ORIGINAL ARTICLE

Factors related to overweight among students in remote service areas of Northern Thailand: the structural equation model

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ABSTRACT

Although the causal relationships of personal, behavioral, and environmental factors related to overweight in adolescents have been studied, there is limited evidence in northern Thailand. This study aimed to investigate the causal relationships of these factors among high school students in Health Region 1, northern Thailand. The study was conducted between November 2021 and March 2022 among 2,250 high school students. A multi-stage sampling method and structural equation modeling (SEM) were used to investigate the causal relationships between personal, behavioral, and environmental factors and overweight. Most participants were female (60.6%) with an average age of 17.0 years, free from chronic illnesses (96.3%), of LANNA ethnicity (56.8%), having moderate dietary habits (48.1%) and insufficient physical activity (83.0%). Weight and height were directly correlated with overweight. Similarly, a causal relationship was observed between dietary behavior (snacks, sweets, fast food, and condiments) ($p < 0.05$), and physical activity (incorporating exercise and sports, recreational activities, screen time, and sedentary behaviors) ($p < 0.001$). The model's goodness-of-fit indices indicated an acceptable fit ($\chi^2 = 262.356$, $df = 59$, $P = 0.082$, $\chi^2/df = 1.65$, RMSEA = 0.017, SRMR = 0.026, CFI = 0.984, TLI = 0.979), which can explain the variance = 72.27 %. In conclusion, dietary behaviors, particularly the consumption of snacks, sweets, fast food, and condiments, as well as physical activity were important factors for being overweight in high school students. These findings can serve as essential knowledge for policy development to promote interventions for improving nutritional status in adolescents.

Keywords:
adiposity, dietary behavior, physical activity, overweight, structural equation modeling

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INTRODUCTION

Overweight in children is a global health issue linked to adverse lifelong outcomes.[1-3] A significant number of children with obesity is increasing, with projections estimating an increase from158 million cases in 2020 to 254 million by 2030. As a result, the growing economic burden of health care costs for overweight and obesity among children is a concern.[4] In the Asia-Pacific region, it is estimated that more than half of the global population will be living with overweight,[5] with nearly half of children also becoming overweight, by 2030. At the same time, Malaysia has the highest prevalence of children with overweight, at 13.3%, followed by Thailand, at 8.5%.[6] Therefore, Thailand has the second position among the 10 ASEAN member states in terms of the prevalence of childhood overweight. The northern region of Thailand is divided into two health administrative areas with 13 provinces. Health Region 1 comprises eight provinces: Chiang Mai, Lamphun, Lampang, Phrae, Nan, Phayao, Chiang Rai, and Mae Hong Son, while Health Region 2 includes the rest of the five provinces.[7] In Health Region 1, 28.0% of high-school students are living with overweight, which is higher than in Health Region 2 (23.8%).

Being overweight has both short-term and long-term consequences. [8,9] For example, high school students who are overweight may experience physiological and psychological comorbidities. Obesity is a multifactorial condition influenced by personal, behavioral, and environmental factors, with a higher risk among students whose parents have chronic illnesses. [10] Overweight status is associated with unhealthy dietary patterns such as fast food, high-calorie food consumption, regular dining out, sedentary behavior, insufficient sleep time, and stress.[11,12] Environmental factors also play an important role, as a study on twins living apart suggested that different environments impact the incidence of obesity. [13] An uncontrolled environment outside the residence contributes to overweight and, over time, increases the risk of chronic non-communicable diseases.[1] [4] Additionally, urban housing characteristics are associated with a higher prevalence of overweight compared to rural areas.[15]

As mentioned, three important risk factors, including personal, behavioral, and environmental factors, have been well studied for their direct effects on overweight and obesity in children. However, studies in northern Thailand Health Region 1, which has a higher prevalence of overweight, are scarce. Thus, the present study aimed to determine the direct effect of these risk factors associated with overweight among students throughout their mediation roles, using structural equation modeling (SEM).

METHODS

Study design

A cross-sectional quantitative study was carried out in schools within Health Region 1 (Chiang Mai, Lamphun, Lampang, Phrae, Nan, Phayao, Chiang Rai, and Mae Hong Son) during the 2021 academic year.

Population and sample

The participants in this study were 179,935 high school students. The sample groups were determined using the rule for sample size in SEM, which states that the ratio of sample units to observed variables should be 15–20 sample units per observed variable.[16] This ensures that the sample is representative of the population and sufficient to produce reliable results. This study included 25 observed variables (for a total of 135 items), and a confidence level of 95% was set with an acceptable margin of error of no more than 5%. The initial sample size was estimated based on these requirements, using 15 sample units per

observed variable, resulting in a minimum sample size of 2,025 individuals (135×15). However, to account for potential missing data, the sample size was increased by 10% to ensure that the study would have sufficient participants even if some data were missing: $n_{adj} = n/1\text{-}R = 2025/(1 - 0.10) = 2025/0.9 = 2{,}250$ individuals, shown in Figure 1. Afterwards, the study was conducted in a multi-stage sampling process, which consisted of the following steps: (1) The researchers used stratified random sampling based on the size of provinces, categorizing them into small, medium, and large provinces. We then randomly selected two provinces from each category. The provinces were then further stratified based on school size, categorizing them as small, medium, large, and large special schools within Health Region 1. Students who voluntarily agreed to participate in the study met the inclusion criteria, and students who were absent or suffered an acute illness during the study period were excluded.

We randomly selected two schools from each size category, resulting in eight schools per province. The researchers then determined the number of students to be sampled from each selected school in proportion to the school's total student population. We also set inclusion criteria for participants, which included being students in Grades 10–12, being willing to participate in data collection, obtaining consent from parents and school administrators, having communication skills, and not having any medical conditions that would hinder their participation. Exclusion criteria included individuals taking medications or dietary supplements that could affect obesity, such as thyroid medications, contraceptives, or antidepressants, and those who did not provide complete information.

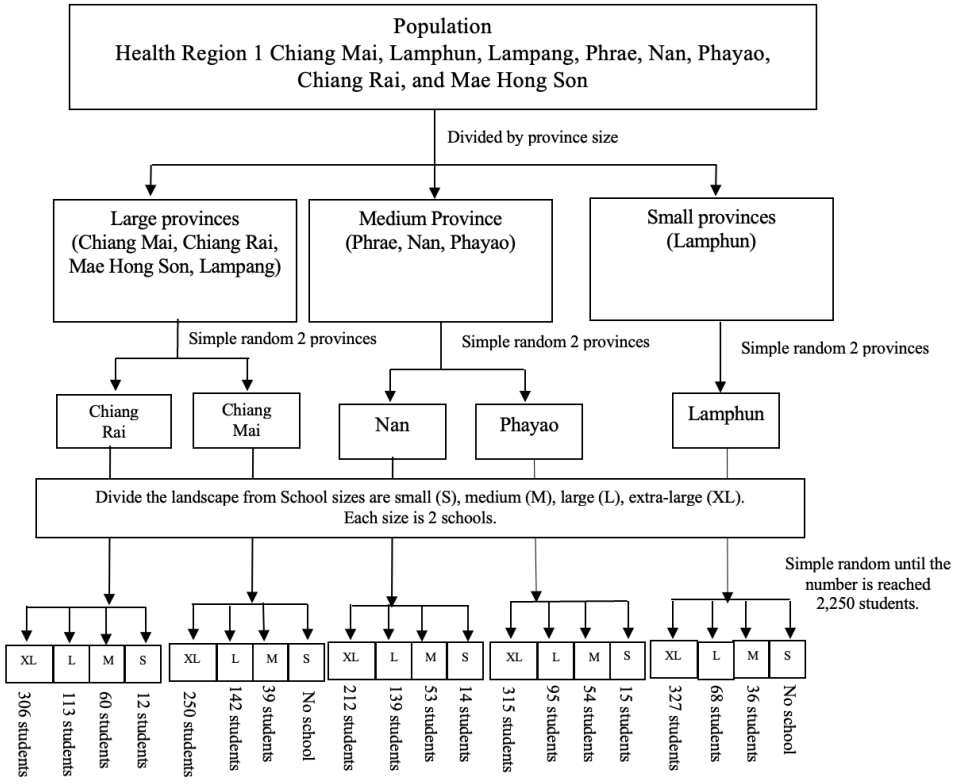

Figure 1. Summary of Phase 1 sample size sampling method

Data collection

Section 1

The data collection tools comprised three components, focusing on personal factors through closed-ended questions. Part 1 covered basic personal information, including gender, school income, chronic illnesses, ethnicity, and parental data (e.g., life status, level of education, body mass index (BMI) , occupation, and chronic illnesses). Part 2 addressed criteria for assessing body composition (e.g., age (yr), biceps (mm), triceps (mm), subscapular (mm), suprailiac (mm), sum 4 skinfold thickness (mm), body fat (mm), waist circumference (cm), hip circumference (cm), weight (kg), height (cm)) and encompassing BMI-for-age. Part 3 assessed participants' knowledge regarding overweight and dietary habits using a scoring criterion of 1 given for correct answers and 0 for incorrect answers, with a maximum score of 10 points. The score was categorized as high: 6.68–10.00 points, moderate: 3.34–6.67 points, and low: 0.00–3.33 points.[17] Part 4 assessed self-efficacy and outcome expectancies for overweight and dietary habits. This section comprised 12 questions, scored on a scale of 1 to 5, and was categorized into three levels: high (44.01–60.00 points), moderate (28.01–44.00 points), and low (12.00–28.00 points).[18] Part 5 assessed attitudes toward overweight conditions and dietary habits, responses ranged from 1 to 6, with a maximum score of 60 points, categorized as high (43.34–60.00 points), moderate (26.67–43.33 points), and low (10.00–26.66 points).[19]

Section 2

Questions on behavioral factors were divided into four parts. Part 1 addressed dietary behavior within the past month based on the Thai Recommended Daily Intakes (RDI), with a total score of 216 points (good dietary habits: 156.02–216.00 points, moderate dietary habits: 96.01–156.00 points, and poor dietary habits: 36.00–96.00 points). Part 2 assessed physical activity in various formats (Thailand Physical Activity Children Survey Ver. 14–17) over the past 7 days. This part classified physical activities into (1) Adequate physical activity (i.e., Exercise, Sports, Recreation for151 minutes or more per week), (2) insufficient physical activity (i.e., Exercise, Sports, Recreation for 0-150 minutes per week), (3) Sedentary behavior (i.e., on-screen, Sit still for 121 minutes or more per day), and (4) Not Sedentary behavior (i.e., on-screen, Sit still for 0-121 minutes per day).[20] Part 3 covers sleep behavior, surveyed using the Thai version of the Pittsburgh Sleep Quality Index, with scores ranging from 0 to 21 points (good sleep quality: 0–5 points; poor sleep quality: 6–21 points). Part 4 addresses stress perception on a 4-point scale, with a total stress score ranging from 10 to 40 points (high: 32–40 points, moderate: 21–31 points, and low: 10–20 points). [21]

Section 3

The survey of environmental factors influencing overweight conditions was divided into three parts. Part 1 covered the characteristics of the housing and community exercise facilities. Part 2 addressed the health and nutrition activities within the community and schools, home cooking practices, and food shop/convenience store locations and distances. Part 3 examined the use of food delivery applications.[22]

Content validity was assessed by presenting the questionnaire to six experts. [23] The index of item-objective congruence (IOC) was calculated in detail: Section 1 (Parts 1–5) had values of 0.82, 0.62, 0.69, 0.70, and 0.66, respectively; Section 2 (Parts 1–4) had values of 0.74, 0.62, 0.81, and 0.89, respectively; and Section 3 (Parts 1–3) had values of 0.74, 0.59, and 0.63, respectively. The reliability of the instrument was evaluated using Cronbach's alpha.[23] The results indicated excellent reliability for knowledge, dietary behavior, and stress (Cronbach's $\alpha = 0.96$, 0.96, and 0.98, respectively); good

reliability for perception, attitude, and sleep (Cronbach's α = 0.82, 0.79, and 0.89, respectively); and moderate reliability for physical activity (Cronbach's α = 0.74).

Statistical Analysis

Continuous variables are summarized as means and standard deviation (SD), and categorical variables as frequencies and percentages. First of all, the data were prepared to ensure accuracy and completeness. Figure 2 shows the steps taken during the analysis. The SEM was encoded and analyzed using exploratory factor analysis (EFA) to uncover latent variables within observed or measured variables, using Analysis of Moment Structures (AMOS) v. 24.0. The results were analyzed at a significance level of 0.05. Data analysis employed an EFA approach and examined the following aspects: (1) pre-analysis data checks, including verification of data accuracy and completeness; (2) encoding and data recording, with automation utilizing computer programs for efficient data handling; and (3) the application of EFA to reveal latent variables underlying observable ones. This approach to data validation and encoding established a solid foundation for comprehensive analysis to unveil hidden variables and understand the underlying data structure. Statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS) v. 25.0 (IBM Corp., Armonk, NY, USA). $p < 0.05$ were regarded as statistically significant. The results were analyzed at a significance level of 0.05.

Ethical Approval

This study was approved by the Human Research Committee of Mahasarakham University in Thailand and received ethical clearance under reference number 337-280/2564 on October 21, 2021, and reference number 102-128/2566 on March 23, 2023. It was also registered with the Thai Clinical Trials Registry (TCTR) under the auspices of the Medical Research Foundation (MRF) with registration number TCTR20220606004 on June 6, 2022

RESULTS

Table 1. Characteristics of Personal Factors, Behavioral Factors, Environmental Factors sampled (n=2,250)

Variables	n (%) or mean ± SD	
	n	%
Personal Factors		
Gender		
Male	887	39.4
Female	1,363	60.6
School income		
< 50 Baht per day	1,431	63.6
50-100 Baht per day	810	36.0
101-200 Baht per day	6	0.2
≥201 Baht per day	3	0.2
Chronic illnesses		
No disease	2,167	96.3
Disease (e.g., asthma, anemia, allergy)	83	3.7

Variables	n (%) or mean ± SD	
	n	%
Ethnicity		
LANNA	1,277	56.8
No LANNA	973	43.2
Level of knowledge		
high	725	32.2
Moderate	1,361	60.5
Low	164	7.3
Level of Self-efficacy and outcome expectancies.		
high	381	16.9
Moderate	1,708	75.9
Low	161	7.2
Level of Attitude		
high	30	1.3
Moderate	897	39.9
Low	1,323	58.8
Body composition	**Male Mean±SD)**	**Female Mean±SD)**
Age (yr)	16.0±0.6	17.0±0.6
Biceps (mm)	9.72±7.27	11.32±5.26
Triceps (mm)	9.62±6.39	12.87±5.66
Subscapular (mm)	12.04±7.18	14.89±7.01
Suprailiac (mm)	12.39±8.63	15.61±6.98
Sum 4 skinfold thickness (mm)†	43.76±26.42	54.80±21.59
Body fat (mm) ‡	15.92±6.32	26.45±4.97
Waist circumference (cm)	73.73±11.38	70.54±9.63
Hip circumference (cm)	91.04±9.89	90.67±8.96
Weight (kg)	61.40±13.91	53.00±1.73
Height (cm)	168.04±13.03	157.37±6.37
BMI for age		
Weight not exceeding (<5th Percentiles)	743(33.0)	1,142(50.8)
Risky and overweight (≥85th to <95th Percentiles)	97(4.3)	158(7.0)
Obesity (>95th Percentiles)	47(2.1)	63(2.8)
Parent	**father n(%)**	**mother n(%)**
Alived		
Died	216(9.6)	157(7.0)
Alive	2,034(90.4)	2,093(93.0)
Level of education		
Primary school or below	844(37.5)	920(40.9)
Junior high school or above	1,190(52.9)	1,172(52.1)
No Data (Died)	216(9.6)	157(7.0)
BMI		
Underweight (<18.5 Kg/m2)	728(32.4)	1,009(44.8)
Normal (18.5-22.9 Kg/m2)	894(39.7)	904(40.2)
Overweight (23.0-24.9 Kg/m2)	320(14.2)	88(3.9)
Class I obesity (25.0-29.9 Kg/m2)	68(3.0)	79(3.5)
Class II obesity (>29.9 Kg/m2))	24(1.1)	13(0.6)
No data (died)	216(9.6)	157(7.0)
Occupation		
Haven't job	122(5.4)	143(6.4)

Variables	n (%) or mean ± SD	
	n	%
Have a job	1,912(85.0)	1,950(86.7)
No Data (Died)	216(9.6)	157(7.0)
Chronic illnesses		
No disease	1,493(66.4)	1,481(65.8)
Disease	541(24.0)	612(27.2)
No Data (Died)	216(9.6)	157(7.0)
Behavioral Factors		
Levels of food consumption behavior		
Good dietary habits	176	7.8
Moderate dietary habits	1,083	48.1
Poor dietary habits	991	44.1
Levels of Physical activity		
Adequate physical activity (i.e., Exercise, Sports, Recreation 151 minutes or more per week)	382	17.0
insufficient physical activity (i.e., Exercise, Sports, Recreation 0-150 minutes per week)	1,868	83.0
Level of sedentary behavior		
Sedentary behavior (i.e., on-screen, Sit still 121 minutes or more per day)	1,868	83.0
Not Sedentary behavior (i.e., on-screen, Sit still 0-121 minutes per day)	382	17.0
Quality of Sleep		
good	868	38.6
poor	1,382	61.4
Levels of Stress		
high	110	4.9
moderate	1,581	70.3
low	559	24.8
Environmental Factors	**n**	**%**
Housing characteristics		
In municipalities	1,187	52.8
Outside municipality	1,063	47.2
Community exercise Facilities		
haved	1,007	44.8
haven't	1,243	55.2
Health and nutrition activities within the community and schools		
haved	840	37.3
haven't	1,410	62.7
Home cooks		
student	140	6.2
Grandparents	669	29.7
Parents	1,344	59.7
other (e.g., Brothers, aunts, chef)	97	4.3
Food shops/convenience stores near the house		
haved	1,505	66.9
haven't	745	33.1
Distance from home to shops/convenience stores (n=1,505)		
≤500 metres	1,398	62.1

Variables	n (%) or mean ± SD	
	n	%
501-1,000 metres	71	3.2
1,001-1,500 metres	16	0.7
1,501-2,000 metres	6	0.3
> 2,000 metres	14	0.6
Food delivery application		
Used	646	28.6
Not Used	1,604	71.4

Annotation:

† The sum of 4 positions refers to the average (i.e., biceps, triceps, Subscapular, and suprailiac) and

‡ Body fat percentage is the average body fat to the equation of Durnin and Womersley (1974) by sum of 4 positions refers to the average (i.e., biceps, triceps, subscapular, and suprailiac)

Personal Factors

A total of 2,250 participants were included in the study. Table 1 shows the characteristics of participants. The majority of participants were female (60.6%). Approximately 30.0% of the participants received income less than 50 Baht daily, 96.3% had no chronic illnesses, and 56.8% were of LANNA ethnicity. The parents of most students were alive (>90%) and had graduated from junior high school or above (Roughly 52%). Thirty-nine percent of fathers had a normal BMI, while 44.8% of mothers were underweight. Most fathers (85.0%) and mothers (86.7%) had a job, while 66.4% of fathers and 65.8% of mothers had no chronic diseases. In terms of body composition, most markers were in the normal ranges except for risk, overweight and obesity. Most students (50.8% of females, 33.0% of males) had normal weight and moderate knowledge of overweight and dietary behavior (60.5%). Perceptions of self-efficacy and outcome expectations related to overweight and dietary behavior were moderate (75.9%). Attitudes toward overweight and dietary behavior were at a low level (58.8%).

Behavioral Factors

Dietary behavior of most participants fell into the category of "Moderate eating habits" (48.1%). Physical activity was generally insufficient regarding children's recommendations (83.0%). Sedentary behaviors were found in 83.0% of participants, and 61.4% experienced poor sleep quality. The majority of participants (70.3%) reported experiencing moderate stress (Table 1).

Environmental Factors

The characteristics of the residential environment within the community (N = 2,250) are shown in Table 1. The residences of students were located in municipality areas (52.8%), but 55.4% of the community lacked exercise facilities. Furthermore, there is a notable absence of health and nutrition activities within the community and schools, with 62.7% reporting this deficiency. Food preparation was done by their parents (59.7%). The living environment typically had food shops/convenience stores near the house within a convenient travel distance. At least one shop was located within a 500-m radius (66.9%), and households had access to such a shop (62.1%). However, most respondents (71.4%) did not use mobile applications for food delivery.

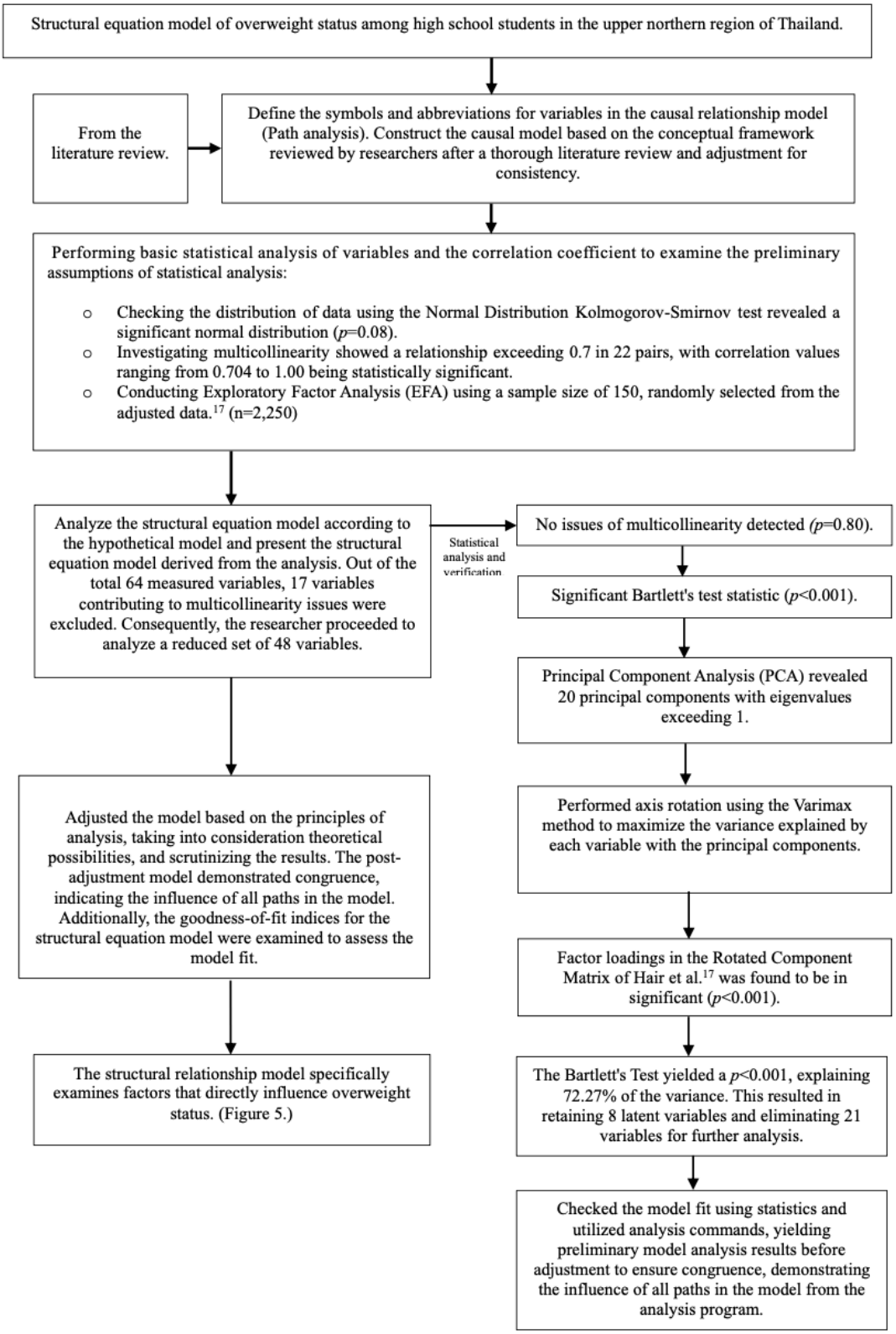

Figure 2. Summarize the steps of analyzing the Structural equation model.

Results of Confirmatory Factor Analysis

Figure 2 shows, the summary of the steps involved in analyzing the Structural equation model using the Normal Distribution Kolmogorov-Smirnov test. The findings found that there was a significant normal distribution ($p > 0.05$). Multicollinearity was tested (>0.7) to check before importing data into the analysis. Exploratory Factor Analysis (EFA) prevents repeated measurement of variables that convey the same thing or with the same meaning by selectively eliminating or retaining variables based on the judgment of the researcher. From the literature review, referring to the reasons, concepts, and related theories, significant relationships were found in 22 pairs of variables with a relationship value (>more than 0.7), and the range of relationship values between 0.704-1.00 was statistically significant. When the variables were cut off as described above, the relationship of the new variables was analyzed. There was no problem of multicollinearity. The Run EFA using random sampling from 150 adjusted data by the conceptual model of study is shown in Figure 3.

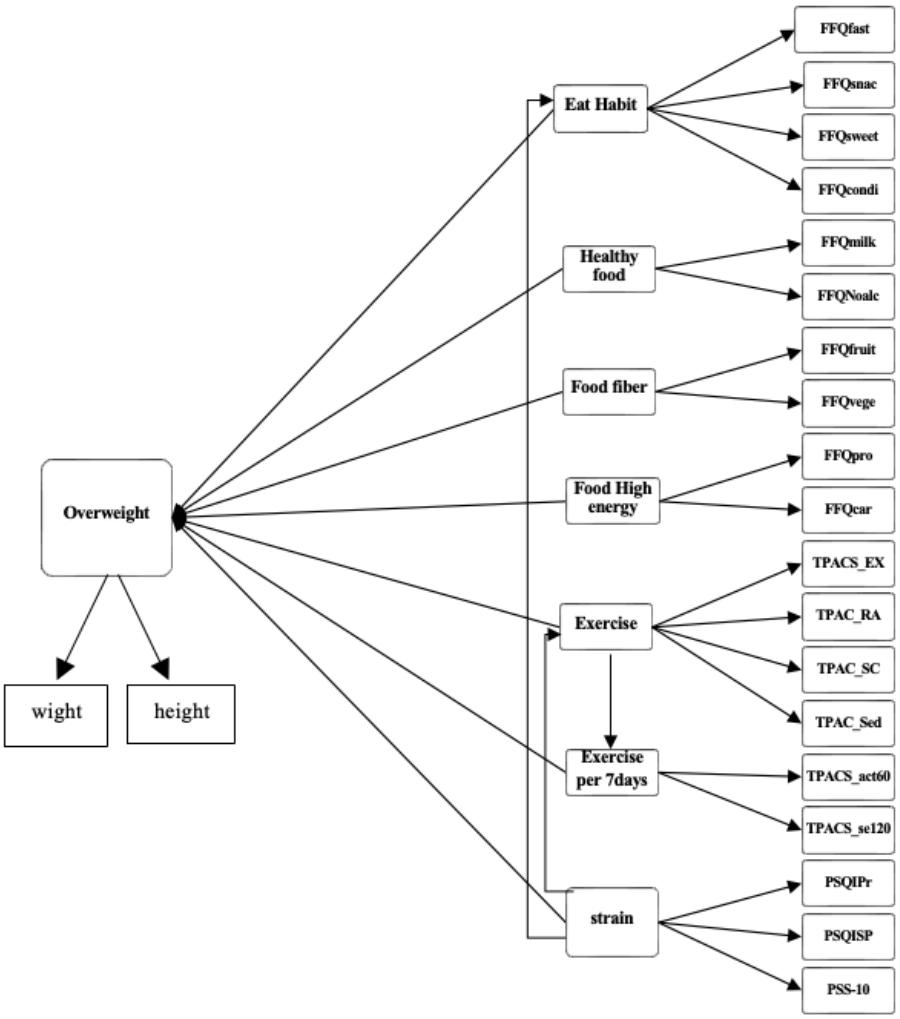

Figure 3. A conceptual model of overweight among high school students

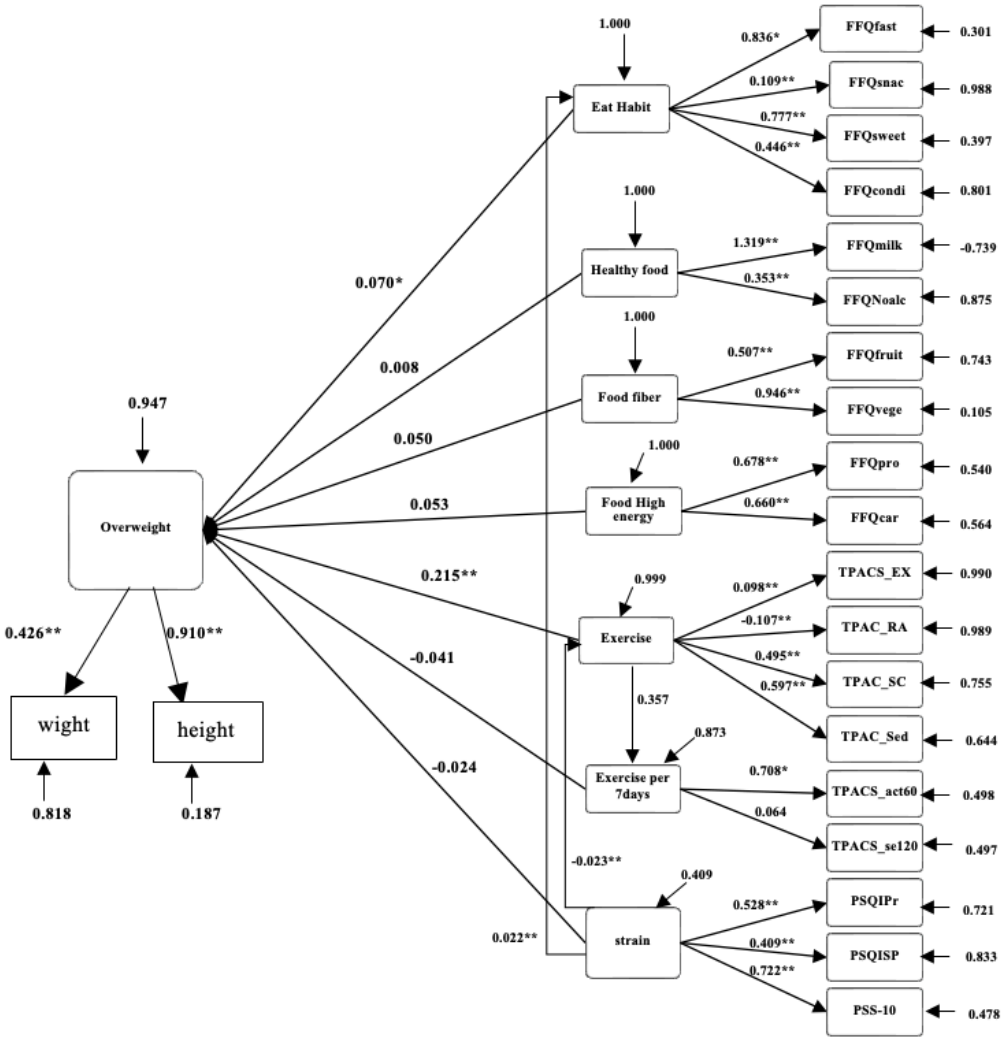

Figure 4. The model after adjustment for empirical consistency all influence curves.

Structural equation model analysis according to the hypothetical model and presentation of the structural equation model from the analysis found that there were 48 observable variables and 150 sample units after considering the criteria for factor extraction by VARIMAX rotation. Figure 4 shows, the model after adjustment for empirical consistency with all influence curves after EFA. The factors obtained from component analysis were used to determine the causal model analysis model followed by confirmatory factor analysis (CFA) before adjusting for empirical consistency. Bartlett's Test produced a value of 0.70, $p < 0.001$, which can explain the variance = 72.27 %. Table 2, indicates that the data was suitable for factor analysis, including eight latent variables and 21 observed variables.

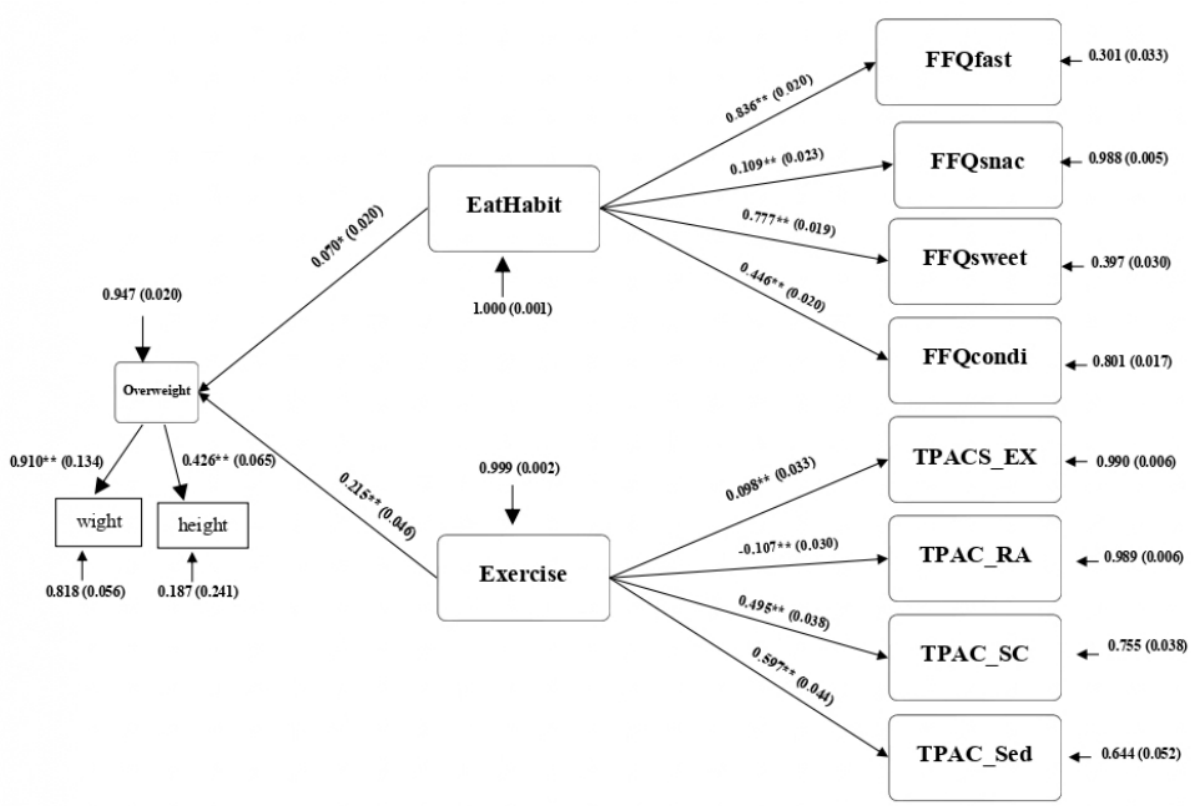

Figure 5. The structural equation model with specific factors directly correlating overweight status
*Annotation: **p <0.001, *p=0.020*

Table 2. Harmony index value of the final structural model in research

final model component variables (Variables: 8 latent,21 observable)	weight matrix element			
	β	SE	t	R^2
1.Eat Habit				
1.fast food (FFQfast)	0.836**	0.020	41.983	0.699**
2.snack (FFQsnac)	0.109**	0.023	4.695	0.012**
3.sweets (FFQsweet)	0.777**	0.019	40.028	0.603**
4.condiments (FFQcondi)	0.446**	0.020	22.858	0.199**
2.Healthy food				
5.milk (FFQmilk)	1.319**	0.309	4.274	0.751*
6.no alcohol (FFQNoalc)	0.353**	0.084	4.211	0.125*
3.Food fiber				
7.fruit (FFQfruit)	0.507**	0.114	4.447	0.257*
8.vegetable (FFQvege)	0.946**	0.210	4.497	0.895*
4.Food High energy				
9.meat-eggs (FFQpro)	0.678**	0.139	4.876	0.460*
10.rice-flour (FFQcar)	0.660**	0.134	4.931	0.436*
5.Exercise				
11.exercise and sports (TPAC_EX)	0.098**	0.033	2.995	0.010
12.recreation (TPAC_RA)	-0.107**	0.030	-3.559	0.011
13.screen (TPAC_SC)	0.495**	0.038	13.076	0.245**
14.sedentary activities (TPAC_Sed)	0.597**	0.044	13.619	0.356**

final model component variables (Variables: 8 latent,21 observable)	weight matrix element			
	β	SE	t	R^2
6.Exercise per 7 days				
15.physical movement, running, playing, exercising for 60 minutes (TPACS_act60)	0.708**	0.010	67.564	0.502**
16.outdoor activities with friends for 120 minutes (TPACS_se120)	0.064	0.086	0.738	0.004
7.Strain				
17.sleep problems past 1 month (PSQIPr)	0.528**	0.029	18.019	0.279**
18.sleep quality (PSQISP)	0.409**	0.026	15.639	0.167**
19.stress (PSS-10)	0.722**	0.036	20.169	0.522**
8.Overweight				
20.wight	0.426**	0.065	6.529	0.182**
21.height	0.910**	0.134	6.750	0.813**

*Annotation: significance * ($p < 0.05$), ** ($p < 0.001$)*

Table 3. The total influence, indirect influence, direct influence value, and statistics of causal relationship patterns on the nutritional status of school-age children

Variable	Eat Habit			Exercise			Exerciseper7days			Overweight		
	TE	IE	DE	TE	IE	DE	TE	IE	DE	TE	IE	DE
Eat Habit	-	-	-	-	-	-	-	-	-	0.07	0.00	0.070*
Healthy food	-	-	-	-	-	-	-	-	-	0.008	-	0.008
Food fiber	-	-	-	-	-	-	-	-	-	0.050	-	0.050
Food energy	-	-	-	-	-	-	-	-	-	0.053	-	0.053
Exercise	-	-	-	-	-	-	0.357	-	0.357**	0.215	0.00	0.215**
Exerciseper7days	-	-		-	-	-	-	-	-	-0.041	-	-0.041
Strain	0.022	-	-0.022	-0.023	-	-0.023	-0.008	-0.008	-	-0.024	-	-0.024
Goodness of Fit	Chi-square = 262.356, df = 159 , p-value = 0.082 , χ^2/df = 1.65 , RMSEA = 0.017 , SRMR = 0.026 , CFI = 0.984, TLI = 0.979											

Latent Variables	Eat Habit	Healthy food	Food fiber	Food energy	Exercise	Exerciseper 7days	Strain	Overweight
Measurement capacity	0.000	-	-	-	0.001*	0.127**	-	0.053*

The findings provide valuable insights for the development of research programs in the subsequent phases of this study. The specific factors directly correlating with overweight status are further detailed. The confirmatory factor analysis (CFA), as hypothesized, exhibits a good fit with the observational data. Table 3 presents the total influence, indirect influence, direct influence values, and statistics of causal relationship patterns on the nutritional status of school-age children. The chi-squared statistic (χ^2) yielded a value of 262.356, $df = 159$, $p = 0.082$, $\chi^2/df = 1.65$, RMSEA = 0.017, SRMR = 0.026, CFI = 0.984, TLI = 0.979. Figure 5 shows that there was a direct correlation between weight and height and overweight status. The behavioral factors include (1) eating habits with an effect size of 0.07 (e.g., snacks, sweets, fast food, condiments) and (2) physical activity, which had a significant impact (e.g., incorporating exercise and sports, recreational activities, screen time, and sedentary behaviors).

DISCUSSION

The SEM of overweight status among high school students in the northern region of Thailand revealed that the factors directly influencing the nutritional status of adolescents, as measured by weight and height, include (1) dietary behavior factors (e.g., snacks, sweets, fast food, condiments) and (2) physical activity factors (e.g., incorporating exercise and sports, recreational activities, screen time, sedentary behaviors). This study demonstrates how SEM can facilitate the testing of complex health behavior models with multiple variables and outcomes. This approach is beneficial for prioritizing interventions and resource allocation for effective future strategies.

Notably, dietary behaviors significantly affect overweight status, which aligns with the findings of Mohammadbeigi et al.,[24] who found a statistically significant association between consuming fast food and overweight status. This finding is also consistent with the research conducted by Ma et al.,[25] who investigated the relationship between the lifestyle habits of Chinese students and overweight status. Their study identified that low levels of physical activity, high levels of sedentary behavior, and poor dietary habits were associated with a significantly increased risk of overweight status.[26] This suggested that having a poor dietary pattern among high school students has a direct impact on overweight status.

Apart from the findings of dietary intake habits, the role of students' physical activity in our study was also confirmed by the results of SEM, which showed a direct effect on the occurrence of overweight status among high school students. Thus, dietary intake habits and physical activity had a direct effect, which agrees with previous evidence. For example, a study that examined factors related to overweight status in the Laotian population found that factors such as consuming food outside the home and low levels of physical activity were significantly associated with overweight status. Liang, Lee, and Yeh,[27] explored the relationship between leisure-time physical activity and weight status in Taiwanese adolescents. They found that physical activity was significantly associated with a reduced risk of overweight and obesity in adolescents. Su et al. [28] studied the long-term relationship between physical activity and sedentary behavior with weight status in Chinese students. They discovered that sedentary behavior in males was significantly associated with overweight status. Roy et al. [29] investigated stress, eating behavior, overweight status, and obesity in urban adolescents and found that increased physical activity was significantly

associated with reduced weight. Our findings are consistent with a study conducted among students from the North of Thailand which suggested that having a poor dietary pattern and low activity had a direct effect on exceeding the standard weight regardless of whether they are in urban or rural areas.

Khan et al.[30] examined the differences in physical activity and dietary behavior among adolescents in Bangladesh. They found that engaging in sedentary activities during leisure time, lack of physical activity, poor nutrition, alcohol consumption, and fast-food consumption were risk factors significantly associated with overweight status. These findings conflict with those of Chong et al.,[31] who conducted a study in Malaysia to investigate the prevalence of, and factors related to, overweight status. They found that physical activity and leisure-time physical activity were not significantly associated with overweight status in overweight individuals. These findings differ from the causal factors of overweight status. Vieira et al.[32] studied the effects of physical activity on weight status in Polish students and found that a lack of physical activity in females was significantly related to overweight status. Furthermore, Zhao et al.[33] investigated the consumption of fast food and its relationship with overweight status and health issues among schoolchildren in China. Their study showed an increased rate of fast-food consumption with increasing age among students but did not find a statistically significant association with overweight status. Lastly, Khan et al.[30] reported that physical activity and dietary behavior were not significantly related to overweight status in overweight individuals. In addition to the factors analyzed by SEM that are directly related to the occurrence of overweight status, several studies reported no relationship between dietary behavior factors, physical activity factors and overweight. The limitation of the present study is that it was conducted in limited areas. Therefore, the findings cannot be generalized to the entire population of Thailand. Although our study attempts to examine the relevant risk factors including attitudes, parents' health status, stress, sleep quality, dietary consumption and sedentary behavior, other important factors could not be included. Therefore, further studies are needed to extend our findings. Our findings provide the causal relationships, both direct and indirect factors for adiposity. However, future research in clinical settings is required to confirm these results.

CONCLUSION

The factors related to overweight status include direct influences composed of dietary behavior factors (e.g., snacks, sweets, fast food, condiments) and physical activity factors (e.g., incorporating exercise and sports, recreational activities, screen time, sedentary behaviors). These factors can be utilized to address issues related to overweight status. They can also be employed for practical activity planning, such as modifying dietary habits, increasing physical activity, reducing sedentary behavior, setting limits on electronic device usage, and minimizing prolonged screen time. These findings can serve as guidelines for policy development to promote non-screen-based recreational activities and physical activities as alternatives to prolonged screen time and extended periods of sitting.

RECOMMENDATIONS

Dietary behavior factors and physical activity factors affect overweight among high school students. It is important to provide an environment conducive to consumption and physical activity both at school and at home. They are confident in making healthy food and physical activity choices appropriately, which may result in

more appropriate adjustments in their behavior. Future research needs to be conducted to confirm our findings in clinical settings and large prospective cohort studies. These findings are useful for health professionals to design tailored interventions for teenage groups.

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CONFLICT OF INTEREST

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