being included through an online survey. The inclusion criteria included the following: (i) having children fitting the target population in terms of age range and (ii) having access to the internet to fill out the survey. A target sample size of 400 individuals in each country was deemed adequate to detect significant differences across groups of exposed individuals based on similar studies conducted in Mediterranean countries with similar aims (30–34). However, given the voluntary nature of the participation in the survey, the sample is not considered representative of a random population but, rather, indicative of the target one. A total of 2,011 individuals were finally enrolled in this study. The study protocol was approved by the ethics committee of Mondragon University (no. IEB-20230704). All the procedures were carried out in accordance with the Declaration of Helsinki (1989) of the World Medical Association and all participants signed an informed consent form prior to their participation.

2.2 Demographic assessment

Parents were asked to provide their child's age, gender, height, weight, sleep duration, screen time, and physical activity levels. Body

mass index (BMI), defined as weight (in kilograms) divided by the square of height (in meters), was subsequently derived. Unrealistic weight or height values (e.g., <5 kg, or <0.1 m) were excluded from the analysis as they were likely the result of clerical error. Children and adolescents were categorized, according to their age and gender (i.e., BMI z-scores), as either (i) normal weight (BMI 5th–84th percentile), (ii) overweight (BMI 85th–94th percentile), or (iii) obese (BMI ≥ 95th percentile) based on the weight-for-height growth charts percentiles for children and teens ages 2 through 19 years by the Centers for Disease Control and Prevention (CDC) (35). Sleep duration (in hours) was grouped into: (i) <8 h, (ii) 8–10 h, and (iii) >10 h, based on the National Sleep Foundation recommendations for school-age children and teenagers (36). Screen time (in hours) was stratified into: (i) <2 h/day, (ii) 2–4 h/day, and (iii) >4 h/day, based on the Australian 24-h movement guidelines for children and adolescents aged 5 to 17 (37). Finally, physical activity level was assessed using the International Physical Activity Questionnaire-Short Form (IPAQ-SF), which reflects the level of physical activity in the 7 days immediately before the assessment. Specifically, the frequency of activity (measured in days per week) and the duration of activity (time per day) were collected separately for each of the three types of activity (walking, moderate-intensity activity, and vigorous intensity activity), which corresponds to low, medium and high level of physical activity, respectively (38). International standards were referenced, if available. Otherwise, national standards were sourced and referenced as an alternative.

Parents were also asked to provide their age, gender, educational level, family status, family income, and area of living. Educational level was split into: (i) low (primary), (ii) medium (secondary), and (iii) high (tertiary). Family status was categorized as: (i) live alone, (ii) live with a partner, and (iii) live with others. Family income (per month) was stratified into: (i) <€2,000, (ii) €2,000–4,000, and (iii) >€4,000. Finally, the area of living was categorised as: (i) urban, and (ii) rural.

2.3 Dietary assessment

A semi-structured 24-h dietary recall and questions on frequency of consumption of major food groups and meal occasions was used to collect data on children's dietary habits. The level of adherence to the Mediterranean diet was assessed using the Mediterranean diet quality index for children and adolescents (KIDMED) (39). This index is derived from 16 components that summarize the principles of the Mediterranean diet and provides an arithmetic score that ranges from −4 to 12; a score less than 3 reflects a poor diet in relative to the Mediterranean diet principles, whereas values between 4–7 and 8+, average and good adherence to the principles of the Mediterranean diet, respectively. The KIDMED index advocates for a daily consumption of at least one serving of fruit and vegetables, and at least three servings of dairy product: one serving at breakfast and at least two servings of yogurt and/or cheese during the remaining part of the day. Grains and cereals are recommended to be consumed daily at breakfast, whereas pasta or rice should be consumed at least five times per week. At least two to three servings of nuts and fish, and at least two servings for pulses each week are recommended. Olive oil is recommended for culinary use, but frequency is not stipulated. Dietary behaviors that are deemed as detrimental and deviate from the principles of the

Mediterranean diet include the frequent intake of sweets and candies (defined as more than twice daily), the consumption of commercially baked goods, pastries and fast-food, and the abstinence from breakfast.

2.4 Psychosocial assessment

Referencing the COM-B model, a search of the scientific literature was conducted to identify the assessment tools that could quantify each factor eliciting behavior change (22). The following factors were shortlisted: (i) food literacy which reflects Capability (C), (ii) perceived barriers and enablers which translates to Opportunity (O), and (iii) healthy-eating attitudes and health consciousness which determines Motivation (M) (22).

The Short Food Literacy Questionnaire (SFLQ) for adults was used to measure a broad range of skills including, but not limited to, the functional and interactive elements of the food literacy of parents (40). It is a nine-part questionnaire with a total of 15 items based on a 4- or 5-point Likert scale, where answers may range from “very bad” to “very good,” “strongly disagree” to “strongly agree,” “very difficult” to “very easy,” “very hard” to “very easy,” or “never” to “always.” Of the 15 items, 10 are on the practical skills such as understanding nutrition information and composing a balanced menu, one is on interactive abilities such as exchanging nutrition information with family and peers, and the remaining four assess the ability to critically judge nutrition information or evaluate the long-term impact of dietary habits on health. A maximum score of 62 may be attained, and a higher score indicates higher food literacy.

Perceived barriers and enablers (PBE) were measured through the construction of a set of questions based on the TPB framework positing the intention to change influenced by the following constructs constituting potential barriers and enablers: (i) attitude towards the behavior, which are the personal opinion about the change that may be positive or negative; (ii) subjective norms, which are the community’s (people in the social circle of the subject) opinion about the change that similarly may be favorable or unfavorable; and (iii) perceived behavior control, which refers to the self-perceived level of difficulty to achieve the behavior change (41). Based on earlier studies (42, 43), a three-part questionnaire with multiple questions within each part has been developed based on the TPB model to identify the barriers and enablers of adherence to a Mediterranean diet perceived by the parents. The first part consists of 14 questions and it assesses the attitude towards the behavior. The response is structured based on a five-point Likert scale ranging from one point for “strongly disagree” to five points for “strongly agree” and zero point for the additional “do not know/no answer” option. The second part consists of four questions which assess the subjective norms. Similarly, the response is structured based on a five-point Likert scale ranging from one point for “highly unlikely” to five points for “highly likely” and zero point for the additional “do not know/no answer” option. The final part contains only one question that assesses the perceived behavior control. The response is structured in the same way as the second part. Hence, a maximum score of 95 may be attained.

The Healthy-Eating Attitudes (HEA) questionnaire assesses parent’s attitude towards their child’s diet composition (44). There are a total of 8 questions on parent’s opinions of their child’s intake of fruit, fibre, vegetables, fish, butter, fat, meat, sweets and pastries. The

answer to each question is binary (yes or no), where 1 point is allocated for “yes” and 0 point is allocated for “no.” Hence, a maximum score of 8 may be attained.

The Theory of Internet Use related to Health (TIUH) questionnaire is a multiple health domain tool that assesses parent’s tendency to seek health information over the internet to evaluate their health consciousness (45). Four domains are assessed: (i) health-information, which identifies the health-related topics that an individual seeks from the internet, and answers are dichotomous (yes or no); (ii) health consciousness, which consists of five items eliciting a response on a scale of 1 to 5, where “1” representing “strongly disagree,” and “5” representing “strongly agree”; (iii) health-information orientation, which comprises of eight items soliciting a response on a scale of 1 to 5; (iv) health-oriented beliefs, which entails 8 items on the perception of health behavior, and the answers are on a scale of 1 to 5. Hence, maximum scores of 6, 25, 40 and 40 may be attained under the respective domains.

2.5 Statistical analysis

Variables were examined for normality and skewness (Kolmogorov and Levene tests). Paired t-test and one-way ANOVA test were used for comparisons of continuous variables according to the normality distribution of the sample. Chi-square test was used to test differences across categorical variables. Univariate linear regression analyses were performed to assess the association between adherence to the Mediterranean diet (calculated as KIDMED score) and scores derived by the assessment tools used to investigate the psychosocial factors within the COM-B model (namely the SFLQ, PBE, HEA, and TIUH). Multivariate linear regression models were additionally performed to assess the relationship between variables of interest (i.e., consumption of certain food groups or compounds, grouped into quantiles) and the outcome by calculating the beta coefficients and standard errors (SEs) adjusted for potential confounding factors, such as children’s age, gender, BMI, physical activity, sleep duration and screen time, parents’ age, gender, education, income, family status, and area of living. *p*-values <0.05 (two-tailed) are considered significant. SPSS 29 (SPSS Inc., Chicago, IL, USA) software was used for all the statistical tests.

3 Results

Responses from 2,011 case subjects have been included in this study. An overview of the key demographic profiles of children and adolescents against the parents’ psychosocial assessment scores is in Table 1. The SFLQ scores were higher in the adequate sleep duration group (8–10 h) and higher physical activity level in children whereas the PBE scores were higher for those in the normal weight category, who have adequate sleep duration, and shorter screen time (Table 1).

On the other hand, the HEA scores showed that parental healthy-eating attitude scores were obese and longer sleep duration groups (Table 1). Moreover, the TIUH scores illustrated that the health-information seeking behavior was stronger in parents of children who are obese, have longer sleep duration, longer screen time, and medium physical activity level. Parents with weaker healthy-eating beliefs are associated with children who are overweight and have low physical

TABLE 1 Mean scores of parental food literacy (based on SFLQ score), perceived barriers and enablers (PBE score), healthy-eating attitudes (based on HEA score), and healthy-eating behavior (based on TIUH score) by demographic characteristics and lifestyle habits of children and adolescents (n = 2,011).

	n (%)	SFLQ	PBE	HEA	TIUH			
					Health-Info	Consciousness	Orientation	Beliefs
Age								
6–11 y	1,047 (52)	31.9 (5.1)	62.9 (9.0)	7.0 (1.8)	3.4 (2.0)	20.5 (3.2)	31.4 (5.2)	31.1 (6.2)
12–17 y	964 (48)	31.5 (5.0)	63.3 (8.1)	6.8 (1.9)*	3.4 (2.0)	20.4 (3.3)	31.1 (5.3)	31.5 (6.1)
Sex								
Male	995 (49)	31.5 (5.0)	63.5 (8.2)	6.8 (1.9)	3.4 (2.0)	20.4 (3.3)	31.3 (5.3)	31.4 (6.2)
Female	1,016 (51)	31.9 (5.1)	62.7 (8.9)	6.9 (1.8)	3.4 (2.1)	20.5 (3.2)	31.2 (5.2)	31.3 (6.1)
BMI								
Normal weight	1,087 (69)	32.2 (4.9)	64.0 (8.7)	6.9 (1.9)	3.0 (2.0)	20.7 (3.2)	31.1 (5.5)	33.4 (4.8)
Overweight	263 (17)	32.0 (4.9)	62.5 (7.4)	6.8 (1.9)	3.4 (2.1)	20.6 (3.1)	31.3 (5.2)	32.8 (4.9)
Obese	232 (15)	32.4 (5.3)	61.2 (7.7)**	7.4 (1.5)**	4.0 (2.0)**	20.9 (3.1)	32.3 (5.1)*	33.9 (5.1)*
Sleep duration								
<8 h	371 (18)	30.9 (5.2)	62.5 (6.6)	6.7 (2.0)	3.6 (1.9)	20.0 (3.2)	31.0 (5.1)	29.3 (6.3)
8–10 h	1,542 (77)	31.9 (4.9)	63.5 (8.7)	6.9 (1.8)	3.4 (2.0)	20.6 (3.2)	31.3 (5.3)	31.8 (5.9)
>10 h	98 (5)	31.7 (5.8)*	59.3 (9.2)*	7.6 (1.6)**	3.8 (2.1)*	20.3 (3.5)*	32.0 (5.8)	31.2 (7.5)**
Screen time								
<2 h/day	1,131 (56)	31.7 (5.1)	63.8 (8.9)	6.9 (1.8)	3.3 (2.0)	20.5 (3.0)	31.3 (4.8)	31.6 (5.8)
2–4 h/day	723 (36)	31.9 (4.9)	62.6 (8.1)	6.8 (1.9)	3.5 (2.0)	20.3 (3.4)	31.2 (5.7)	31.0 (6.4)
>4 h/day	157 (8)	31.2 (5.7)	61.7 (8.4)*	7.1 (1.7)	3.8 (2.0)*	20.6 (3.5)	31.2 (6.2)	30.8 (7.3)*
Physical activity level								
Low	1,017 (51)	30.9 (5.1)	62.5 (9.0)	6.9 (1.8)	3.3 (2.0)	20.2 (3.2)	31.0 (5.2)	30.9 (6.2)
Medium	461 (23)	32.7 (4.8)	63.6 (7.4)	7.0 (1.8)	3.8 (2.0)	20.8 (3.2)	32.0 (5.1)	32.1 (5.9)
High	533 (27)	32.3 (4.9)**	63.8 (8.6)	6.7 (1.8)	3.3 (2.1)**	20.6 (3.3)*	31.0 (5.5)*	31.5 (6.2)*

BMI, Body Mass Index; SFLQ, Short Food Literacy Questionnaire; PBE, Perceived Barriers and Enablers; HEA, Healthy-eating Attitudes; TIUH, Theory of Internet Use related to Health; y, years. **p* < 0.05, ***p* < 0.001.

activity level, while those with stronger beliefs are associated with children who have adequate sleep duration and shorter screen time (Table 1). An overview of the key demographic profile of the parents against their psychosocial assessment scores is summarized in Table 2. The SFLQ scores were higher in younger mothers with higher educational level, living with a partner and higher family income (Table 2). In contrast, the PBE scores were higher for mothers with mid-range education and income, living with a partner in a rural area (Table 2). However, the HEA scores were similar for most demographic characteristics apart from the age and sex of the parent (Table 2). The TIUH scores were generally higher for young mothers with high education and income who were living with a partner (Table 2). Table 3 shows the association between parents' psychosocial factors and children's lifestyle and eating habits. Contrary to expectations, not all constructs were significantly associated with variables of interest and even not in the expected direction. For instance, SFLQ scores predicted higher levels of physical activity; BMI and screen time also decreased with higher scores of PBE; and physical activity levels, breakfast, and family eating habits increased with higher scores on beliefs (Table 3). In contrast, health

info was directly associated with BMI and screen time, and inversely with breakfast, eating with family, but also directly with frequency of eating alone and at school (Table 3). Figure 1 provides a graphical illustration of the differences between the psychosocial assessment mean scores across the banded KIDMED scores (i.e., poor, average, and good) resulting in significant differences in all psychosocial constructs analyzed. The results of the unadjusted and multivariate-adjusted linear regression analyses putting in relation the KIDMED scores with those of the psychosocial assessment scores are summarized in Table 4. After adjusting for various potential confounding factors, all models showed significant results demonstrating a strong association between children's adherence to the Mediterranean diet and parental food literacy [$\beta = 0.180$ (SE 0.011)], perceived barriers and enablers [$\beta = 0.135$ (SE 0.009)], healthy-eating attitude [$\beta = 0.069$ (SE 0.030)], and health consciousness [for health-info, consciousness, orientation, and beliefs, $\beta = 0.037$ (SE 0.029), $\beta = 0.162$ (SE 0.017), $\beta = 0.147$ (SE 0.010), and $\beta = 0.158$ (SE 0.011), respectively] (Table 4). An analysis including the relation between various psychosocial constructs and individual components of the KIDMED showed that, in general,

TABLE 2 Mean scores of parental food literacy (based on SFLQ score), perceived barriers and enablers (PBE score), healthy-eating attitudes (based on HEA score), and healthy-eating behavior (based on TIUH score) by demographic characteristics (n = 2,011).

	n (%)	SFLQ	PBE	HEA	TIUH			
					Health Info	Consciousness	Orientation	Beliefs
Age								
≤44 y	423 (21)	32.5 (5.1)	63.8 (8.2)	7.3 (1.7)	4.5 (1.7)	20.5 (3.3)	32.5 (5.1)	30.8 (6.9)
≥45 y	1,588 (79)	31.5 (5.0)**	62.7 (8.8)	6.8 (1.8)**	3.1 (2.0)**	20.4 (3.2)	30.9 (5.2)**	31.5 (5.9)
Gender								
Male	823 (41)	30.9 (5.0)	60.4 (6.6)	6.8 (1.9)	3.3 (2.0)	20.1 (3.4)	30.7 (5.4)	30.5 (6.5)
Female	1,188 (59)	32.3 (5.0)**	64.2 (9.0)**	6.9 (1.8)*	3.5 (2.0)*	20.7 (3.1)**	31.7 (5.1)**	31.9 (5.9)**
Education level								
Low	91 (5)	28.5 (6.2)	62.3 (7.9)	6.6 (2.3)	3.2 (2.1)	19.4 (4.2)	30/0 (6.6)	28.2 (8.0)
Medium	750 (39)	31.1 (4.8)	65.2 (8.7)	6.8 (1.7)	3.0 (1.9)	20.4 (3.2)	30.7 (5.3)	31.4 (5.7)
High	1,093 (57)	32.5 (4.9)**	62.2 (8.1)**	6.9 (1.8)	3.7 (2.0)**	20.7 (3.1)*	31.8 (5.0)**	31.8 (6.1)**
Family status								
Live alone	249 (12)	31.2 (5.4)	61.4 (8.1)	6.8 (1.9)	3.3 (2.1)	19.8 (4.0)	30.4 (5.8)	30.2 (7.2)
Live with a partner	1716 (85)	31.8 (5.0)	63.5 (8.6)	6.9 (1.8)	3.4 (2.0)	20.6 (3.1)	31.4 (5.1)	31.5 (5.9)
Live with others	46 (2)	30.4 (6.0)*	59.3 (7.4)*	6.3 (1.9)	3.9 (1.6)	19.5 (3.1)**	31.1 (5.3)*	30.5 (7.5)*
Family income								
< €2,000	467 (27)	30.8 (5.2)	63.2 (8.7)	6.8 (1.7)	3.4 (1.9)	20.1 (3.2)	31.1 (5.2)	30.3 (6.2)
€2,000-4,000	796 (47)	32.1 (4.8)	63.7 (8.2)	6.8 (1.8)	3.4 (2.0)	20.5 (3.3)	31.1 (5.3)	32.2 (5.8)
> €4,000	442 (26)	33.0 (4.8)**	62.0 (7.5)*	7.0 (1.9)	4.1 (1.9)**	20.9 (3.1)*	32.4 (5.1)**	32.0 (6.6)**
Area of living								
Urban	1,629 (81)	31.8 (5.1)	62.8 (8.4)	6.9 (1.8)	3.5 (2.0)	20.5 (3.2)	31.3 (5.3)	31.5 (6.1)
Rural	382 (19)	31.3 (4.8)	66.1 (8.9)**	6.8 (1.8)	3.0 (2.0)**	20.4 (3.1)	31.1 (5.0)	30.8 (6.3)

SFLQ, Short Food Literacy Questionnaire; PBE, Perceived Barriers and Enablers; HEA, Healthy-eating Attitudes; TIUH, Theory of Internet Use related to Health; y, years.
*p < 0.05, **p < 0.001.

higher scores were in line concerning fruit and vegetable, nuts, and olive oil components, while contrasting associations were found for others and no relation at all for legumes, sweets, and breakfast were retrieved (Table 5).

4 Discussion

In the present study, the role of parental psychosocial factors related to various aspects of diet and nutrition have been put in relation with their children’s lifestyle and eating habits, ultimately to test whether there was an association with higher adherence to the Mediterranean diet. The results obtained from this study are of particular interest: there were no clear trends between parental psychosocial factors and positive lifestyle and eating outcomes (resulting in mixed results in terms of significance and direction of the associations) but a consistent and strong relation between all psychosocial constructs investigated and higher adherence to the Mediterranean diet was found. Higher food literacy, tendency to seek health information, and beliefs were the constructs associated with the

highest number of individual dietary components of the KIDMED score. Recognising the pivotal role that family plays during the formative years of children’s development (46), this study examined how the key attributes of family (in particular parents) are associated with children’s adherence to the Mediterranean diet (46). We have referenced the COM-B model, a robust and comprehensive framework that offers a more holistic approach which considers a wide range of social and environmental influences on behavior taking into account the influence of both internal and external factors (22). Moreover, the COM-B model is dynamic in nature and it acknowledges the synergistic relationship among the three components studied (i.e., capability, opportunity and motivation) (22). More importantly, the COM-B model can provide actionable insights which are constructive for intervention design (22). As a result of its application, a strong association between parents’ food literacy, perceived barriers and enablers, healthy-eating attitude, and health consciousness, and their children’s adherence to the Mediterranean diet was found.

To contextualize our findings against the participants’ demography and uncover potential confounding factors, we also delved into characteristics such as the age, sex, education, income and living

TABLE 3 Association between parental food literacy (based on SFLQ score), perceived barriers and enablers (PBE score), healthy-eating attitudes (based on HEA score), and healthy-eating behavior (based on TIUH score) and adolescents' and children's lifestyle and eating habits.

	SFLQ	PBE	HEA	TIUH			
				Health Info	Consciousness	Orientation	Beliefs
Lifestyle habits							
BMI	0.072 (0.169)	−1.341 (0.359)**	0.225 (0.063)**	0.447 (0.069)**	0.073 (0.109)	0.551 (0.184)*	0.133 (0.166)
Sleep duration	0.504 (0.285)	−0.589 (0.641)	0.372 (0.106)**	−0.021 (0.117)	0.413 (0.184)*	0.593 (0.311)	0.979 (0.281)**
Screen time	−0.168 (0.198)	−1.088 (0.430)*	0.095 (0.073)	0.263 (0.081)**	−0.013 (0.127)	−0.093 (0.216)	−0.002 (0.195)
Physical activity level	0.777 (0.148)**	0.623 (0.341)	0.018 (0.055)	0.03 (0.061)	0.280 (0.095)*	0.187 (0.161)	0.431 (0.146)*
Eating habits							
Breakfast	0.150 (0.178)	1.691 (0.424)**	0.008 (0.064)	−0.323 (0.067)**	0.328 (0.112)*	−0.069 (0.185)	0.711 (0.209)**
Eating with family	0.376 (0.269)	0.513 (0.634)	−0.009 (0.097)	−0.327 (0.101)**	0.330 (0.169)*	0.379 (0.280)	1.034 (0.315)**
Eating alone	0.293 (0.196)	−1.369 (0.486)*	0.173 (0.070)*	0.402 (0.074)**	−0.226 (0.123)	0.170 (0.204)	−0.718 (0.230)*
Eating at school	0.020 (0.139)	−0.729 (0.359)*	0.077 (0.050)	0.237 (0.052)**	−0.066 (0.087)	0.192 (0.144)	−0.194 (0.163)
Eating home-made foods	0.647 (0.174)**	1.305 (0.439)*	−0.128 (0.063)*	−0.403 (0.065)**	0.215 (0.110)*	−0.316 (0.181)	1.394 (0.204)**

KIDMED, Quality Index for Children and Adolescents, SFLQ, Short Food Literacy Questionnaire; PBE, Perceived Barriers and Enablers; HEA, Healthy-eating Attitudes; TIUH, Theory of Internet Use related to Health. * $p < 0.05$, ** $p < 0.001$.

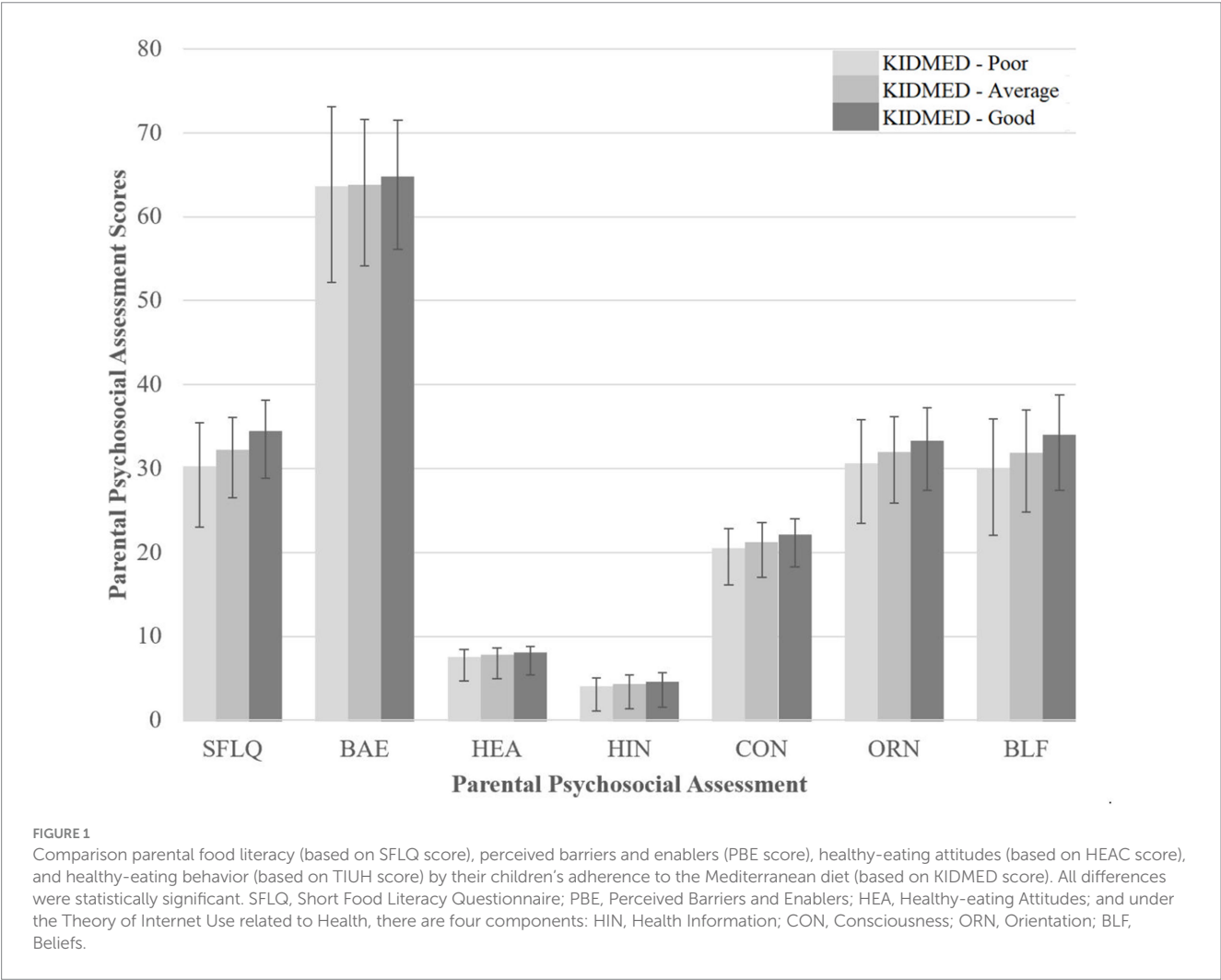


TABLE 4 (PBE score), healthy-eating attitudes (based on HEA score), and healthy-eating behavior (based on TIUH score) and their children’s adherence to the Mediterranean diet (based on KIDMED score).

	Adherence to Mediterranean diet, beta (SE)						
	SFLQ	PBE	HEA	TIUH			
				Health Info	Consciousness	Orientation	Beliefs
Model 1	0.102 (0.009)**	0.023 (0.008)*	0.089 (0.025)**	0.064 (0.023)*	0.101 (0.014)**	0.058 (0.009)**	0.071 (0.007)**
Model 2	0.090 (0.010)**	0.021 (0.008)*	0.106 (0.027)**	0.089 (0.025)**	0.108 (0.016)**	0.067 (0.009)**	0.075 (0.010)**
Model 3	0.090 (0.010)**	0.018 (0.008)*	0.115 (0.027)**	0.125 (0.025)**	0.100 (0.015)**	0.068 (0.009)**	0.071 (0.01)**
Model 4	0.072 (0.011)**	0.028 (0.009)*	0.086 (0.030)*	0.070 (0.029)*	0.090 (0.017)**	0.055 (0.01)**	0.059 (0.011)**

KIDMED, Quality Index for Children and Adolescents; SFLQ, Short Food Literacy Questionnaire; PBE, Perceived Barriers and Enablers; HEA, Healthy-eating Attitudes; TIUH, Theory of Internet Use related to Health. Model 1, unadjusted. Model 2, adjusted for children’s and adolescents’ age, gender, weight status, physical activity, sleep duration, and screen time. Model 3, adjusted for variables in model 2 + breakfast frequency, eating with family, eating alone, eating at school, eating home-made foods. Model 4, adjusted for variables in model 3 + parents’ age, gender, education, income, family status, and area of living. * $p < 0.05$, ** $p < 0.001$.

TABLE 5 Associations between parental food literacy (based on SFLQ score), perceived barriers and enablers (PBE score), healthy-eating attitudes (based on HEA score), and healthy-eating behavior (based on TIUH score) and their children’s adequacy to individual component of the KIDMED score.

	Individual components of the KIDMED, beta (SE) ^a						
	SFLQ	PBE	HEA	TIUH			
				Health Info	Consciousness	Orientation	Beliefs
Fruit, 1 serv/d	1.288 (0.556)*	1.874 (1.569)	0.275 (0.207)	−0.074 (0.221)	−0.193 (0.365)	0.258 (0.591)	0.691 (0.673)
Fruit, 2 serv/d	0.302 (0.254)	−0.909 (0.654)	−0.029 (0.095)	0.292 (0.101)*	0.073 (0.167)	0.195 (0.27)	0.534 (0.308)
Vegetables, 1 serv/d	−0.169 (0.481)	−2.250 (1.225)	0.014 (0.179)	0.364 (0.191)	0.105 (0.315)	0.729 (0.511)	−0.694 (0.582)
Vegetables, 2 serv/d	1.476 (0.248)**	1.029 (0.649)	0.289 (0.092)*	0.178 (0.098)	0.577 (0.162)**	0.963 (0.263)**	0.465 (0.30)
Fish, 2–3 serv/w	0.948 (0.239)**	2.048 (0.616)**	0.025 (0.089)	−0.221 (0.095)*	0.186 (0.157)	−0.130 (0.254)	1.800 (0.290)**
Meat, 1 serv/w	0.238 (0.233)	0.327 (0.587)	0.445 (0.087)**	0.349 (0.093)**	0.358 (0.153)*	1.008 (0.248)**	−0.688 (0.282)*
Legumes, 1 serv/w	−0.350 (0.244)	0.210 (0.633)	0.008 (0.091)	−0.159 (0.097)	0.067 (0.160)	−0.228 (0.259)	0.332 (0.295)
Pasta, 5 serv/w	−0.816 (0.726)	−4.803 (1.782)*	0.147 (0.270)	0.872 (0.289)*	−0.192 (0.476)	0.532 (0.772)	−1.105 (0.878)
Cereals or grains for breakfast	0.278 (0.281)	−0.004 (0.807)	−0.105 (0.104)	0.208 (0.112)	0.077 (0.184)	0.578 (0.298)	−0.761 (0.340)**
Nuts, 2–3 serv/w	1.242 (0.258)**	−0.223 (0.649)	0.138 (0.096)	0.379 (0.103)**	0.519 (0.169)*	1.085 (0.275)**	0.297 (0.313)
Olive oil consumption	2.124 (0.570)**	1.962 (1.652)	0.321 (0.212)	0.483 (0.227)*	0.882 (0.374)*	0.756 (0.606)	4.214 (0.690)**
Skipping breakfast	0.600 (0.602)	−1.251 (1.771)	0.074 (0.224)	0.177 (0.239)	0.315 (0.395)	−0.113 (0.64)	−0.152 (0.729)
Milk or yogurt for breakfast	0.009 (0.257)	4.079 (0.648)**	−0.176 (0.096)	−0.858 (0.102)**	0.363 (0.169)*	−0.343 (0.273)	1.916 (0.311)**
Cakes or pastries for breakfast	−0.869 (0.621)	2.906 (1.596)	0.098 (0.231)	−0.84 (0.247)**	−0.299 (0.407)	−0.871 (0.66)	0.053 (0.751)
Dairy, 2–3 serv/d	1.093 (0.298)**	−1.858 (0.931)*	0.149 (0.111)	0.425 (0.118)**	0.320 (0.195)	1.003 (0.317)*	1.178 (0.36)**
Sweets, several serv/d	−0.884 (0.648)	3.149 (2.026)	−0.149 (0.241)	0.119 (0.258)	−0.422 (0.425)	−0.508 (0.689)	−1.305 (0.784)

SFLQ, Short Food Literacy Questionnaire; PBE, Perceived Barriers and Enablers; HEA, Healthy-eating Attitudes; TIUH, Theory of Internet Use related to Health. * $p < 0.05$; ** $p < 0.001$.
^aLinear regression analyses adjusted for all components of the KIDMED score.

arrangements of parents. Considering such factors, younger mothers with higher education and family income have fared better in terms of food literacy, healthy-eating attitude and health consciousness, and their children displayed higher adherence to the Mediterranean diet. Such a profile has been commonly described in previous studies and

demonstrated the importance of parental influence in cultivating healthy-eating behavior of young children also in Mediterranean countries (47). There is consistent evidence from the scientific literature relating parents’ education to higher adherence to the Mediterranean diet (48). This finding translates to more specific

evidence associating food and nutrition literacy with higher likelihood of adopting a Mediterranean diet, as reported in several studies conducted in Mediterranean countries (49–53). Parents who have the knowledge on the Mediterranean diet and its health benefits will be able to appreciate why their children should adopt the Mediterranean diet and what constitutes a Mediterranean diet. Conversely, failing to understand the effects of diet on health (often perceived as a short-term gain rather than a long-term determinant of health) may lead to an underappreciation of adoption of healthy dietary patterns per se as well as being translated to their children. From the socio-economical point of view, some behavioral constructs significantly differ by parental family income, which are knowingly associated with children's dietary adherence (54, 55). The relative ease of access of healthy or unhealthy foods, including the availability or the convenience, have also been shown to strongly influence dietary choices and level of adherence to the Mediterranean diet (56).

While previous studies have established an association between various psychosocial factors and dietary adherence, the underlying mechanism remains unclear till date (19). Dietary adherence is a manifestation of human behavior: the cultivation or modification of a human behavior involves a complex confluence of theories from various disciplines, including psychology, sociology, public health and behavioral economics (57). Perceived barriers and enablers have been widely investigated in nutrition science (58). They both play a role in favor or against a trigger for change (22). Children are often nudged and motivated by environmental cues (overt and/or covert) that often come from their parents (59). Hence, parents' healthy-eating attitude (e.g., opinion on children's vegetable and fruit intake) and health consciousness (e.g., belief that a healthy diet is the key to disease prevention), which are reflected through words and actions, have a huge influence on children's dietary choices. From our study findings, we recognise that it is possible to cultivate a behavior (i.e., an adherence to diet) in the presence of the requisite capability (i.e., food literacy), opportunity (i.e., perceived enablers and barriers), and motivation (i.e., healthy-eating attitudes and health consciousness). Every component is critical and they work hand-in-hand to effect a change. The value of the findings shown in the present study relies on the consistent significance of the results across each domain investigated, suggesting the validity of the hypothesis that all components of the COM-B model are implicated when exploring the psychological reasons behind dietary choices (and more specifically in this case, adoption of a Mediterranean diet).

The results presented in this study further investigated also the association between parents' psychosocial factors with their children's lifestyle and eating behaviors, revealing that most constructs also predicted overall healthier habits, although not unequivocally. Specifically, while nutrition knowledge and recognizing barriers and enablers showed consistent relations with BMI and physical activity, other constructs, such as attitudes and seeking health information on the internet were negatively related with BMI, sleep duration, and other eating habits. While the contrasting findings may underline heterogeneous relations, the retrieved results further reinforce the associations accounted for psychosocial factors and adherence to the Mediterranean diet, as those not significant or even resulting in counterintuitive directions are evidently not acting as confounding factors. Other studies fostered evidence for such relations, for instance concerning parents' nutrition knowledge and children's physical activity levels (60). Besides, the inconsistency of results concerning

those retrieved in relation to seeking information on the internet may be explained by lack or paucity of official portals to retrieved reliable information or, in contrast, exposure to excessive unreliable sources of information, a common well-known issue encountered in other fields, such as vaccination (61).

From a public health perspective, the findings from this study suggest that future studies could include public health nutrition policies leveraging on theoretical framework models, such as the COM-B. Firstly, information should be made more accessible to build capability. Food literacy is a fundamental element as it provides the rationale (i.e., why is a change needed) and roadmap (i.e., how can a change be brought about) for the change (62). For this reason, in Europe, interest in evaluating food literacy within the context of public health has grown, as monitoring this factor can help support professional and policy decisions aimed at improving the well-being of the population (49). Future studies could involve the maternity wards in hospitals and childcare facilities, which are the early touchpoints for young parents, to kickstart education on early feeding practices. Secondly, public infrastructure could be involved to address perceived barriers in order to create opportunity. This may manifest in the form of improving availability, accessibility and affordability of healthy foods. Governments could work with food suppliers (i.e., independent grocers and major supermarket chains) to ensure that healthy food items are well-stocked, physical stores are located at major residential districts, and delivery options are available. In addition, a time-limited subsidy on healthy food items for the lower-income families could also serve as a financial incentive to smoothen the transition. One other hurdle is cultural norms: more effort should be devoted to formulate healthier recipes that respect and preserve the flavors of the local cuisine (i.e., use healthier substitutes – replacing sugar with honey, and high-caloric sauces with herbs). Finally, more environmental cues could be introduced to increase motivation. Public health organizations can consider holding roadshows or campaigns to socialize the population to the concept of healthy eating. Ultimately, the cornerstone of a successful policy is achieving the goal in a palatable and sustainable manner. However, a healthy lifestyle goes beyond diet, it also includes an adequate amount of physical activity. Building on the present study, future studies could examine the factors influencing the level of physical activity in children. Put together, the findings from these two studies have the potential to guide the formulation of an early intervention to elevate the nutritional profile of the children in a sustainable manner.

The findings of this study should be considered in light of its strengths and limitations. This study was conducted in five different countries bordering the Mediterranean Sea. It encompasses representations from South-Western Europe (i.e., Portugal, Spain and Italy), Western Asia (i.e., Lebanon) and North Africa (i.e., Egypt) – the three major coastal regions that demarcate the Mediterranean. Although previous studies have been conducted in these countries, the results shown in the present report are directly multinational in nature sharing the same methodology. This study provides a comprehensive understanding of the factors affecting dietary adherence in the Mediterranean diet taking into account the cultural, economic, and political differences in the three coastal regions. Apart from the good geographical spread, the large sample size also lends greater credibility to the findings of this study. There are also some limitations in this study that are worth mentioning. First, this is a cross-sectional study and therefore its findings cannot be used to establish causality for the

associations that are found to be significant. Second, the sample was recruited on a voluntary basis, hence it cannot be considered fully representative of the population although the number of participants is comparable to other studies exploring similar topics. Third, the self-reported data from this study collected through surveys and questionnaires has its inherent limitations. For instance, there may be social desirability bias and memory bias. Also self-rated assessment of psychological factors may be affected by similar limitations. Apart from these biases, which are hard to detect and neutralize, there are genuine clerical errors from self-reporting that renders the response invalid, thereby reducing the sample size. Fourth, data accuracy may also be compromised, referencing KIDMED responses provided by parents. Fifth, there is also a need to recognise and better understand the impact of the wider environment (i.e., extra-familial) on the nutritional status of children, which is not covered in the present study. Such factors include school education, peers and media influences and public infrastructure.

In conclusion, this study has fortified and provided greater clarity to the understanding of parental influence on children's dietary choices and eventual adherence to the Mediterranean diet. Our results showed a strong positive association among parental food literacy, perceived enablers and barriers to healthy-eating, health-eating attitude, and their children's adherence to the Mediterranean diet. Investigating the role of family environment, including knowledge, attitudes, and barriers in influencing dietary adherence can also inform more targeted interventions. Studies that delve into the psychological aspects of eating behaviors, including the influence of peer pressure and social media, can provide a more comprehensive understanding of the factors driving dietary choices among young populations. However, studies with an intervention design are needed to properly assess causation of influence of parental psychosocial factors and children's dietary adherence. The interventions should promote healthy traditional dietary patterns and act on modifiable determinants of adherence, but aiming at improving parents' nutritional expertise could be crucial to affect their children's future dietary choices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, upon reasonable request.

Ethics statement

The studies involving humans were approved by Institutional review board of Mondragon University (protocol code no. IEB-20230704, approval date 4 July 2023). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SC: Conceptualization, Formal analysis, Supervision, Visualization, Writing – original draft. WRC: Conceptualization, Formal analysis, Methodology, Visualization, Writing – review & editing. AR: Formal

analysis, Visualization, Writing – original draft. TAM: Writing – review & editing. FS: Writing – original draft. FG: Writing – original draft. EF-T: Visualization, Writing – review & editing. OA: Funding acquisition, Writing – review & editing. MA: Writing – review & editing. AA: Writing – review & editing. JP: Funding acquisition, Project administration, Writing – review & editing. LV-A: Funding acquisition, Writing – review & editing. FML: Writing – review & editing. LM: Writing – review & editing. AS: Writing – review & editing. ND: Writing – review & editing. AM: Data curation, Resources, Writing – review & editing. AC: Data curation, Resources, Writing – review & editing. PB: Data curation, Funding acquisition, Methodology, Resources, Writing – review & editing. GG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Resources, Supervision, Writing – original draft.

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How does sugar-sweetened beverage consumption relate to sleep and mental health in adolescents? A scoping review

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Introduction: Over the last years, adolescents have exhibited high consumption of sugar-sweetened beverages (SSBs). During this developmental stage, characterized by profound biological and psychosocial changes, individuals are more susceptible to sleep disturbances, as well as psychological, behavioral, and emotional difficulties. The present scoping review aims to offer insights into how SSBs consumption relates to sleep and mental health outcomes in adolescents.

Methods: A systematic search and selection process was conducted across four electronic databases. Studies, published in peer-reviewed international scientific journals up to April 2025, in English, and examining the relation between SSBs, sleep, and mental health in adolescents were considered eligible.

Results: The search identified 288 references after duplicate removal. Based on PCC framework, 57 studies were included. Slightly fewer studies investigated the association between SSBs consumption and sleep outcomes ($n = 25$), compared with those focusing on mental health outcomes ($n = 32$). Evidence suggests a potential link between SSBs consumption, sleep, and mental health, indicating that higher intake may be associated with increased sleep disturbances and mental health problems.

Discussion: Overall, the results of this review advance the hypothesis of a possible bidirectional relationship between SSBs consumption and both adverse sleep and mental health outcomes. These findings should be interpreted with caution, due to the main gaps identified. The current evidence calls for future studies that use interventional and longitudinal designs, focus on adolescence, target regions with rising SSBs consumption and sleep or mental health issues, analyze SSBs subgroups separately, and address all sleep dimensions. This review also highlights the need for tailored public health intervention strategies that address all lifestyle domains relevant to adolescent health.

Scoping review registration: <https://osf.io/kzu7y/overviewn>, DOI: 10.17605/OSF.IO/KZU7Y.

KEYWORDS

adolescents, diet, food intake, mental health, sleep, sugar-sweetened beverages

1 Introduction

Sugar-sweetened beverages (SSBs) are defined as a broad category of drinks containing free sugars, such as soft drinks, certain fruit juices, energy drinks (EDs), and some caffeinated beverages (1).

Children and adolescents exhibit the highest consumption of SSBs across population groups (2), with these beverages representing the predominant source of free sugars in their diet (3, 4).

The widespread use of SSBs in childhood has been recognized as a major public health concern worldwide (5) and has been targeted through national and international policies and strategies aimed at counteracting its spread (1). Consistently, several nutritional guidelines advise a limited consumption of SSBs in pediatric age (6, 7), in line with the World Health Organization (WHO) recommendation to reduce free sugars to less than 10% of total energy intake across the life course to prevent obesity, its complications, and dental caries (8).

Nevertheless, a recent population-based study including 185 countries reported a 23% increase (0.68 servings per week) in SSBs consumption among children and adolescents from 1990 to 2018. Higher intakes were observed in older versus younger participants, those resident in urban versus rural areas, and those with parents of higher versus lower educational attainment, highlighting the need to address the determinants of SSBs consumption especially in adolescents and socially vulnerable groups (2).

A variety of factors encompassing economic, individual, behavioral, and environmental drivers could explain this phenomenon (9). Evidence suggests that the accessibility and availability of SSBs, together with exposure to food advertising through media use, are associated with higher consumption. Parental modeling and peer influence also play key roles in determining adolescents' beverage choices (9, 10).

High consumption of SSBs significantly contributes to overall energy intake, promoting weight gain, and playing a central role in the childhood obesity epidemic and associated metabolic diseases (3, 11, 12). Consequently, most research on SSBs so far has focused on their impact on these conditions (3, 4, 13, 14). However, in recent years, a growing body of evidence indicates the relevance of additional pediatric health challenges, particularly in adolescence, including sleep problems and mental health issues (15, 16).

Epidemiological studies have revealed that sleep problems are highly prevalent among adolescents, affecting around 40% in Europe and Asia and about one-third of children and adolescents in the United States (17, 18). Although lower than the sleep problems, the Global Burden of Disease Study estimates a still concerning prevalence of about 13–14% for mental health disorders in adolescents, with depression and anxiety being the most common (16). These two conditions are closely interconnected and often influence each other. Systematic reviews and meta-analyses have shown that insufficient or poor-quality sleep is associated with an increased risk of depression, anxiety, and other emotional difficulties in adolescents (19, 20). Conversely, mental health problems, particularly internalizing disorders, can exacerbate sleep disturbances, suggesting a bidirectional relationship between these domains (21, 22).

Dietary habits can influence both sleep and mental health outcomes in adolescents, with unhealthy patterns being associated with poorer sleep quality and increased emotional difficulties (3, 23).

Among dietary factors, SSBs appear particularly relevant, as higher consumption has been linked to shorter sleep duration, lower sleep quality, and elevated risk of depressive and anxiety symptoms, thereby contributing significantly to the complex interplay between sleep and mental health outcomes (3, 24, 25).

Overall, the high prevalence of SSBs consumption in adolescents, together with their increased vulnerability to sleep and emotional regulation problems, underscores the need to examine the relationship between these factors specifically in this age group. Indeed, adolescence is characterized by profound neurobiological and psychosocial changes, including greater autonomy over dietary choices and a pubertal shift toward later sleep timing, which may amplify the potential effects of SSBs on both sleep and emotional regulation (26, 27). These issues need to be addressed separately from younger children to develop effective targeted prevention strategies.

Despite existing research, no study has yet provided a comprehensive overview of the mechanisms linking SSBs intake with sleep and mental health outcomes in this age group. This study therefore aims to fill this gap and offer insights into how SSBs consumption relate to these outcomes, by addressing the following research questions: (1) Is there an association between SSBs consumption and sleep and mental health outcomes in adolescents? (2) Does SSBs consumption affect sleep and mental health? Is the opposite also true? (3) What are the potential mechanisms underlying this relationship?

2 Materials and methods

A Scoping Review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping review (PRISMA-ScR) guidelines (28) to guide the search and identification process.

The protocol was registered in the Open Science Framework (OSF) database (registration DOI: [10.17605/OSF.IO/KZU7Y](https://doi.org/10.17605/OSF.IO/KZU7Y)).

2.1 Eligibility criteria

The PCC (Population, Concept, Context) framework followed to establish eligibility criteria is presented in Table 1. According to the WHO definition of adolescence (29), the age range of 10–19 years was selected as an inclusion criterion. Studies that analyzed the consumption of SSBs and its relationship with mental health and sleep-related outcomes were included. All types of SSBs (e.g., caffeinated drinks, energy drinks), and mental health and sleep-related outcomes were considered eligible.

No restrictions were applied to the setting and geographical context.

The criteria for excluding an article were: not targeted at adolescents, focused on the analysis of dietary patterns that included SSBs consumption (without analyzing individual food groups) and on health outcomes other than mental health and sleep, not published in peer-reviewed international scientific journals, not available in English.

TABLE 1 Population, concept, context (PCC) framework.

Parameter	Description
Population	<i>Inclusion:</i> Adolescents (10–19 years old)
	<i>Exclusion:</i> Children (<10 years old), adults (>19 years old), elderly (>70 years old)
Concept	<i>Inclusion:</i> SSBs consumption; Mental health outcomes; Sleep-related outcomes
	<i>Exclusion:</i> Dietary patterns that included SSBs consumption; Other health-related outcomes
Context	<i>Inclusion:</i> Every setting and geographical context
	<i>Exclusion:</i> None
Types of evidence sources	<i>Inclusion:</i> Observational studies (prospective cohort studies, cross-sectional studies and case-control studies) and RCTs, published in peer-reviewed international scientific journals up to April 2025, in English
	<i>Exclusion:</i> Studies not published in peer-reviewed international scientific journals, not in English

SSBs, Sugar-Sweetened Beverages; RCTs, Randomized Clinical Trials.

2.2 Search strategy

A literature search was performed using four electronic databases: MEDLINE (PubMed), Embase, Scopus, and Web of Science. Using relevant subject headings and free text search terms, the search strategy was based on the following keywords: ‘sugar-sweetened beverages’, ‘sugary beverages’, ‘sugary drinks’, ‘adolescent’, ‘teenager’, ‘youth’, which were used in combination with words relating to mental health and sleep outcomes, including ‘sleep hygiene’, ‘sleep quality’, ‘sleep duration’, ‘sleep disorders’, ‘mental health’, ‘psychological symptoms’, and their variants. The search strategies are available in [Supplementary Table S1](#).

2.3 Study selection

Two reviewers (A.D.N., E.C.) selected and screened the studies to be included in this review. Duplicate studies were removed using the software system Rayyan (30). No formal pilot testing was conducted. However, the screening criteria were discussed among the reviewers at a preliminary phase, in order to adjust the procedure. All identified articles were initially screened by title and abstract. The reviewers were blinded to each other’s decisions and disagreements between individual judgements were resolved by consensus. Applying the eligibility criteria, the articles were subsequently screened by full text, jointly by the reviewers. The software systems used for managing articles were Microsoft Excel 2016 and Mendeley (Mendeley Reference Manager v2.137.0, Elsevier, London, UK).

2.4 Data extraction

Data extraction was performed by two reviewers (A.D.N., E.C.) in parallel. Uncertainties were resolved by the reviewers through discussion.

The following data were extracted from each eligible paper, using a data extraction tool developed by reviewers: first author’s last name; year of publication; study design; country; number and age of participants; objective; and main results (adjusted for confounders, where possible).

Studies that included both children and adolescents, as well as those that classified individuals aged 18–19 years as adults, were considered to ensure that no adolescent-related findings were excluded. For the same reasons, papers that did not analyze data by age subgroups were also included. However, whenever possible, information on the size of the adolescent subsamples was extracted. Finally, studies that assessed SSBs consumption alongside other relevant dietary variables (e.g., fast-food consumption) and studies that examined the mediating role of SSBs in the relation between health outcomes of interest were included.

3 Results

The process of study selection is summarized in [Figure 1](#). A total of 433 articles were initially retrieved from four electronic databases. After removing 145 duplicate records, 288 articles remained for title and abstract screening, which led to 77 studies being selected for full-text screening. Of these, 20 articles were excluded for not meeting the inclusion criteria (see [Supplementary Table S2](#)), resulting in a final set of 57 studies included in this scoping review. Data extraction with key characteristics of these studies are presented in [Tables 2, 3](#). Most of the included studies had a cross-sectional design ($n = 48$), followed by cross-sectional and longitudinal ($n = 4$), longitudinal ($n = 3$), and the remaining two with an interventional study design.

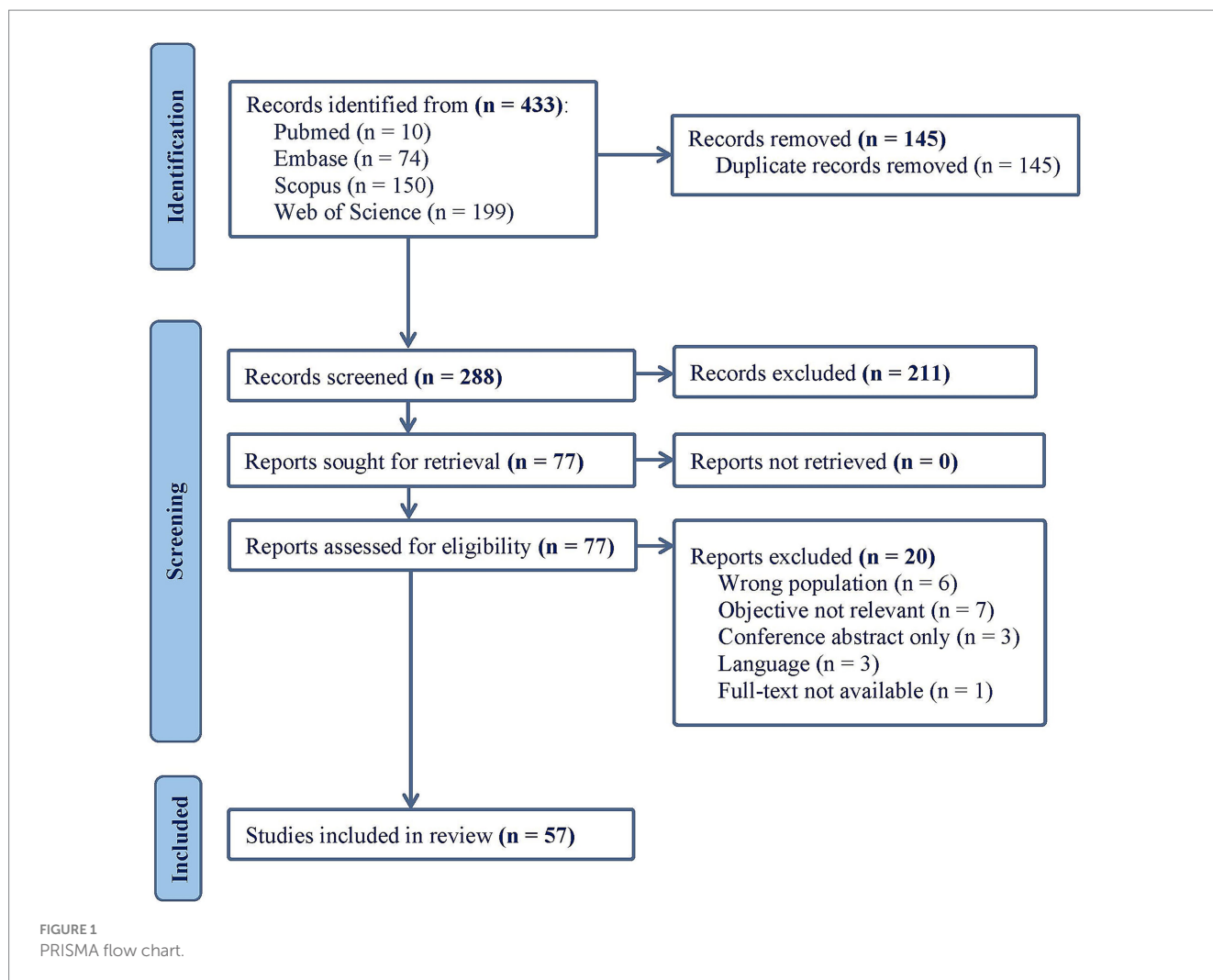
The age of participants in the studies included ranged from approximately 6–27 years, owing to the inclusion of both children and young adults in some cases.

Most of the articles ($n = 33$) were conducted in Asia, particularly in China ($n = 20$). The Americas contributed 15 studies, predominantly from the United States ($n = 9$), while fewer were reported from Oceania ($n = 5$) and Europe ($n = 3$). Additionally, one study was international, involving participants from 37 different countries.

Regarding health outcomes, slightly fewer studies investigated the association between SSBs consumption and sleep outcomes ($n = 25$) compared with those focusing on mental health outcomes ($n = 32$).

3.1 Sleep and sugar-sweetened beverage consumption

Overall, this scoping review included 25 studies on the relationship between sleep outcomes and SSBs. According to the RU-SATED model (31), sleep is recognized as a multidimensional construct characterized by six key dimensions, which were investigated across the included studies as follows: 16 on Sleep Duration (SD) (32–47), 1 on Sleep Efficiency (SE) (48), 2 on Sleep Timing (ST) (35, 49), 1 on Sleep Satisfaction (SS) (38), 4 on Sleep Regularity (SR) (45, 50–52), and 1 on Sleep-related daytime functioning (53). In addition, 5 studies assessed Sleep Quality (SQ) (33, 53–56), which reflects an overall evaluation across multiple sleep dimensions.



3.1.1 Sleep duration

Most of the studies examining the relationship between SSBs or EDs consumption and SD indicate that regular or higher consumption of these beverages is associated with shorter sleep, compared with the recommendations of the American Academy of Pediatrics (AAP), which advise 9–12 h of sleep for children and adolescents aged 6–12 years and 8–10 h for those older than 12 years (57). Particularly noteworthy for their large sample sizes are studies conducted by Min et al. (38) and Huang et al. (34), respectively in Korea and China. The Korean study reported that adolescents sleeping less than 6 h per night were more likely to consume soft drinks at least five times per week, with soda intake showing a clear upward trend in the short-sleep group (38). In addition, the Chinese study found that adolescents consuming SSBs 4–5 times per week or more than five times per week had markedly higher odds of insufficient sleep compared with those consuming them less frequently (34).

EDs and sugar sweetened soda were also linked to insufficient sleep (32, 40, 41, 44, 46), with students not meeting sleep recommendations showing increased odds of regular consumption compared to peers with adequate sleep (46).

Highlighting the importance of moderating SSBs consumption to support healthy sleep patterns, the only interventional study—a community-based program targeting SSBs intake and sleep

outcomes—reported increased SD and higher odds of adequate sleep after 2 months (39). However, the intervention effect was not maintained at 6 months (39). On the other hand, a longitudinal study examining the effects of high school start time delays—a proven sleep-promoting intervention—found small but significant decrease in caffeinated SSBs consumption between baseline and the second follow-up period (after 2 years) in students attending the policy-change schools, with no changes observed for total SSBs intake relative to comparison schools (43).

In contrast with the majority of findings, Liu et al. (36) reported that overall snack consumption, including SSBs, was lower among slightly short sleepers and severely short sleepers compared with those with moderate sleep. Moreover, when specifically considering the consumption of SSBs at least once per day, no significant differences were observed across SD groups. Nonetheless, the authors also reported that children aged 6–17 years with severely short sleep were more likely to select SSBs as snacks (8.7%) and consumed them more frequently, averaging 204.7 g during the day and 26.7 g at night. The cross-sectional studies by Watts et al. (2018) (42) and Boozari et al. (2021) (24) reported no statistically significant associations. In Watts et al. (2018) (42), individual regression analyses initially indicated that longer SD was associated with lower SSBs consumption. However, this association was no longer significant in

TABLE 2 Characteristics of the studies addressing sleep that were included in the review.

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
Asia	Almulla A. et al. (2020) (32)	Multi-center cross-sectional	United Arab Emirates	1,611 10–18 y (13.5 $\pm$ 2.3)	To investigate the prevalence of EDs consumption and its relationship with socio-demographic characteristics, eating habits, BMI, SD, PA, and ST.	EDs consumers were less likely to meet sleep duration recommendation (39% vs. 61%, $p < 0.001$). Students not meeting sleep recommendation duration were 1.5 times more likely to consume EDs (AOR = 1.47; 95% CI: 1.14, 1.89; $p = 0.003$).
	Boozari B. et al. (2021) (33)	Cross-sectional	Iran	395 18–43 y (22.8 $\pm$ 3.9) ≤ 23 y: 261 (66.08%) >23 y: 134 (33.92%)	To evaluate the relationship between SD and SQ with sugar and SSBs intake.	Short sleepers (<6 h/day) had higher consumption of SSBs intake (86.54 vs. 65.73 g/day; $p = 0.05$) in comparison with those who had more than 8 h/day of sleep. Poor quality sleepers had significantly higher intake of SSBs compared with those with good quality of sleeping (87.09 vs. 56.73 g/day; $p = 0.004$). No significant correlation was found between SD and SSBs intake. SQ score was positively correlated with SSBs intake (rp:0.14, $p = 0.007$) in whole population. Similar results were found in younger individuals (rp:0.27, $p = 0.002$) and non-obese participants (rp:0.14, $p = 0.006$).
	Gan W. et al. (2019) (54)	Cross-sectional	Malaysia	421 12–16 y (13.3 $\pm$ 1.3)	To assess the associations of lifestyle and socio-environmental factors, and body weight status with consumption of SSBs.	Simple linear regression showed that poorer SQ ($\beta = 0.196$; $p < 0.001$) was associated with higher SSBs intake. This association remained significant in multiple linear regression ($\beta = 0.228$; $p < 0.001$).
	Huang Z. et al. (2025) (34)	Cross-sectional	China	186,723 6–18 y 6–12 y (1st–6th grade): 86,254 (46.19%) 12–15 y (7th–9th grade): 57,938 (31.03%) 15–18 y (10th–12th grade): 42,531 (22.78%)	To investigate sleep status and its association with dietary habits.	The univariable analysis revealed that times of SSBs consumption per week were significantly associated with the sleep status ($X^2 = 16.322$; $p < 0.001$). Results of multivariable logistic regression analysis showed that who consumed SSBs 4 ~ 5 times/week (OR = 2.066; 95% CI: 1.903–2.243) or >5 times/week (OR = 2.021; 95% CI: 1.838–2.223) had significantly higher odds of insufficient sleep compared to those with SSBs consumption <4 times/week ($p < 0.001$).
	Li W. et al. (2018) (35)	Cross-sectional	China	788 19.8 $\pm$ 1.1 y 18–19 y (grade 1): 212 (26.9%) 19–20 y (grade 2): 255 (32.4%) 20–21 y (grade 3): 321 (40.7%)	To explore the key mediating role of SSBs consumption in the association among SD, late chronotype, and weight gain.	The significant indirect effect of SSBs consumption was found between chronotype and BMI (effect = -0.03 , SE = 0.01, 95% CI [-0.05 , -0.02]) and between SD and BMI (effect = -0.12 , SE = 0.05, 95% CI [-0.16 , -0.09]). In addition, physical exercise and psychological condition also play mediating effects between chronotype and BMI (effect = -0.04 , SE = 0.01, 95% CI [-0.06 , -0.01] and effect = -0.03 , SE = 0.02, 95% CI [-0.05 , -0.01]), but their mediating effect was not found between SD and BMI.
	Liu A. et al. (2022) (36)	Cross-sectional	China	5,254 6–17 y 6–12 y: 3,573 (68.01%) 13–17 y: 1,681 (31.99%)	To explore the associations of short sleep with breakfast and snacking behaviors.	53.2% of children and adolescents consumed snacks (including SSBs), which was lower among participants with slightly short sleep (OR = 0.78; 95% CI: 0.68, 0.89) and severely short sleep (OR = 0.63; 95% CI: 0.49, 0.82) compared to those with moderate sleep after adjusting for the influence factors. The rate of consuming snacks at least once per day was 28.3%, and no significant difference among the three sleep groups was found. Among children and adolescents with severely short sleep, 8.7% choosed SSBs as snacks (204.7 g/day and 26.7 g/night).

(Continued)

TABLE 2 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
	Ma L. et al. (2021) (37)	Cross-sectional and Longitudinal	China	3,298 6.5–17.5 y (11.5 $\pm$ 2.0) 6.5–12 y (1st–6th grade): 1,819 (55.2%) 12–17.5 y (7th–11th grade): 1,479 (44.8%) 1,691 6.5–16 y (11.2 $\pm$ 1.9)	To examine correlates of sleep and assess its associations with weight status and related behaviors.	Longer sleep was longitudinally associated with less SSBs intake (β = -0.12 ; 95% CI: -0.20 , -0.03) after adjusting for covariates, such as age and sex. Sex-stratified analysis found longer SD to be associated with less SSBs consumption (β = -0.15 ; 95% CI: -0.28 , -0.02) in boys.
	Min C. et al. (2018) (38)	Cross-sectional	Korea	118,462 12–18 y (15 $\pm$ 1.7)	To identify the associations between SD, SQ, and food intake.	Short SD (<6 h) were associated with a higher intake of soft drinks for ≥ 5 times a week (AOR = 1.73; 95% CI: 1.57, 1.91; p < 0.001). Soda intake showed an increasing trend in the group getting <6 h of sleep. Poor SQ was related with a higher intake of soda and soft drink for ≥ 5 times a week (AOR = 1.55; 95% CI: 1.40, 1.70 and AOR = 1.58; 95% CI: 1.43, 1.73 respectively; p < 0.001).
America	Cetiner O. et al. (2021) (50)	Cross-sectional	United States	1,556 12–17 y (14 (IQR: 13–16) in no SJL group, 14 (IQR: 13–16) in mild SJL group, 15 (IQR: 13–16) in severe SJL group)	To determine the association between SJL, and the frequency of consumption of multiple food and beverage groups and BMI percentile.	The median frequency of consumption of SSBs (per serving) was higher in the severe SJL (>2 h) group compared with the no SJL (<1 h) and mild SJL (1–2 h) groups (median 1.0 vs. 0.87 and 0.87; p < 0.001). Total sugar consumption and sugar consumption from SSBs (tsp) were higher in the severe SJL group (with a median value of 15.46 tsp. for total sugar, p = 0.004; and 5.34 tsp. for sugar from SSBs, p < 0.001) than in the no SJL and mild SJL groups (median total sugar consumption was 14.62 tsp. and 14.06 tsp. in the no SJL and mild SJL groups, respectively; and, median sugar consumption from SSBs was 4.2 tsp. in the no SJL and mild SJL groups).
	Egan K. A. et al. (2022) (39)	Pilot-site randomized trial	United States	100 9–12 y (10.1 $\pm$ 1.0)	To examine temporal associations between participation in a community-based intervention targeting sugary drink intake and sleep outcomes.	The intervention was associated with increased SD (b = 0.74; 95% CI: 0.03–1.45; p = 0.04) and higher odds of adequate sleep (OR = 2.47; 95% CI: 1.06–5.74; p = 0.04) at 2 months. Sleep did not differ by treatment condition at 6 months.
	Ievers-Landis C. E. et al. (2016) (51)	Cross-sectional	United States	315 13–18 y (14.5 $\pm$ 1.35)	To examine associations of SD and regularity with dietary intake and eating-related cognitions among adolescents with overweight and obesity.	Staying up (i.e., bedtime shift) (beta estimate = 0.23, p = 0.006) and sleeping in later (i.e., wake-time shift) (beta estimate = 0.59, p = 0.02) on weekends compared with weekdays significantly relates to drinking more SSBs, the latter for males.
	Lima R. J. C. P. et al. (2023) (53)	Cross-sectional	Brazil	2,515 18–19 y	To analyze the association between modifiable behavioral risk factors for NCDs and SQ and EDS, considering overweight as a mediator of these pathways.	The main modifiable behavioral risk factors for NCDs (physical inactivity, alcohol consumption, SSBs consumption, socioeconomic status) are associated with worse sleep indicators in adolescents, such as poor sleep quality and excessive daytime sleepiness, and are independent of overweight. Higher consumption of SSBs was associated with EDS (SC = 0.128; p < 0.001) and poor SQ (SC = 0.089; p = 0.003). Overweight was neither a mediator nor associated with SQ or EDS.

(Continued)

TABLE 2 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
	Park S. et al. (2012) (40)	Cross-sectional	United States	16,188 14–18 y (9th–12th grade)	To examine the association of demographic characteristics, weight status, self-reported academic grades, and behavioral factors with sugar-sweetened soda intake.	The percentage of students who drank sugar-sweetened soda at least 1 time/day was higher among those who had <8 h of sleep on an average school night ($p = 0.004$). Sleeping <8 h on an average school night was significantly associated with sugar-sweetened soda intake at least 1 time/day during the past 7 days (OR = 1.18; 95% CI: 1.08–1.29).
	Sampasa-Kanyinga H. et al. (2018) (41)	Cross-sectional	Canada	9,473 11–20 y (15.2 ± 1.8) 11–13 y: 2,084 (22.0%) 14–17 y: 6,489 (68.5%) 18–20 y: 900 (9.5%)	To examine the relationship between SD and consumption of SSBs and EDs.	After adjusting for covariates, short SD was associated with greater odds of consuming SSBs in middle school students (OR = 1.64; 95% CI = 1.21, 2.24) but not those in high school (OR = 1.06; 95% CI = 0.86, 1.31). Short SD was associated with greater odds of EDs consumption in both middle (OR = 1.60; 95% CI = 1.10, 2.34) and high school (OR = 1.78; 95% CI = 1.38, 2.30) students after adjusting for sociodemographic factors. Although boys were more likely than girls to consume SSBs and EDs, the relationship between SD with consumption of SSBs and EDs did not differ by sex.
	Vézina-Im L. A. et al. (2024) (48)	Cross-sectional	Canada	218 14–17 y (15.3 ± 1.1)	To verify if the consumption of different beverages (e.g., water, 100% pure fruit juice, and SSBs) is associated with SQ.	The total water ($rs = 0.09$; $p = 0.1630$), 100% pure fruit juice ($rs = 0.07$; $p = 0.2910$), and SSBs ($rs = -0.09$; $p = 0.1755$) consumption levels were not significantly correlated with SQ in adolescents. Among caffeinated SSBs, EDs ($rs = -0.16$; $p = 0.0197$) and sugar-sweetened coffee ($rs = -0.33$; $p < 0.0001$) intake was correlated with adolescents' SQ. EDs consumption ($\beta = -0.0048$; $p = 0.0005$) and being male ($\beta = 0.6033$; $p < 0.0001$) were associated with adolescents' SQ. There was an interaction between sugar-sweetened coffee intake and biological sex that was associated with adolescents' SQ ($p = 0.0053$). Sugar-sweetened coffee consumption was correlated with adolescent girls' abilities to go to bed ($rs = -0.21$; $p = 0.0203$) and fall asleep ($rs = -0.28$; $p = 0.0020$), while in boys, it was only significantly correlated with their abilities to go to bed ($rs = -0.27$; $p = 0.0069$).
	Watts A. W. et al. (2018) (42)	Cross-sectional	United States	2,793 14.4 $\pm$ 2.0 y	To identify the most important factors within the personal, family/home, peer, school, neighborhood, and media contexts associated with SSBs intake, and to determine their contribution in explaining SSBs intake.	Results of individual regression analyses showed that more hours of sleep were associated with lower SSBs consumption ($\beta = -0.07$; SE = 0.02; $p < 0.001$). However, in the mutually adjusted model the association was no longer statistically significant.

(Continued)

TABLE 2 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
	Weiss A. J. et al. (2023) (43)	Longitudinal with natural experiment design	United States	Baseline (Complete sample): 2,134 14–15 y (15.2 $\pm$ 0.3) (9th grade) Baseline (Policy sample): 1,267 14–15 y (15.1 $\pm$ 0.3) (9th grade) Baseline (Control schools): 867 14–15 y (15.2 $\pm$ 0.4) (9th grade)	To examine the effects of high school start time delay, a proven sleep-promoting intervention, on SSBs consumption	Mean baseline SSBs consumption was 0.9 ($\pm$ 1.5) beverages/day in policy change schools and 1.2 ($\pm$ 1.7) beverages/day in comparison schools. No evidence of impact of start time change on total SB consumption. Difference-in-difference estimates revealed a small decrease in the number of caffeinated SSBs consumed between baseline and the second follow-up period (after 2 y) in students attending the policy change schools relative to comparison schools in both crude ($-0.11/\text{day}$ ($-0.2165, -0.0011$), $p = 0.048$) and adjusted analyses ($-0.11/\text{day}$ ($-0.2001, -0.0112$), $p = 0.028$).
	Widome R. et al. (2019) (44)	Cross-sectional	United States	2,134 14–15 y (9th grade)	To assess how self-reported SD on school nights was associated with weight-related behaviors (eating, diet, and physical activity) and overweight/obesity.	Shorter SD was associated with more frequent consumption of sugar-sweetened, diet, caffeinated, and sports/energy beverages ($p < 0.0001$ for all items, in both unadjusted and adjusted models).
	Zhang K. et al. (2022) (52)	Cross-sectional	Canada	1,031 13–18 y (15.1 $\pm$ 0.7)	To assess whether greater SJL is associated with higher SSBs consumption in adolescents, and whether associations are stronger in one gender.	The odds of any SSBs intake were significantly higher in adolescents with SJL between 1 and 2 h (OR: 1.65; 95% CI: 1.14, 2.38) and over 2 h (OR: 1.87; 95% CI: 1.11, 3.14), compared with 1 h or less; associations were stronger and only significant in girls. Girls with over 2 h of SJL had almost twice the odds of drinking any SSBs (OR: 1.97; 95% CI: 1.06, 3.66), compared with girls with ≤ 1 h of SJL.
Europe	Kjeldsen J. S. et al. (2014) (45)	Cross-sectional	Denmark	676 8–11 y	To investigate association between objectively measured SD as well as parent-reported sleep problems and dietary risk factors for overweight and obesity.	SD was negatively associated with energy density (ED) of the diet (kJ/g) (β (95% CI) = -0.32 (0.54–0.11), $p = 0.003$), intake of sugar from SSBs (E%) [β (95% CI) = -1.50 (2.27–0.73), $p < 0.001$], and dietary energy from added sugar (E%) [β (95% CI) = -1.07 (1.61–0.54), $p < 0.001$]; SD variability was positively associated with intake of SSBs [β (95% CI) = 0.20 (0.03–0.38), $p = 0.03$], and the CSHQ score with ED [β (95% CI) = 0.16 (0.004–0.31), $p = 0.04$]. ED, added sugar and SSBs were higher ($p \leq 0.03$) among short sleepers (7.47–8.56 h/night; $n = 169$) compared with long sleepers (9.32–10.50 h/night; $n = 168$) when divided into quartiles.
	Kristjansson A. L. et al. (2014) (55)	Cross-sectional	Iceland	11,132 10–12 y	To assess the prevalence of caffeinated SSBs consumption and examine the relationship between this consumption and common physical complaints.	For both genders, the prevalence of sleep problems increased with greater frequency of cola drink consumption. The AORs show a dose–response relationship between cola drink consumption and sleep problems only in boys (SSBs consumption $\geq 1/\text{day}$ vs. no consumption: OR: 1.31; 95% CI: 1.03, 1.67). For boys and girls the prevalence of sleep problems generally increased with greater EDs use. The AOR models show a dose–response relationship between EDs consumption and sleep problems only in boys (EDs consumption $\geq 1/\text{day}$ vs. no consumption: OR: 1.63; 95% CI: 1.25, 2.12).

(Continued)

TABLE 2 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
Oceania	Matricciani L. et al. (2020) (49)	Cross-sectional	Australia	1,043 11–12 y (12.0 $\pm$ 0.4)	To determine sleep profiles of Australian adolescents and their parents and examine sociodemographic and lifestyle correlates.	Overall good sleeper's consumed fewer sugary drinks, while participants with a late to bed sleep profile consumed higher amounts of sugary drinks (RR = 1.31; 95% CI: 1.02, 1.68; p = 0.034). Further analysis of constituent food group categories revealed statistically significant differences in cluster membership and adolescent's consumption of EDs (RR = 0.28; 95% CI: 0.11, 0.71; p = 0.007).
	Morrissey et al. (2019) (56)	Cross-sectional	Australia	2,253 8.8–13.5 y (10.91 $\pm$ 1.1) ~9–10 y (4th grade):1,167 (51.8%) 11–12 y (6th grade):1,086 (48.2%)	To investigate the influence of lifestyle factors on children's sleep dimensions and whether they modify the association between sleep and weight status.	Consuming two or more SSBs per day, or consuming an SSBs in the hour prior to bedtime, increased the odds of having 2 sleep problems (OR = 1.70; CI: 1.19, 2.43; and OR = 1.82; CI: 1.18, 2.80, respectively) or ≥ 3 problems (OR = 1.96; CI: 1.37, 2.80; and OR = 2.21; CI: 1.32, 3.72, respectively), compared with consuming an SSBs once per day and sometimes/never before bed.
	Nuss T. et al. (2021) (46)	Cross-sectional	Australia	8,942 12–17 y (14.7 $\pm$ 1.2)	To examine the patterns in consumption of EDs and identify sociodemographic and behavioral correlates associated with regular consumption.	The factor most strongly associated with regular EDs consumption was consumption of other sugary drinks: students who reported drinking ≥ 4 cups/week of other varieties of sugary drinks being nearly four times as likely to also regularly consume EDs compared to students who usually drank ≤ 3 cups of other sugary drinks (OR = 3.81 (3.12–4.66) p < 0.001). Students who were not meeting sleep recommendations were more than twice as likely to be regular EDs consumers, compared to those who reported sleeping for at least the minimum recommended hours on a usual school night (OR = 2.10, 95% CI: 1.74–2.53, p < 0.001).
	Scully M. et al. (2017) (47)	Cross-sectional	Australia	7,835 12–17 y (8th–11th grade)	To examine demographic and behavioral correlates of high consumption of soft drinks and to explore the associations between high consumption and soft drink perceptions and accessibility.	Behavioral factors associated with high soft drink consumption (≥ 4 cups/week) were low fruit intake (≤ 1 serving/d) (OR = 1.70, 95% CI: 1.35–2.15, p < 0.001), consuming energy drinks ≥ 1 cup/week (OR = 2.01, 95% CI: 1.59–2.54, p < 0.001), eating fast foods ≥ 1 times/week (OR = 2.36, 95% CI: 1.98–2.80, p < 0.001), eating snack foods ≥ 14 times/week (OR = 2.58, 95% CI: 2.10–3.16, p < 0.001), watching television for > 2 h/d (OR = 1.48, 95% CI: 1.21–1.81, p < 0.001) and sleeping for < 8 h/school night (OR = 1.34, 95% CI: 1.09–1.65, p = 0.005)

EDs, Energy Drinks; BMI, Body Mass Index; SD, Sleep Duration; PA, Physical Activity; ST, Screen Time; AOR, Adjusted Odds Ratio; CI, Confidence Interval; SQ, Sleep Quality; SSBs, Sugar-Sweetened Beverages; SBs, Sugary Beverages; IQR, Interquartile Range; SJL, Social Jetlag; TSP, Teaspoon; CSHQ, Children's Sleep Habit Questionnaire; NCDs, Non-Communicable Diseases; EDS, Excessive Daytime Sleepiness.

TABLE 3 Characteristics of the studies addressing mental health that were included in the review.

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
Asia	Bui C. et al. (2023) (59)	Cross-sectional	Taiwan	18,509 13 y (7th grade) and 16 y (10th grade)	To examine the association between the clustering of unhealthy behaviors and DSs.	Individuals exhibiting clustering of unhealthy behaviors were more likely (AOR = 1.53, 95% CI: 1.48–1.58, $p < 0.001$) to exhibit DSs than those who have no or only one unhealthy behavior. Frequent SSBs consumption significantly associated with DSs (OR = 1.35, 95% CI: 1.24–1.47, $p < 0.001$).
	Candrarukmi D. et al. (2025) (60)	Cross-sectional	Indonesia	1,413 10–17 y (14.48 $\pm$ 1.61)	To ascertain the prevalence of DSs and identify related risk factors.	Adolescents who consume SSBs more than three times/week (OR = 2.472; 95% CI: 1.623–3.765) were more likely to experience DSs.
	Chen D. et al. (2024) (83)	Cross-sectional	China	7,928 6–16 y 6–11 y: 4,962 (62.59%) 12 y: 2,966 (37.41%)	To find out the risk factors associated with BPs.	Student's intake of SSBs is associated with BPs in Chinese children and adolescents ($X^2 = 46.11$; $p < 0.001$). Students with a SSBs intake of ≥ 1 times/week (OR = 1.26; 95% CI: 1.10–1.45) were at significantly increased risks for BPs.
	Chen L. et al. (2025) (61)	Cross-sectional	China	47,520 12–18 y (15.12 $\pm$ 1.88)	To examine the associations of BRI and SSBs consumption with PSs.	The results of LRA showed that adolescents in the group consuming SSBs ≥ 4 times/week (OR = 1.32; 95% CI: 1.22–1.42) had a significantly higher risk of developing PSs ($p < 0.001$). Moderate intake (2–3/week) was associated with lower risk (OR = 0.91; 95% CI: 0.86–0.96). The results of ordered LRA showed that adolescents in the group with BRI quartiles of Q4 and SSBs consumption ≥ 4 times/week (OR = 2.01; 95% CI: 1.77–2.30) had the highest risk of developing PSs ($p < 0.001$). The same trend was observed in boys (OR = 1.77; 95% CI: 1.48–2.13) and girls (OR = 2.61; 95% CI: 2.13–3.20) ($p < 0.001$).
	Guo X. et al. (2024) (62)	Cross-sectional	China	5,307 6–16 y 6–12 y (1st–6th grade): 3,768 (71.00%) 12–15 y (7th–9th grade): 1,539 (29.00%)	To identify direct causal factors and pathways leading to NSSI in children and adolescents using computational causal discovery and machine learning methods.	The prevalence of NSSI was higher among students who consumed SSBs (33.98% in the SSBs+ group vs. 29.04% in the SSBs- group). Analysis identified 9 nodes with direct causal relationships to NSSI, including SSBs. SSBs consumption is linked to elevated depression risks and increased NSSI likelihood.
	Jin Z. et al. (2024) (63)	Cross-sectional	China	22,868 10–19 y (14.6 $\pm$ 1.8)	To examine the individual and interactive associations between ST, SSBs, and DSs.	After adjusting for confounding factors, ST on weekdays (OR = 2.22, 95% CI 1.97–2.51; OR = 1.69, 95% CI 1.51–1.90), ST at weekends (OR = 1.73, 95% CI 1.57–1.91; OR = 1.43, 95% CI 1.30–1.56) and SSBs (OR = 1.48, 95% CI 1.31–1.68; OR = 1.40, 95% CI 1.24–1.57) were found to be positively correlated with DSs. No age group difference could be found in the association of SSBs with DSs. Interaction models indicated that ST and SSBs in combination were related to greater odds of DSs. Compared with late adolescents, early adolescents had a higher probability of DSs when exposed to the joint effects.

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TABLE 3 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
	Khan A. et al. (2017) (64)	Cross-sectional	Bangladesh	755 13–16 y (14.26 $\pm$ 1.15)	To assess the prevalence and socio-demographic correlates of DSs.	High SDs intake (≥ 5 /week) increased the odds of DSs (OR = 2.38; 95% CI: 1.06, 5.35; $p = 0.035$).
	Kim Y. et al. (2023) (90)	Cross-sectional	Korea	55,748 12–18 y	To examine the association between BSM and UEB.	Adolescents who underestimated their body shape were likelier to have UEB (AOR = 1.18; 95% CI: 1.11, 1.25; $p < 0.001$). Adolescents with high-level stress (AOR = 1.59; 95% CI: 1.43, 1.77) and depression (AOR = 1.29; 95% CI: 1.23, 1.36) showed more likely to have UEB and statistically significant ($p < 0.001$). The underestimation group of boys showed a higher likelihood of UEB (AOR = 1.16; 95% CI: 1.08, 1.26) than the accurate estimation group. Similarly, girls who underestimated their body shape were likelier to have UEB (AOR = 1.19; 95% CI: 1.09, 1.30) than the accurate estimation group ($p < 0.001$).
	Lin C-J, et al. (2024) (65)	Longitudinal	Taiwan	1,560 6–11 y (1st–6th grade, for depressive symptoms) and 12–17 y (7th–12th grade, for SSBs habits)	To examine the associations between childhood DSs trajectories and adolescent SSB-habit trajectories, and mediating role of sleep problems in these associations.	Children who had moderate-stable (AOR = 1.35; 95% CI: 1.04–1.77), high-stable (AOR = 2.01; 95% CI: 1.28–3.15), or increasing (AOR = 1.97; 95% CI: 1.26–3.06) trajectories of DSs relative to those in the low-stable group were significantly more likely to belong to the high-stable trajectory of SSBs than to the low-stable SSBs group. The Z-mediation test showed that sleep problems significantly mediated the associations between trajectories of childhood DSs and trajectories of SSBs during adolescence (all $p < 0.05$).
	Noor Z et al. (2025) (87)	Cross-sectional	Pakistan	377 14–19 y (16)	To evaluate the impact of academic stress on eating patterns, dietary preferences, and sleep duration.	A weak negative correlation was found between academic stress and both eating patterns ($\rho = -0.124$, $p < 0.05$) and sleep duration ($\rho = -0.116$, $p < 0.05$), indicating that higher academic stress was linked to unhealthy eating habits and reduced sleep duration in adolescents. Among female students, those with high levels of academic stress were 2.13 times more likely to consume beverages, including SDs compared to females with low stress levels (OR = 2.13, 95% CI: 1.03–4.41, $p < 0.05$). Females with moderate stress levels were 3.23 times more likely to consume beverages like colas and sodas compared to low-stressed counterparts (OR = 3.23, 95% CI: 1.24–8.40, $p < 0.05$).
	Qiu Q. et al. (2024) (66)	Cross-sectional	China	3,026 19–22 y	To investigate the current status of SSBs consumption, SQ, and ASs, and their associations.	The results of LRA showed that college students with SSBs consumption of 2–5 times/week (OR: 1.38; 95% CI: 1.12, 1.70) and SSBs consumption of ≥ 6 times/week (OR: 2.47; 95% CI: 1.98, 3.08) had a higher risk of ASs ($p < 0.01$). The results of ordered LRA showed that college students with SSBs ≥ 6 times/week and poor SQ (OR: 5.06; 95% CI: 3.75–6.83) had the highest risk of ASs ($p < 0.001$). College students in the SSBs ≥ 6 times/week and poor SQ group had a higher risk of developing ASs among boys (OR: 7.61; 95% CI: 4.94–11.71) than girls (OR: 3.26; 95% CI 2.13 ~ 5.00) ($p < 0.001$).

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TABLE 3 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
	Ra J. S. (2022) (67)	Cross-sectional	South Korea	24,006 15–18 y (10th–12th grade)	To identify the effects of combining the consumption of SSBs and fast foods on mental health, including stress, DSs, and suicidal ideation.	Compared to low SSBs consumption (reference), medium (AOR: 1.07; 95% CI: 1.00, 1.14) and high SSBs consumption were associated with increased stress (AOR: 1.20; 95% CI: 1.11, 1.29). In addition, high SSBs consumption was associated with increased DSs (AOR: 1.19; 95% CI: 1.09, 1.30) and suicidal ideation (AOR: 1.18; 95% CI: 1.05, 1.32) compared to the reference.
	Ra J. S. (2023) (68)	Cross-sectional	South Korea	21,046 15–18 y (10th–12th grade)	To identify the combinations of SSBs consumption, screen-based sedentary time, and sleep duration and their association with adolescents' DSs and suicidal ideation.	After adjusting for biological, social, and psychological factors, high SSBs consumption was associated with greater DSs (AOR = 1.18; 95% CI: 1.08, 1.30) than low SSBs consumption. However, SSBs consumption was not associated with suicidal ideation.
	Tang N. et al. (2025) (69)	Cross-sectional	China	50,222 12–18 y (15.09 $\pm$ 1.89)	To analyze the association between SSBs consumption, MVPA duration, and PSs.	The results of LRA showed that adolescents with SSBs consumption >4 times/week (OR = 1.36; 95% CI: 1.25, 1.49) had a higher risk of prevalence of PSs ($p < 0.001$). The results of ordered LRA showed that the adolescents in the group with SSBs consumption >4 times/week and MVPA duration <30 min/day group (OR = 2.28; 95% CI: 1.98, 2.64) had the highest risk of the prevalence of PSs ($p < 0.001$). The same trend was observed in boys and girls.
	Wang Y. et al. (2022) (70)	Cross-sectional	China	6,120 19–22 y (20.16 $\pm$ 1.03)	To assess the association between SSBs consumption and PSs during the COVID-19 pandemic.	Compared to SSBs consumption of <2 times/week, college students with SSBs consumption of ≥ 2 times/week (OR = 2.96, 95% CI: 2.36–3.70) had a higher risk of PSs ($p < 0.001$). The same trend was found for emotional symptoms (OR = 4.31, 95% CI: 3.49–5.31; $p < 0.001$), behavioral symptoms (OR = 4.55, 95% CI: 3.73–5.54; $p < 0.001$), and social adaptation (OR = 3.99, 95% CI: 3.26, 4.91; $p < 0.001$) difficulties dimensions.
	Xu H. et al. (2019) (71)	Cross-sectional	China	14,500 10–20 y (14.9 $\pm$ 1.8)	To illustrate current eating pattern and to explore their association with PSs.	The SSBs pattern was significantly associated with higher risk of all PSs (psychopathological symptoms: AOR = 1.38; 95% CI: 1.23, 1.55; emotional problems: AOR = 1.34; 95% CI: 1.20, 1.49; conduct problems: AOR: 1.25; 95% CI: 1.13, 1.38; social adaptation problems: AOR = 1.56; 95% CI: 1.36, 1.78). A significant dose–response relationship was observed (p -trend < 0.01).
	Xu et al. (2020) (73)	Cross-sectional	China	14,500 10–20 y (14.9 $\pm$ 1.8)	To evaluate the association between co-consumption of FF and SSBs and self-reported mental health.	The β value increases as the quantile of SSBs, and co-consumption of SSBs with FF increases in the quantile regression model (p trend < 0.01). The β values of the higher quantile are significantly higher than that of the lower quantile. In the interaction model, FF and SSBs in combination were associated with greater odds of PSs (AOR = 1.90; 95% CI: 1.69, 2.12). The synergy index, relative excess risk of interaction, and attributable proportions were 1.86 (95% CI: 1.17, 2.96), 0.41 (95% CI: 0.20, 0.63), and 0.22 (95% CI: 0.11, 0.33), respectively.

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TABLE 3 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
	Xu H. et al. (2020) (72)	Cross-sectional	China	14,500 10–20 y (14.9 $\pm$ 1.8)	To examine the association between ST, FF, SSBs and DSs and evaluate the mediating effects of FFs and SSBs in the association between ST and DSs.	ST, FFs and SSBs, were more likely to be associated with DSs, and ORs (95%CI) was 1.075 (1.036–1.116), 1.062 (1.046–1.078) and 1.140 (1.115–1.166) in the model adjusted for sociodemographic variables ($p < 0.001$). The mediating effects of FFs and SSBs in the association between ST and DSs in adolescents are also evaluated. The direct effect of ST on DSs was 0.125; the total mediating effect is 0.034; the total effect was 0.159; the ratio of mediating effect to total effect was 0.214.
	Xu H. et al. (2023) (74)	Cross-sectional	China	31,856 17–25 y 17–18 y: 12,783 (40.13%) 19–20 y: 16,311 (51.20%) 21–25 y: 2,762 (8.67%)	To analyze the association between consumption of various SSBs and DSs.	After adjusting for sociodemographic variables and potential influencing factors of adolescent DSs in Generalized Linear Models, consumption of carbonated beverages ($\beta = 0.10$; 95% CI: 0.07–0.13; $p = 0.000$), tea beverages ($\beta = 0.05$; 95% CI: 0.01–0.08; $p = 0.010$), and milk tea ($\beta = 0.08$; 95% CI: 0.05–0.11; $p = 0.000$) was associated with DSs in college students. Stratified analysis by gender showed that carbonated beverages ($\beta = 0.11$; 95% CI: 0.07–0.15; $p = 0.000$) and milk tea ($\beta = 0.07$; 95% CI: 0.01–0.13; $p = 0.021$) consumption was associated with DSs in boys; and carbonated beverages ($\beta = 0.09$; 95% CI: 0.05–0.13; $p = 0.000$), tea beverages ($\beta = 0.09$; 95% CI: 0.04–0.13; $p = 0.000$), and milk tea ($\beta = 0.08$; 95% CI: 0.04–0.11; $p = 0.000$) consumption was associated with DSs in girls. The direct effect value of SSBs on DSs was 0.012 ($p = 0.169$), and mediating effect value of physical sub-health was 0.052 ($p < 0.01$). The total effect value was 0.064. The direct effect accounted for 18.7% of the total effect, and the mediating effect for 81.3% of the total effect.
	Yu C. J. et al. (2016) ⁸⁹	Case-control	Taiwan	332 (173 cases with ADHD and 159 non-ADHD controls) 4–15 y (8.9 $\pm$ 2 cases with ADHD and 9.2 $\pm$ 2.7 non-ADHD controls)	To analyze the association between SSBs consumption and ADHD.	Children with higher SSBs consumption had a greater risk of having ADHD. After adjusting for confounding factors, the OR was 1.36 (95% CI: 0.61–3.05) for children who consumed 1–6 servings/week, and the OR was 3.69 (95% CI: 1.291–10.60) for children who consumed ≥ 7 servings/week.
	Zeng Y. et al. (2025) (75)	Cross-sectional and Longitudinal	China	7,829 10.6 $\pm$ 2.17 y	To investigate the associations between life changes during the COVID-19 lockdown, and DSs/ASs.	Cross-sectional analyses revealed that higher risks of DSs/ASs were associated with a decrease in SSBs consumption (OR = 1.57; 95% CI: 1.30, 1.90 and OR = 1.39; 95% CI: 1.14, 1.70, respectively). In longitudinal analyses, no new association was found between SSBs consumption and DSs/ASs, and the previously observed cross-sectional associations disappeared.

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TABLE 3 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
	Zhang Y. et al. (2021) (84)	Cross-sectional	China	30,188 6–18 y (12.44 $\pm$ 3.47) 6–12 y (1st–6th grade): 13,420 (44.50%) 12–15 y (7th–9th grade): 8,232 (27.30%) 15–18 y (10th–12th grade): 8,536 (28.30%)	To investigate the association between SSBs consumption, takeaway dietary pattern, and PBPs.	The top three SSBs in the intake frequency were milk beverages drinks (not milk), vegetable protein drinks, and fruit and vegetable juice drinks. More frequent intake of SSBs (OR = 2.23, 95% CI = 2.0–2.47, $p < 0.01$) and higher takeaway consumption (OR = 2.34, 95% CI = 1.81–3.03, $p < 0.01$) were associated with higher SDQ total difficulties scales. The same results about SSBs consumption were also found in emotional symptoms (OR = 1.73, 95% CI = 1.60–1.87, $p < 0.01$). When low and medium consumption of SSBs was compared, who have high SSBs intake were more associated with total difficulties score (OR = 3.10, 95% CI = 2.67–3.59, $p < 0.01$). The joint associations of SSBs and takeaway pattern with SDQ were stronger than the associations individually.
	Zhang Y. et al. (2022) (76)	Cross-sectional	China	11,787 20.51 $\pm$ 1.88 y ≤ 19 y: 3,860 (32.70%) 20–22 y: 6,426 (54.50%) 23 y: 1,501 (12.70%)	To examine the associations between factors related to COVID-19 measures and mental health symptoms.	Higher SSBs intake was correlated with higher DSs (Soda beverages: $\chi^2 = 172.88$; Tea beverages: $\chi^2 = 157.10$) and ASs (Soda beverages: $\chi^2 = 115.70$; Tea beverages: $\chi^2 = 94.71$). The students who reported higher consumption of SSBs (> 4 bottles/day) had higher DSs (Soda beverages: OR = 2.25, 95% CI: 1.14–4.429; Tea beverages: OR = 2.57, 95% CI: 1.28–5.15) and ASs (Soda beverages: OR = 2.71, 95% CI: 1.35–5.48; Tea beverages: OR = 2.92, 95% CI: 1.41–6.07).
	Zhang Y. et al. (2025) (77)	Cross-sectional	China	11,018 13–18 y (15.81 $\pm$ 1.60)	To explore the associations between SSBs consumption, and relative grip strength with PSs.	The prevalence of PSs was significantly higher in adolescents in the SSBs consumption of >4 times/week group (OR = 1.95, 95% CI: 1.69–2.24), using the SSBs consumption of <1 time/week group as the reference group ($p < 0.001$). Adolescents in the SSBs consumption of >4 times/week group and relative grip strength quartiles as Q1 group (OR = 2.77, 95% CI: 2.09–3.67) had the highest risk of PSs ($p < 0.001$).
	Zhao et al. (2025) (85)	Cross-sectional	China	1,126 9.53 $\pm$ 0.66 y	To investigate dietary habits status and their associations with EBPs in pre-teen children, as well as explore the mediating effect of child self-concept in the associations between healthy dietary habits and EBPs.	Children who had unhealthy SSBs intake were at an elevated risk of EBPs (OR = 1.41; 95% CI: 1.03, 1.95).

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TABLE 3 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean $\pm$ standard deviation)	Objective	Main results
America	Dabravolskaj J, et al. (2023) (79)	Cross-sectional and longitudinal	Canada	24,274 13–18 y (14.8 $\pm$ 1.2) and 13–18 y (15.8 $\pm$ 1.2)	To examine individual and overall adherence to lifestyle recommendations and to assess the relationship between adherence to these recommendations and the severity of DSs and ASs.	Adherence to SSBs recommendation at baseline was associated with lower DSs and ASs at follow-up (β = -0.20 ; 95% CI: -0.34 , -0.06 and β = -0.19 ; 95% CI: -0.31 , -0.07 , respectively). Males adhering to the SSBs recommendation had lower severity of both DSs and ASs (β = -0.22 ; 95% CI: -0.42 , -0.03 and β = -0.19 ; 95% CI: -0.37 , -0.01 , respectively), whereas in females the association was observed only for ASs (β = -0.21 ; 95% CI: -0.38 , -0.04).
	Dabravolskaj J, et al. (2024) (78)	Cross-sectional and longitudinal	Canada	13,887 12–18 y (14.9 $\pm$ 1.2) and 12–18 y (15.8 $\pm$ 1.2)	To examine the association of diet with DSs, ASs, and psychological wellbeing.	SSBs consumption was associated with greater severity of DSs (β = 0.04; 95% CI: 0.01, 0.06) and ASs (β = 0.02; 95% CI: 0, 0.05), and poorer psychological wellbeing (β = -0.03 ; 95% CI: -0.05 , -0.01) at follow-up; associations were stronger in male students.
	Dennison-Farris M. et al. (2017) (80)	Cross-sectional	United States	121 7–13 y (10.5 $\pm$ 1.6) 7–9 y: 35 (28.90%) 10–13 y: 86 (71.10%)	To determine the relationship between DSs and obesogenic behaviors and whether self-efficacy mediates that relationship, independent of obesity.	Higher DSs were associated with higher diet soda intake (Beta + SE = 0.044 $\pm$ 0.017; p = 0.012). No significant association with other SSBs intake, considered alone or pooled. Dietary and physical activity self-efficacy were not mediators in the relationship between DSs and obesogenic behaviors.
	Kaidbey J. H. et al. (2022) (86)	Virtual single-arm intervention	United States	150 8–14 y (11.4 $\pm$ 2.0)	To examine children's physical and emotional responses during 3 days of SDs cessation.	At baseline 59.4% of participants consumed <2 servings/day of SDs. 77% of participants reported some caffeinated SDs consumption, and approximately a quarter (n = 35) of the full sample reported consumption of caffeinated SDs daily. During SDs cessation, children reported physical and emotional improvements, including being less tired, angry, and annoyed; having less trouble sleeping; and less frequently arguing with others, getting in trouble, and getting mad. Unfavorable responses, such as mood disturbances and having less energy, were reported by some participants.
Europe	Jonsson et al. (2024) (88)	Cross-sectional	Sweden	3,692 11–15 y	To investigate the association between dietary behaviors, overweight/obesity, and mental health and wellbeing.	Consumption of ≤ 1 time/week of SSBs was associated with higher life satisfaction (OR = 1.27; 95% CI: 1.04–1.55), and a lower likelihood of experiencing two or more psychosomatic health complaints in a week (OR = 0.68; 95% CI: 0.60, 0.79) and school-related pressure (OR = 0.83; 95% CI: 0.72, 0.97).

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TABLE 3 (Continued)

Continent	Articles	Study design	Country	Population Sample size (N) and age (mean ± standard deviation)	Objective	Main results
Oceania	Smout S. et al. (2023) (81)	Cross-sectional	Australia	6,640 11–14 y (12.7 ± 0.5) (7th grade)	To investigate associations between key modifiable lifestyle behaviors (sleep; physical activity; fruit, vegetable and SSBs consumption; ST; alcohol use and tobacco use) and mental health.	Lower consumption of SSBs was associated with lower anxiety, depression and psychological distress symptomology (anxiety: F6,55,806 = 11.3352, $p < 0.001$; depression: F6,5,786 = 21.0525, $p < 0.001$; psychological distress: F6,5,812 = 13.0627, $p < 0.001$). The lowest mean scores were observed in those who did not drink SSBs, who had an average ASs score 24% lower (Δ Mscore: 6.3, 95% CI: 3.8–8.8), an average depression score 49% (Δ Mscore: 3.9, 95%CI: 2.6–5.1), and an average psychological distress symptom score 31% lower (Δ Mscore: 2.6, 95% CI: 1.2–4.1) than those who drank ≥ 14 cups/week. In a model including all behaviors and adjusting for sociodemographic factors, the relationship with depression remained significant for moderate-to-vigorous physical activity (F7,4,623 = 2.2358, $p = 0.03$), fruit consumption (F7,4,623 = 2.3038, $p = 0.02$), SSBs consumption (F6,4,623 = 2.7934, $p = 0.01$), sleep (F15,4,623 = 14.9503, $p < 0.001$), ST (F16,4,623 = 5.7318, $p < 0.001$) and tobacco use (F1,4,623 = 9.9597, $p = 0.002$).
International	Walsh S. D. et al. (2020) (82)	Multi-center cross-sectional	37 Countries	32,884 15 y (15.51 ± 0.36)	To explore a contemporary and empirically based model of clusters of risk for adolescents and to examine how they are associated with adolescent mental wellbeing.	Between the factors, low social support and problematic Social Media Use showed the largest effect on Life Satisfaction (ORs = 2.167 and 1.330, respectively) and psychosomatic complaints (ORs = 1.687 and 1.386, respectively). However, sugary foods and drinks also showed significant effects on Life Satisfaction and psychosomatic complaints (ORs = 0.863 and 1.117, respectively).

DSs, Depressive Symptoms; AOR, Adjusted Odds Ratio; CI, Confidence Interval; SSBs, Sugar-Sweetened Beverages; OR, Odds Ratio; SBs, Sugary Beverages; BPs, Behavioral Problems; BRI, Body Roundness Index; PSs, Psychological Symptoms; LRA, Logistic Regression Analysis; NSSI, Non-suicidal self-injury; ST, Screen Time; SDs, Sugary Drinks; BSM, Body Shape Misperception; UEB, Unhealthy Eating Behaviors; SQ, Sleep Quality; ASs, Anxiety Symptoms; MVPA, Moderate-to-vigorous physical activity; FF, Fast Foods; ADHD, Attention Deficit/Hyperactivity Disorder; PBPs, Psychological and Behavioral Problems, SDQ, Strength and Difficulties Questionnaire; EBPs, Emotional and Behavioral Problems.

the mutually adjusted model. Similarly, Boozari et al. (2021) (24) found no significant correlation between SD and SSBs intake, although mean daily SSBs consumption differed across sleep-duration categories.

Interestingly, Li et al. (35) examined the key mediating role of SSBs consumption in the association among SD, late chronotype, and weight gain, performing statistical mediation analyses. Results indicated that SSBs could act as potential mediators in the relationship between SD and BMI. Likewise, Kjeldsen et al. (45) reported inverse associations between SD and dietary energy density, sugar intake from SSBs as a percentage of energy, and energy intake from added sugars, suggesting an overall obesity-promoting dietary pattern.

With regard to gender differences in the association between SSBs consumption and SD, findings across studies were inconsistent. Ma et al. (37) reported, in sex-stratified analyses, that longer SD was associated with lower SSBs intake in boys. In contrast, Sampasa-Kanyinga et al. (41) found that although boys were more likely than girls to consume SSBs and EDs, the associations between SD and beverage consumption did not differ by sex.

3.1.2 Sleep efficiency

SE – which measures sleep continuity by considering sleep latency, number of awakenings, time spent awake after sleep onset, and unplanned early awakening (31) – was evaluated in only one study, conducted by Vézina-Im et al. (48), in a cross-sectional sample of Canadian adolescents. The authors examined whether the consumption of various beverages, including SSBs, was associated with SQ, assessed using the validated short version of the Adolescent Sleep–Wake Scale. This instrument captures multiple components of SE, including ease of going to bed, falling asleep, resuming sleep after nocturnal awakenings, and returning to wakefulness in the morning.

Overall, total SSBs intake was not significantly correlated with SQ. However, caffeinated SSBs, particularly EDs and sugar-sweetened coffee, showed significant negative associations with adolescents' SQ.

Further sex-stratified analyses revealed an interaction between sugar-sweetened coffee consumption and biological sex in relation to SQ. Among girls, sugar-sweetened coffee intake was correlated with greater difficulty going to bed and falling asleep, whereas in boys, the association was limited to difficulties going to bed.

3.1.3 Sleep timing

Sleep timing refers to the placement of sleep within the 24-h day, typically operationalized through habitual bedtime and wake time (e.g., chronotype) (31). Evidence on ST in relation to SSBs consumption was limited, with only two studies addressing this dimension (35, 49). Both reported that later sleep patterns were associated with higher intake of SSBs.

In the study by Matricciani et al. (49), adolescents classified as good sleepers consumed fewer SSBs, whereas those with a late-to-bed profile showed significantly higher intake. This delayed sleep pattern was also linked to greater consumption of EDs.

Consistent with these findings, Li et al. (35) observed that a later chronotype was directly associated with higher SSBs consumption. The study further contributed by providing insights into the potential mediating role of SSBs in the relationship between chronotype and BMI, using mediation analyses. Results showed that SSBs partially explained this association, along with physical activity and psychological condition.

3.1.4 Sleep satisfaction

SS, reflecting subjective perceptions of restfulness or sleep-related difficulties (31), was assessed only in the cross-sectional study by Min et al. (38), which examined associations between SD, SQ, and food intake. Participants who reported poor or very poor recovery from fatigue after sleep, a measure of SQ used to operationalize SS, showed a higher likelihood of consuming soda and soft drinks ≥ 5 times per week.

3.1.5 Sleep regulatory

Sleep regularity was investigated in four studies, which collectively suggested that adolescents who frequently consumed SSBs tended to exhibit more irregular sleep patterns (45, 50–52). SR concerns the stability of sleep patterns across days, both in terms of timing and duration (31).

Most studies focused on SJL, a form of circadian misalignment resulting from discrepancies between weekday and weekend sleep–wake schedules (58). Both Cetiner et al. (50) and Zhang et al. (52) reported a dose–response association, with higher SSBs consumption observed in adolescents with greater SJL. Specifically, Cetiner et al. (50) found that those with >2 h of SJL showed higher median intake (1.0 servings/day) compared with those with <1 h or 1–2 h. Similarly, Zhang et al. (52) reported increased odds of any SSBs intake in adolescents with 1–2 h or >2 h of SJL, although associations were significant only in girls.

Ievers-Landis et al. (51) examined SJL through weekend delays in bedtime and wake time, finding that later bedtime and wake time were associated with higher SSBs intake, with the latter association observed only in males.

Finally, evidence from a cross-sectional study in Danish schoolchildren (8–11 y) also supports this association, indicating that greater variability in nightly sleep duration was associated with higher intake of SSBs (45).

3.1.6 Sleep-related daytime functioning

Sleep-related daytime functioning refers to the ability to remain alert, energetic, and attentive throughout the day, without excessive sleepiness or fatigue, underscoring that sleep health extends beyond the nocturnal period (31). This dimension was investigated only in the cross-sectional study by Lima et al. (2023) (53), which assessed excessive daytime sleepiness (EDS) as an indicator of impaired alertness. Specifically, using a structural equation model (SEM), this study aimed to analyze the associations between modifiable behavioral risk factors for NCDs and sleep outcomes in adolescents, with overweight included as a potential mediator (53). Results indicated that higher SSBs consumption was significantly associated with greater EDS, independent of overweight, which neither mediated the association nor was directly related to EDS (53).

3.1.7 Sleep quality

Five studies assessed overall SQ by considering multiple dimensions of sleep health. Across these investigations, adolescents with poorer SQ consistently reported higher consumption of both SSBs and EDs (33, 53–56).

Two small cross-sectional studies from Iran (33) and Malaysia (54) reported that SQ, measured with the validated Pittsburgh Sleep Quality Index (PSQI), was associated with higher SSBs intake.

Similar results were also obtained in two larger cross-sectional studies conducted in Iceland (55) and Australia (56), respectively. Kristjansson et al. (55) found a higher prevalence of sleep problems among high consumers of caffeinated SSBs in both genders, although the specific type of sleep problems was not detailed. Furthermore, a dose–response relationship was observed in boys between daily cola consumption or EDs intake and a greater occurrence of sleep problems.

Consistently, Morrissey et al. (56) reported that adolescents consuming ≥ 2 SSBs per day had increased odds of experiencing two sleep problems or ≥ 3 problems, compared with those consuming SSBs once per day or less frequently.

Finally, particularly noteworthy is the cross-sectional study by Lima et al. (53), which investigated the potential mediating role of overweight in the association between behavioral risk factors, including SSBs consumption, and SQ in a sample of Brazilian adolescents using SEM. Results showed that higher consumption of SSBs was associated with poorer SQ. However, despite the well-established link between overweight and sleep disturbances, excess weight did not emerge as a mediator in this association.

3.2 Mental health and sugar-sweetened beverage consumption

This review included 32 articles aimed at studying the relationship between SSBs consumption and mental health. Most of the studies ($n = 25$) were conducted in Asian countries. Psychological symptoms (PSs) in various forms were studied in 24 articles (59–82), while the remaining studies examined other related outcomes [behavioral and emotional problems: $n = 4$ (83–86), academic stress: $n = 2$ (87, 88), attention deficit/hyperactivity disorder (ADHD): $n = 1$ (89), body misperception: $n = 1$ (90)].

3.2.1 Psychological symptoms

Studies focusing on PSs have used various validated tools designed to assess these symptoms as a whole or to investigate specific aspects, such as anxiety, depression, and their consequences.

Three recent cross-sectional studies (61, 69, 77), carried out in three different samples of Chinese adolescents, found that higher SSBs consumption (>4 times/week) was positively associated with a greater prevalence of PSs.

Wang and colleagues (70) assessed the association between SSBs consumption and PSs during the COVID-19 pandemic, observing that, compared to SSBs consumption of <2 times/week, college students with SSBs consumption of ≥ 2 times/week had a significantly higher prevalence of PSs. The same trend was found for emotional symptoms, behavioral symptoms, and social adaptation difficulties dimensions (70). Similar results were observed by Zhang et al. (76) in a web-based survey during the pandemic, who reported that students with higher consumption of SSBs (>4 bottles/day) had higher depressive symptoms (DSs) and anxiety symptoms (ASs). In contrast, another study (75), aimed at investigating the associations between life changes during the COVID-19 lockdown and DSs/ASs using both cross-sectional and longitudinal designs, showed that decreased SSBs consumption was associated with higher prevalence of these symptoms. These associations attenuated or disappeared 1 year later (77).

Three studies included in this review were conducted in the same sample of Chinese adolescents (71–73). It has been observed that the SSBs pattern was significantly associated with higher probability of all PSs (71), and that the co-consumption of Fast Foods (FFs) and SSBs was associated with greater odds of PSs. The authors also observed that screen time (ST), FFs and SSBs consumption were more likely to be associated with DSs, and that FFs and SSBs consumption might play a role of mediating variable in the association between ST and DSs (72). Specifically, using a Bayesian multiple mediation model, the direct, mediating, and total effects linking SSBs, ST and FFs consumption to DSs were examined, showing that FFs represented the main mediator, while SSBs contributed a smaller mediating role (72). Moreover, the chain mediation path involving ST, FFs and SSBs further strengthened the association with DSs (72). In another study included (63), multiplicative and additive interaction models were performed to estimate the interaction effects of ST and SSBs on DSs, highlighting that ST and SSBs in combination were related to greater odds of DSs. Compared to older adolescents, younger adolescents had a higher likelihood of DSs when exposed to the combined effects (63).

Four studies included reported that frequent SSBs consumption significantly increased the odds of DSs (59, 60, 64, 74). Specifically, Bui and colleagues (59) also observed that adolescents exhibiting clustering of unhealthy behaviors, including frequent SSBs consumption, insufficient physical activity, and screen-based sedentary behaviors, were more likely to exhibit DSs than those who have no or only one unhealthy behavior. On the other hand, the article by Xu et al. (74), also showed that the mediating effect of physical sub-health – considered as a chronic condition of unexplained deterioration in physiological function, halfway between health and disease, manifested by a certain degree of physiological dysfunction, insufficient physical activity, decreased adaptability and immune function, and poor mental health – accounted for 81.3% of the total effect in the mediating model of SSBs associated with DSs.

A cross-sectional study aimed at determining the associations between DSs and obesogenic behaviors in school-aged American Indian children (10.5 ± 1.6 years) (80), reported a significant relationship between DSs and diet soda consumption, meal skipping, and certain ST variables. No significant association with other SSBs intake (considered alone or pooled), physical activity, fruit and vegetable intake, and BMI percentile was found (80). A longitudinal analysis by Lin and colleagues (65), instead, showed that children who had moderate-stable, high-stable, or increasing trajectories of DSs, relative to those in the low-stable group, were significantly more likely to belong to the high-stable trajectory of SSBs than to the low-stable SSBs group. Additionally, the study identifies sleep problems as a mediating factor in these observed associations during adolescence (65).

Regarding severe depression and its associated consequences, one study analyzed Non-Suicidal Self-Injury (NSSI) (62), while two studies conducted in South Korea examined suicidal ideation, among other outcomes (67, 68). In the first article (62), the prevalence of NSSI was higher among students who consumed SSBs (33.98% in the SSBs+ group vs. 29.04% in the SSBs– group). Analysis identified 9 nodes with direct causal relationships to NSSI, including SSBs consumption. The latter was linked to elevated depression and increased NSSI likelihood. In 2022, Ra (67) noticed that, compared to low SSBs consumption (reference), high SSBs consumption was associated with increased stress, DSs, and suicidal ideation. In

addition, combining high consumption of SSBs and low to high consumption of FFs might have dose-dependent negative effects on stress, DSs, and suicidal ideation in Korean adolescents (67). In 2023 the same author reported that high SSBs consumption was associated with greater DSs, but it was not associated with suicidal ideation (68). The effect of the combination of SSBs consumption, screen-based sedentary time, and SD on DSs and suicidal ideation was also observed (68).

Only one study focused exclusively on ASs, reporting that college students who consumed SSBs 2–5 times/week or ≥ 6 times/week showed a higher probability of experiencing ASs (66). It has been also observed that students with SSBs ≥ 6 times/week and poor SQ had the greatest odds of ASs ($p < 0.001$) (66).

Smout et al. (81) investigated the associations between key modifiable lifestyle behaviors and mental health, reporting that lower consumption of SSBs was associated with lower anxiety, depression and psychological distress symptomology; with the lowest mean scores observed in those who did not drink SSBs. In a model including all behaviors and adjusting for sociodemographic factors, the relationship with depression remained significant for moderate-to-vigorous physical activity, fruit consumption, SSBs consumption, sleep, ST and tobacco use (81).

ASs and DSs were examined together in the studies by Dabravolskaj et al., who analyzed data from the large longitudinal COMPASS (Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behavior) study in Canada (78, 79). The authors observed that adherence to SSBs recommendation at baseline was associated with lower DSs and ASs at follow-up (79); and that SSBs consumption was associated with greater severity of DSs, and poorer psychological wellbeing at follow-up (78).

Finally, this review includes an article presenting the findings of a contemporary, large, cross-national representative sample of adolescents aged 15 years from 37 countries (82). A seven-factor model of risk (substance use and early sex, low social support, insufficient nutrition, bullying, sugary foods and drinks, physical health risk, and problematic social media use) for mental wellbeing was suggested (82). Among these factors, low social support and problematic social media use showed the largest effect on Life Satisfaction and psychosomatic complaints. Sugary foods and drinks were also significantly associated with both outcomes, although with smaller effect sizes (82).

3.2.2 Academic stress

Two studies examined the relationship between SSBs consumption and school-related stress (87, 88).

Noor and colleagues (87) conducted a cross-sectional survey aimed at evaluating the impact of academic stress on eating patterns, dietary preferences, and SD in Pakistani adolescents. A weak negative correlation between academic stress and both eating patterns and SD was found, indicating that higher academic stress was linked to unhealthy eating habits and reduced SD in adolescents. Among female students, those with high levels of academic stress were 2.13 times more likely to consume beverages, including sugary drinks compared to females with low stress levels. Females with moderate stress levels were 3.23 times more likely to consume beverages like colas and sodas compared to low-stressed counterparts. For male students, the analysis demonstrated that those experiencing high levels of academic stress were significantly more likely to consume FFs.

The cross-sectional study conducted by Jonsson et al. (88) in a sample of Swedish adolescents, investigated the association between dietary behaviors, overweight/obesity, and mental health and wellbeing. The analyses by individual food group revealed that the consumption of SSBs once per week or less was associated with higher life satisfaction, and a lower likelihood of experiencing two or more psychosomatic health complaints in a week and school-related pressure.

3.2.3 Behavioral and emotional problems

Behavioral and emotional problems (BPs and EPs), considered as two main dimensions of mental disorders (91), were examined in four included studies (83–86).

Chen and colleagues (83) conducted a cross-sectional study to identify the risk factors associated with BPs and EPs, using total BPs, internalizing and externalizing problems, and eight specific syndromes (92, 93) to capture the different dimensions of these issues. Findings showed that intake of SSBs is associated with BPs in Chinese children and adolescents. In particular, students with a SSBs intake of ≥ 1 times/week showed significantly higher odds of BPs. Similar results were observed by Zhao et al. (85), in a sample of Chinese pre-teen children. The scale used to detect children's EBP (Emotional Behavioral Problems) at home or school was classified into three subscales (i) neurotic behaviors that represent different aspects of emotional difficulties; (ii) anti-social behaviors that estimate the conduct problems (iii) mixed behaviors containing the rest of problematic behaviors, such as hyperactive (94, 95). It has been observed that the unhealthy SSBs intake was positively associated with EBPs. The last study conducted in Asia on these aspects was carried out by Zhang and colleagues (84). The authors assessed psychological BPs using the Strengths and Difficulties Questionnaire (SDQ), including hyperactivity problems, emotional symptoms, conduct problems, peer problems, and prosocial problems (96). More frequent intake of SSBs and higher takeaway consumption were associated with higher SDQ total difficulties scales. The same results relating to SSBs consumption were also found in emotional symptoms, conduct problems, peer problems, and prosocial problems, with the exception of hyperactivity. Compared with low and medium SSBs consumption, children and adolescents with high SSBs intake showed higher total difficulties scores. Moreover, the combined associations of SSBs and takeaway consumption with SDQ scores were stronger than those observed for either factor individually.

Finally, Kaidbey et al. (86) examined physical and emotional responses during 3 days of sugary drinks cessation, in a sample of children (ages 8–14 years), who reported habitual consumption of ≥ 12 ounces of sugary drinks daily in the United States. During the cessation, children reported physical and emotional improvements, including being less tired, angry, and annoyed, having less trouble sleeping, and less frequently arguing with others, getting in trouble, and getting mad. However, unfavorable responses, such as mood disturbances and having less energy, were reported by some participants.

3.2.4 Other mental health-related outcomes

Body shape misperception (BSM) and Attention Deficit/Hyperactivity Disorder (ADHD) are studied in relation to SSBs consumption in two included studies (89, 90).

The article by Kim and colleagues (90) examined the association between BSM and Unhealthy Eating Behavior (UEB)

among Korean adolescents in a cross-sectional study. The authors defined UEB as the high consumption frequency (>3 times/week) of at least one of the following items: caffeinated EDs, FFs, carbonated beverages, and SSBs. Adolescents who underestimated their body shape were likelier to have UEB. Adolescents with high-level stress and depression were more likely to have UEB. The underestimation group of boys showed a higher likelihood of UEB than the accurate estimation group. Similarly, girls who underestimated their body shape were likelier to have UEB than the accurate estimation group.

Yu and colleagues (89) conducted a case-control study in a sample of Taiwanese children, hypothesizing that children with ADHD drink more SSBs. The results showed a dose-response relationship between ADHD and SSBs consumption, indicating that children with higher SSBs consumption had a greater risk of having ADHD. Specifically, the adjusted OR showed that children who consumed ≥ 7 servings/week of SSBs had nearly 4-fold greater odds of having an ADHD diagnosis than the reference group. A logistic regression analysis excluding females suggested that boys with ≥ 7 servings/week of SSBs intake had a greater risk of having an ADHD diagnosis than the reference group.

4 Discussion

The findings of this scoping review suggest that higher SSBs intake is potentially associated with adverse sleep and mental health outcomes. These results are in line with recent systematic reviews reporting that frequent consumption of SSBs is linked to shorter SD, poorer overall SQ, and increased risk of depressive and anxiety symptoms (23–25, 97). However, these studies are largely descriptive, offering limited insights into the physiological pathways through which SSBs consumption may relate to sleep and mental health, which need to be further explored to better elucidate this relationship. A summary of the potential mechanisms proposed in the literature and adopted or advanced by the studies included to account for the observed associations is presented in Figure 2.

4.1 Potential mechanisms linking sleep and sugar-sweetened beverages

Several mechanisms have been proposed in the literature to explain the relationship between sleep patterns and food intake, including biological, cognitive, emotional, and behavioral aspects (98).

Disruptions of the circadian rhythm of appetite-related hormones and alterations in reward-related brain function were the mechanisms most frequently discussed across the reviewed studies, reflecting hypotheses primarily derived from the broader literature. Inadequate sleep seems to be associated with hormonal changes, such as decreased leptin and increased ghrelin levels, which may enhance appetite for energy-dense foods and beverages, including SSBs (34, 38, 49). Furthermore, short SD and poor SR during adolescence appear to be linked to circadian misalignment and dysregulation of reward-related neural responses to food stimuli, ultimately contributing to a greater preference for energy-dense and sugar-rich foods (45).

Another explanatory pathway proposed in the literature is that altered SD, SQ, and SR increase stress and fatigue, encouraging

adolescents to intentionally consume SSBs or caffeinated SSBs to boost alertness, reduce sleepiness, and improve mood (34, 43). Moreover, insufficient sleep prolongs wakefulness, giving adolescents more opportunities to eat and drink, often leading to the consumption of easily accessible foods and beverages among youth in the late evening, when parental supervision is limited (37, 41, 54).

Possible explanations for the association between SSBs consumption and sleep outcomes were also hypothesized in the opposite direction, namely the potential impact of both SSBs and EDs on sleep. Several of the reviewed articles, consistent with broader literature, further elaborated on these proposed mechanisms. Caffeinated SSBs appear to play a central role in this mechanism, as their excessive intake, especially in the evening, may impair SQ. This, in turn, increases daytime sleepiness and encourages further consumption of these beverages, creating a self-reinforcing sleep-caffeine cycle (48, 50). Additionally, high sugar intake may exert stimulating effects, disrupting SD and SQ, increasing nocturnal awakenings, and contributing to excessive daytime sleepiness (34, 53).

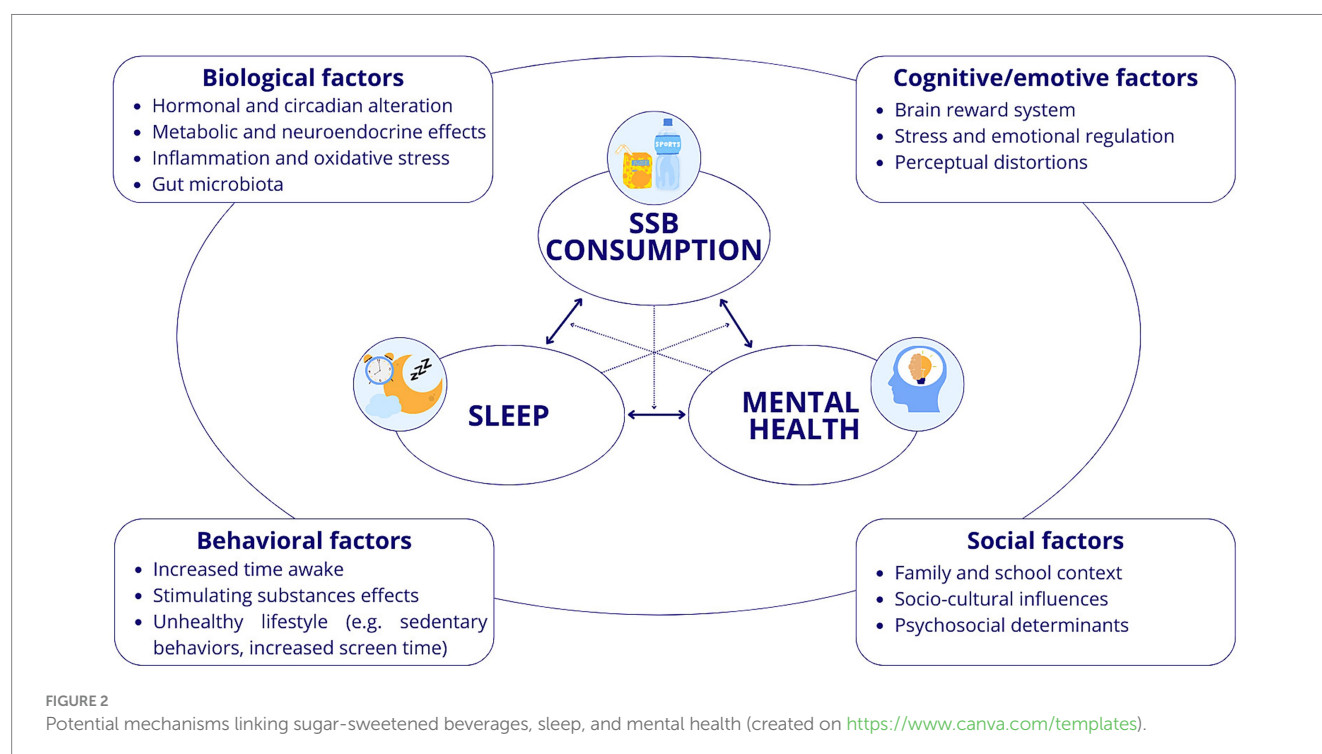
Some of the studies included in this review have also attempted to clarify whether SSBs may mediate the relationship between sleep and obesity, showing inconsistent results due to the cross-sectional nature of available studies (35, 45, 53, 56). Although this remains an emerging and understudied line of research, findings from a systematic review suggest that adolescents with poorer sleep tend to consume more SSBs, which may partially explain their higher obesity risk (99).

Finally, within the studies reviewed, several have explored potential gender differences in the relationship between SSBs consumption and sleep outcomes, although results remain inconsistent across studies. Nevertheless, some evidence suggests that males may be more likely to increase SSBs intake in response to shifts in sleep timing, such as sleeping in on weekends. This may be related to the fact that males are more likely to be evening types, which could influence this particular association. However, the mechanisms underlying these gender differences remain unclear and require further investigation (51).

4.2 Potential mechanisms linking mental health and sugar-sweetened beverages

The association between eating behavior and mental health is complex and appears to be influenced by an interplay of psychological, biological, and social factors (71, 87). The cross-sectional design of most of the included studies does not allow causal inferences or deeper exploration of this association (83, 85, 87, 89). Importantly, adolescents' mental health and wellbeing could shape their dietary behaviors; conversely, UEB may exacerbate poor mental health outcomes (72, 88).

Adolescents' eating behaviors appear to be strongly shaped by psychological state. Acute stress can suppress appetite through cortisol release, leading to under-eating, whereas prolonged stress often promotes compensatory overeating and a preference for energy-dense foods (67, 87). More broadly, psychological wellbeing supports healthier food choices, while individual personality traits – including neuroticism and agreeableness – further modulate responsiveness to food and tendencies toward emotional eating (71). In this context, SSBs may function as a coping strategy to manage anxiety and stress (88). Coping style plays a pivotal moderating role: maladaptive



strategies are linked to greater psychological distress, whereas cognitive and prosocial coping promote better mental health and wellbeing (76).

The evidence reviewed highlights several biological and neurobehavioral mechanisms - drawn from hypotheses proposed in the broader literature - through which SSBs consumption may influence PSs in adolescents. Excessive SSBs intake contributes to obesity, a known risk factor for poor mental health outcomes (61, 69, 77). SSBs alter gut microbiota composition, with downstream effects on hormonal regulation and brain function, potentially fostering emotional dysregulation (61, 69, 73). Moreover, high sugar intake promotes dopamine release, reinforcing consumption, and creating cycles of mood relief, appetite stimulation, and weight gain that increase psychological vulnerability (61, 70, 72). At the metabolic level, excessive fructose intake has been linked to insulin resistance, hypertension, and dyslipidemia, which not only increase cardiovascular risk but also activate the hypothalamic–pituitary–adrenal (HPA) axis, elevating glucocorticoids that are implicated in a spectrum of PSs (63, 70).

Across the included studies, there is a largely consistent hypothesis that unhealthy dietary patterns contribute to poor adolescent mental health through mechanisms involving oxidative stress, inflammation, and lack of micronutrients (e.g., B vitamins, omega-3 fatty acids, zinc, magnesium) essential for neural functioning and emotional regulation (64, 73, 74). Specifically, the combined consumption of FFs and SSBs appears to exert a synergistic effect, amplifying biological vulnerability to depression and anxiety (67, 73). The article by Zhang et al. (84) showed that both SSBs and takeaway dietary patterns independently and interactively increased the risk of psychological BPs: high SSBs consumption exacerbated the impact of frequent takeaway eating on PBPs. These UEB may be driven by environmental influences such as food advertising, ST, and home and school food availability, in line with the theory of planned behavior (100, 101). According to this

framework, lifestyle changes influence not only dietary behaviors but also the cognitive processes underpinning them, with SSBs consumption interacting with other behaviors such as ST and physical activity in mutually reinforcing ways (76). In this context, UEB tends to cluster and reinforce one another, suggesting that interventions targeting a single behavior (e.g., reducing SSBs intake) could generate broader positive spillover effects (84).

Diet is one of the “Big 6” lifestyle domains shaping adolescent mental health, alongside physical activity, ST, sleep, tobacco, and alcohol use (81).

Evidence suggests that excessive SSBs consumption combined with low levels of moderate-to-vigorous physical activity (MVPA), heightens the prevalence of PSs via multiple pathways (69). Conversely, regular MVPA is potentially associated with better psychological wellbeing, enhanced academic outcomes, and greater self-confidence (69). Findings from rural China further indicate that high SSBs consumption combined with low muscle strength amplifies the prevalence of PSs, likely through reduced physical activity, inflammation, neuronal damage and obesity-related declines in strength (77).

It has been observed that SSBs consumption also interacts with ST, showing both multiplicative and additive effects on DSs in adolescents (63). Specifically, when ST is low, SSBs consumption is associated with an increased risk of DSs (multiplicative interaction), whereas when high ST and SSBs consumption coexist, the risk of DSs further increases (additive interaction) (63). While multiplicative interaction reflects statistical interaction and is more suitable for exploring potential causal mechanisms, additive interaction reflects biological interaction and is primarily used to inform public health priorities and intervention needs (63). Findings from Xu et al. (72) support the hypotheses that consumption of FFs and/or SSBs during ST may enhance the association with DSs in adolescents, with possible underlying explanations rooted in social, behavioral, and neuropsychological

mechanisms, as suggested by other evidence in the literature. Moreover, differences reported in one of the included studies between weekday and weekend screen use highlight that weekend ST, often dominated by social media, is more strongly associated with DSs, likely due to reduced face-to-face interaction, social isolation, and exposure to cyberbullying (68, 80). ST may also serve as an avoidant coping strategy for existing DSs, reinforcing a negative cycle (80). Overall, these findings should be interpreted with caution due to the cross-sectional design of the studies.

The reviewed studies identify sleep as another potential mediator, aligning with hypotheses from the broader literature: DSs disrupt sleep regulation, and poor sleep in turn weakens prefrontal control over impulses, fostering reliance on high-sugar drinks as a form of emotional coping (65, 68). Excessive SSBs intake also disrupts circadian rhythms and hormonal balance, further impairing SQ and amplifying risks for anxiety and emotional instability (66). Both pathways converge on metabolic and neuroendocrine dysregulation—through cortisol, melatonin, and inflammatory responses—creating a cycle in which depression, poor sleep, and UEB reinforce one another (65, 66).

Overall, the results emphasize the importance of considering clustered risks in understanding adolescent mental wellbeing, and highlight the need for multidimensional, composite measures of risk to better identify vulnerable adolescents and guide prevention strategies (60, 63, 82).

Evidence from a short-term sugary drink cessation study (86) suggests that reducing habitual intake may lead to improvements in children's BPs and EPs. Reported benefits included reduced irritability, oppositionality, restlessness, and sleep disturbances, with minimal withdrawal symptoms (86). Several mechanisms may explain these effects: more stable glycemia; better SQ; expectancy effects and social desirability; individual differences in habitual caffeine intake, sensitivity to sugar, and compensatory dietary behaviors (86).

Zhang and colleagues (84) did not observe a direct link with hyperactivity in their sample, probably due to beverage heterogeneity and offsetting effects. In contrast, one study included in this review indicated a dose–response relationship between ADHD and SSBs consumption (89). The potential impact of SSBs on ADHD and BPs/EPs has been attributed to multiple components in the literature, including sugar, artificial food colorings (AFCs), and preservatives. Proposed mechanisms for the adverse effects of sugar include: (a) sugar intolerance (physical discomfort after eating or drinking sugary foods); (b) body's reactive hypoglycemia after ingestion; (c) decrease in intake of essential micronutrients; and (d) increased insulin released and brain serotonin concentration (linked to emotional dysregulation and later distress) (61, 84, 85, 89). However, reverse causality has also been suggested, whereby children with ADHD and BPs/EPs may have a greater propensity to consume SSBs (89). Evidence regarding AFCs and preservatives is inconclusive, and concerns remain, especially over azo dyes and compounds like sodium benzoate (89, 102). Given the multifactorial nature of BPs and the potential confounding role of food synergy, attributing these problems solely to SSBs intake is overly simplistic (83, 85, 89).

Finally, another interesting outcome was studied in relation to SSBs intake by Kim and colleagues (90). This study indicates that adolescents who underestimate their body shape are more likely to engage in UEB. Adolescents who misperceive their body shape are more likely to adopt unhealthy eating or weight control behaviors, driven by misconceptions or reduced motivation to adopt healthy

habits or pursuit of an idealized body image (90, 103). Sociocultural factors, including media exposure and idealized body norms, contribute to body misperception, with girls tending to overestimate and boys to underestimate their body size, influencing sex-specific eating behaviors (64, 90). Importantly, in the study by Kim et al. (90) both sexes show a consistent association between underestimation of body shape and UEB, suggesting that interventions should target adolescents regardless of sex. However, given that most of the current evidence has sought to identify a relationship between exaggerated body size and mental problems or disordered eating focusing mainly on girls, future studies should determine sex-based associations between underestimating body shape and food consumption (90).

4.3 Strengths and limitations

To the best of our knowledge, this is the first review specifically focused on the relationship between SSBs intake, sleep, and mental health outcomes in adolescents, providing a comprehensive overview of the potential mechanisms currently available in the literature underlying these associations. Another strength is that, addressing adolescence, SSBs, and the various dimensions of sleep, the present work adopted detailed and widely shared definitions, considering established reference standards when available (29, 31).

However, the studies included present several limitations that warrant careful consideration. First, most of the studies had a cross-sectional design that does not allow for confirmation of causal relationships, highlighting the need for further randomized controlled trials and longitudinal cohort studies. Second, several studies included children and adolescents within the same sample, as well as individuals aged 18–19 years as part of an adult population, even though these age groups show biological, behavioral, and social differences that may distinctly influence the relationship under investigation. Moreover, these studies did not perform age-stratified analyses, thereby limiting the ability to draw adolescence-specific inferences. Third, most of the studies came from Asia, particularly China, followed by the Americas, whereas in countries that have recently seen an increase in SSBs consumption, the phenomenon remains largely unexplored. This may be related to a potential selection bias in this review, which only included articles in English. These patterns underscore the need to extend the search to evidence published in languages other than English and to conduct such investigations in currently underrepresented regions. Fourth, the lack of a standard definition of SSBs led to differences in how studies assessed these beverages, sometimes including or excluding certain types, making comparisons difficult. In addition, given the wide variety of beverages included in the SSBs group, it may be useful in future to conduct analyses by subgroup, in order to better clarify their potential effects. Fifth, most studies on sleep health focused on SD. Given that different dimensions of sleep interact with each other and contribute equally to overall sleep health (31), it would be desirable for future research to examine these other dimensions more thoroughly. Finally, most of the included studies assessed SSBs consumption and sleep and mental health outcomes through self-reported measures, contributing to potential recall, social desirability, and response biases.

5 Conclusion

Overall, the findings of this scoping review advance the hypothesis that higher SSBs intake may be involved in a potential bidirectional association with adverse sleep and mental health outcomes. The possible mechanisms linking SSBs consumption to sleep dimensions appear to be better described in the existing literature, whereas the pathways connecting SSBs intake with mental health outcomes remain less delineated due to their greater complexity and variability.

The main gaps identified in the currently available evidence warrant cautious interpretation of the findings and underscore the need for future studies that: adopt interventional and longitudinal designs; focus specifically on adolescence, in accordance with the WHO definition; are conducted in regions experiencing an increased prevalence of SSBs consumption, as well as sleep and mental health disorders; examine each SSB subgroup individually; and address all dimensions of sleep. Conducting research focused on specific age subgroups and establishing a shared definition of SSBs represent key priorities for improving study comparability.

The present review also emphasizes the importance of framing SSBs consumption not only as a nutritional concern but also as a behavioral and psychological risk factor in adolescence, highlighting the need for school- and community-based prevention strategies that adopt a comprehensive approach to fostering healthier environments.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Author contributions

ADN: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft. EC: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft. LR: Supervision, Writing – review & editing. MS: Project administration, Writing – review & editing.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fnut.2025.1718230/full#supplementary-material>

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