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Combined effects of sugar-sweetened beverage consumption, screen-based sedentary behavior, and sleep duration on South Korean adolescent obesity: a cross-sectional study

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Purpose: This study examined the combined effects of sugar-sweetened beverage (SSB) consumption, screen-based sedentary behaviors, and sleep duration on adolescent obesity. **Methods:** It followed a cross-sectional study design and conducted secondary analysis on data from 20,497 high school students who participated in the 17th (2021) Korea Youth Risk Behavior Web-based Survey. This study underwent logistic regression analysis in complex sampling analysis. **Results:** The combinations of low and medium consumption of SSBs, excessive screen-based sedentary behaviors, and short sleep durations were associated with a 1.18 and 1.12 fold increased likelihood of obesity (95% confidence interval [CI]=1.03–1.35) and (95% CI=1.02–1.22), respectively. The combination of high SSB consumption, appropriate screen-based sedentary behaviors, and short sleep duration (adjusted odds ratio [aOR]=1.15, 95% CI=1.01–1.31) and high SSB consumption, excessive screen-based sedentary behaviors, and short sleep duration (aOR=1.40, 95% CI=1.16–1.69) were associated with obesity. **Conclusion:** Integrated and tailored programs considering combination patterns of SSB consumption, screen-based sedentary behaviors, and short sleep duration need to be developed for preventing adolescent obesity.

Keywords: Adolescent; Obesity; Sugar-sweetened beverages; Screen time; Sleep duration

INTRODUCTION

Childhood and adolescent obesity have become a significant public health issue in the 21st century, having reached epidemic proportions [1]. The World Obesity Federation has predicted that by 2025, 206 million individuals aged 5 to 19 will be affected by obesity, a number projected to increase to 254 million by 2030 [2]. In Korea, the prevalence of obesity among adolescents surged from 5.1% in 2009 to 11.1% in 2019, reflecting an average annual increase of 0.47% [3].

Overweight and obesity negatively affect adolescents' physical (e.g., type 2 diabetes) and psychosocial health (e.g., low self-esteem and social isolation) [4]. Additionally, obesity during adolescence is a strong predictor of complications associated with obesity in adulthood [1]. Early prevention and management of obesity with modifiable factors are important for promoting health during childhood, adolescence, and later life. Adolescence, marked by significant psychological and biological changes, represents a critical period where individuals can make autonomous decisions regarding lifestyle factors [5]. Thus, adolescents may have self-determined unhealthy lifestyle behaviors, including dietary habits, such as consuming sugar-sweetened beverages (SSBs), sedentary behaviors (prolonged screen time), and poor sleep patterns (short sleep durations) [6].

In terms of dietary behaviors, adolescents tend to consume

more SSBs (including sodas and sports drinks) and less milk than younger children. According to Southerland et al. [7], approximately 63% of adolescents in the United States consume SSBs more than once a day. Similarly, approximately 96% of Korean high school students regularly consume SSB [8], of which, 40% consume them more than once a day. Thus, its frequent intake of SSBs has been significantly linked to elevated energy intake, contributing to the prevalence of adolescent obesity.

Screen-based sedentary behaviors are a common adolescent leisure activity, owing to increased availability of screen-based electronic devices, including televisions, computers, tablets, and mobile phones [9]. Adolescents in the United States, spent an average of 8.6 hours a day on screen-based sedentary behaviors in 2021, though the country's recommended limit for children and adolescents was <2 hours per day [10]. A Korean national study also showed that 66.5% of adolescents spent at least 2 hours a day on screen-based sedentary behaviors [11]. As sedentary behaviors involve low energy expenditure (<5 metabolic equivalents), excessive screen-based sedentary behaviors increase adolescents' risk of obesity [9]. In the same vein, ≥2 or 3 hours a day of screen time was linked to a likelihood of obesity in adolescents [9].

Additionally, short sleep owing to short durations is a widespread issue among adolescents. According to Wheaton and Claussen [12], 31.2% of adolescents in the United States are impacted by short sleep durations. Korean high school students, on average, slept for 6.2 hours a day on weekdays, with 63% of Korean adolescents getting less than the recommended 8 to 10 hours of sleep per day for individuals in their age group [13]. Previous studies have consistently highlighted the effects of short sleep duration on an increased likelihood of obesity among adolescents [13,14]. Thus, frequent SSB consumption, excessive screen-based sedentary behaviors, and/or short sleep durations may be associated with an increased risk of adolescent obesity.

Furthermore, frequent consumption of SSB, excessive sedentary time, and short sleep durations may be related to lifestyle behaviors [15]. Previous studies reported that increased sedentary behaviors were linked to shorter sleep durations and higher SSB consumption [15]. Additionally, higher SSB consumption and screen-based sedentary behaviors have been associated with shorter sleep durations [16]. Hence, they might be clustered behaviors, that could result in neutralized or synergetic combination effects, which differ from their independent effects. However, most of the previous studies focused on isolating the individual effects of SSB consumption, screen-based sedentary behaviors, and sleep duration on obesity in adolescents [9,14,17]. Hence, this study investigates the combined effects of SSB consumption, screen-based sedentary behaviors, and sleep duration on obesity in Korean high school students.

Childhood obesity develops through a complex pathway, and involves several underlying factors. Thus, while considering the effects of various multi-level covariates, the effects of SSBs, screen-based sedentary behaviors, and sleep duration on adolescent obesity need to be identified. According to Williams et al. [18], individuals' obesity development is shaped by biological factors (age and sex), social factors (educational levels and socioeconomic status), and psychological elements (mood and health-related behaviors). Similarly, Hoffman and Driscoll [19] proposed that a biopsychosocial model may provide a framework for a comprehensive understanding of multivariate factors associated with metabolic health, including obesity. A literature review revealed, that the biological factor—sex; social factors—grades [1,20] and families' socioeconomic status [1,20,21]; and psychosocial factors—depressive symptoms [1,22], daily stress [23], perceived body shape [24], skipping breakfast [25], fast-food consumption [1,26], lack of physical activity [1,20], and current consumption of cigarettes and alcohol [27], were associated with increased adolescent obesity.

In particular, to understand national trends of SSB consumption, screen-based sedentary behaviors related to screen use and duration of sleep, and their correlations with Korean high school students' obesity, secondary analysis of nationally representative survey data using systemic sampling methods might be helpful. Thus, through a secondary analysis of data obtained from the Korea Youth Risk Behavior Web-based Survey (KYRBS), this study aimed to identify the combined effects of SSB consumption, screen-based sedentary behaviors, and sleep durations on adolescent Korean high school students' obesity, by controlling for relevant covariates.

METHODS

Ethical statements: This study obtained an exemption from the Institutional Review Board (IRB) at Chungnam National University (No. 202307-SB-107-01) as it involves the utilization of secondary data with anonymity.

1. Study Design

This study adopted a cross-sectional design for secondary data analysis, using data collected from the 17th (2021) KYRBS— an anonymous and online based self-reported survey. The reporting of this study followed the guidelines outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines [28].

2. Data Source

The data set was obtained through a free download from the Korea Disease Control and Prevention Agency's website, after seeking permission from the Agency for using the raw data. KYRBS is an annually conducted national survey to collect data on the physical and mental health status, health-related behaviors, and environmental factors. The 17th KYRBS was conducted among 96.3% (30,015 out of 31,181) middle school students and 89.1% (24,833 out of 27,885) high school students, representing 800 schools spanning 17 provinces in South Korea. This study analyzed data of 24,833 high school students, but finally used 20,497 (10,563 males and 9,934 females) students' data, as it excluded data of 30,015 middle school and 4,336 high school students, having missing information on items to assess SSB consumption, screen-based sedentary behaviors, sleep duration, and covariates (Figure 1).

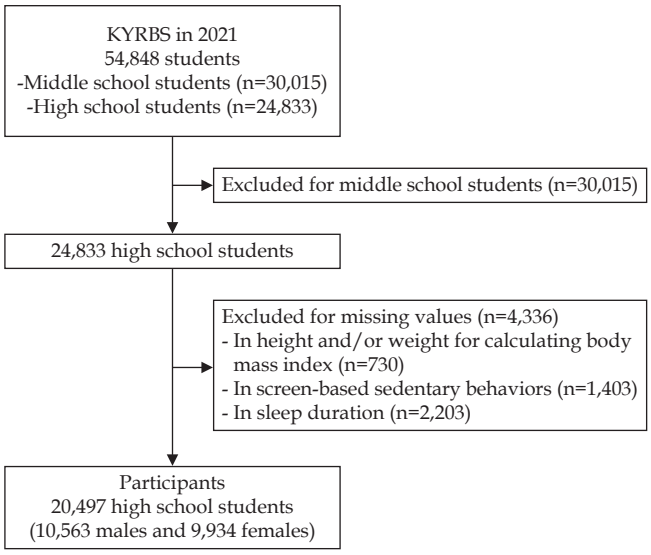

Figure 1. Sampling process for a study of the combined effects of sugar-sweetened beverage consumption, screen-based sedentary behavior, and sleep duration on South Korean adolescent obesity. KYRBS, Korea Youth Risk Behavior Web-based Survey.

3. Study Variables

1) Outcome variable

(1) Adiposity

To evaluate adiposity (obesity/non-obesity), body mass index (BMI) was computed using adolescents' self-reported height and weight. For considering age (months) and sex of adolescents, BMI percentile was evaluated with BMI using the 2017 Korean national growth charts for children and adolescents, and classified as: underweight (<5th percentile), normal weight (≥5th and <85th percentile), overweight (≥85th and <95th percentile), and obese (≥95th percentile) according to the screening criteria for growth abnormalities in the 2017 Korean national growth charts [29]. For the statistical analysis, adiposity was categorized into two groups: non-obese (underweight and normal weight) and obese (overweight and obese).

2) Independent variables

(1) SSB consumption

Consumption of SSBs was assessed using two questions about the experience (frequency) of SSB consumption (sodas and other sugar-containing beverages) within the last seven days. The responses to these questions were then converted to represent the number of consumptions per week (e.g., once a day=7 times a week). Thereafter, the weekly SSB consumption for each item was summed. Following Ra [30], quartile values were calculated based on the sum of weekly SSB consumption, and the frequency of SSB consumption was divided into three quartiles: Q1 (low, ≤3 times a week), Q2 (medium, >3 times and <7 times a week), and Q3 (high, ≥once a day).

(2) Screen-based sedentary behaviors

Screen-based sedentary behaviors were evaluated by asking two questions about average hours and/or minutes per day spent in such activities for leisure, including smartphone and computer use, on both weekdays and weekends. The average daily duration of sedentary behaviors was then categorized as either ≥2 hours a day (excessive) or <2 hours a day (appropriate), following the American Academy of Pediatrics Committee on Public Education's guidelines [10].

(3) Sleep duration

Sleep duration was evaluated through four questions related to bedtime and wake-up time on both weekdays and weekends. The average duration of sleep (hours) per day was computed based on the provided bedtime and wake-up time and categorized into <8 hours a day (short) and ≥8 hours a day (sufficient), following the guidelines of the American Academy of Sleep Medicine [31].

3) Covariates

(1) Biological factors

Sex

Sex was used to classify participants into male and female.

(2) Social factors

Grade

Grades were classified as 1st, 2nd, or 3rd grades.

Family's socioeconomic status

Family's socioeconomic status was classified as high, medium, or low, based on participants' responses to a single question about their family's perceived economic status.

(3) Psychological factors

Depressive symptoms

Depressive symptoms were assessed, through a single question about feelings of sadness or hopelessness over the last 12 months, to which participants had to select either a yes or no response.

Daily stress

This factor was assessed through a single question about perceived daily stress levels. Responses were classified as yes or no.

Perceived body shape

This factor was assessed using a question regarding subjective body shape judgment, where responses were categorized as being fat, average, or skinny.

Skipping breakfast

This factor was assessed through a single question about the frequency of skipping or having breakfast over the last seven days. Responses were classified as yes or no.

Fast-food consumption

This factor was evaluated using a question about fast-food consumption frequency over a week. For calculating quartile values based on the total weekly fast-food intake, following Ra [30], frequency of fast-food consumption (times a week), responses were categorized into three quartile groups: Q1 (low, ≤1.5 times a week), Q2 (medium, >1.5 times and ≤3.5 times a week), and Q3 (high, >3.5 times a week).

Moderate and vigorous physical activity

This factor was evaluated through two questions about the frequency of its occurrence in the past seven days. Responses were categorized as ≥3 days or <3 days, following the physical activity recommendations for Korean children [32].

Current cigarette consumption

Current cigarette consumption was assessed through a single question about smoking experiences within a month (30 days). Responses were categorized as yes or no.

Current alcohol consumption

Current alcohol consumption was evaluated using a single question about alcohol experiences within a month (30 days). Responses were categorized as yes or no.

4. Data Analyses

It used IBM SPSS 26 (IBM Corp.) to perform a complex sampling analysis with sampling weights according to a complex sampling method (cluster and strata) based on the 17th (2021) KYRBS's analysis instructions. The prevalence of the outcome variable (adiposity), independent variables (SSB consumption, screen-based sedentary behaviors, and sleep duration), and covariates (biological factors, social factors, and psychological factors) were analyzed using descriptive statistics (unweighted frequency and weighted percentage), whereas the combination effects of SSB consumption, screen-based sedentary behaviors, and sleep duration on obesity were tested using logistic regression analysis. In a logistic analysis model, outcome variables, independent variables, as well as covariates were inputs to controlling effects from covariates.

RESULTS

1. Prevalence of Adiposity and SSB Consumption, Screen-based Sedentary Behaviors, and Sleep Duration

Approximately 32.8% of participants were either overweight or obese. Independently, 37.4%, 26.4%, and 36.2% of participants were categorized into three quartile groups: Q1 (low), Q2 (medium), and Q3 (high), respectively, based on their SSB consumption. In terms of independent screen-based sedentary behaviors and sleep duration, 70.6% of participants manifested excessive screen-based sedentary behav-

iors (≥2 hours a day), whereas 84.5% of participants slept <8 hours a day (short sleep duration) (Table 1). Among the 12 groups created by combining SSB consumption, screen-based sedentary behaviors, and sleep duration, the group with the highest prevalence (22.4%) was identified as having Q3 SSB consumption, screen-based sedentary behaviors, and short sleep duration (Table 1).

2. Independent Effects of SSB Consumption, Screen-based Sedentary Behaviors, and Sleep Duration on Adolescent Obesity

In Q2 and Q3, SSB consumption was associated with a 1.12 and 1.12 fold increased likelihood of obesity (95% confidence interval [CI]=1.01–1.24) and (95% CI=1.01–1.25) than the reference (Q1 of SSB consumption), whereas screen-based sedentary behaviors was not related with obesity. Short sleep duration was linked to a 1.18 fold increased likelihood of obesity (95% CI=1.02–1.35) than the reference (≥8 hours of sleep duration a day) (Table 2).

3. Combination Effects of SSB Consumption, Screen-based Sedentary Behaviors, and Sleep Duration on Adolescent Obesity

Combined SSB consumption, appropriate screen-based sedentary behaviors, and sufficient sleep duration in Q1 was used as a reference. The combination of SSB consumption in Q1 and Q2, excessive screen-based sedentary behaviors, and short sleep durations was linked to a 1.18 and 1.12 fold increased likelihood of obesity (95% CI=1.03–1.35) and (95% CI=1.02–1.22), respectively, compared to the reference. Finally, as compared to the Q1 reference, Q3's combination of: SSB consumption, appropriate screen-based sedentary behaviors, and short sleep duration (adjusted odds ratio [aOR]=1.15, 95% CI=1.01–1.31) and SSB consumption, excessive screen-based sedentary behaviors, and short sleep duration (aOR=1.40, 95% CI=1.16–1.69) were associated with obesity (Table 3).

DISCUSSION

This study identified the combined effects of SSB consumption, screen-based sedentary behaviors, and sleep duration on adolescent obesity. Its results showed that combinations of both, low/medium consumption of SSBs, excessive screen-based sedentary behaviors, and short duration of sleep; and high consumption of SSB, appropriate/excessive screen-based sedentary behaviors, and short sleep duration, were associated with an increased likelihood of obesity in adolescents. Thus, a combination of low/medium/high SSB consumption, excessive screen-based sedentary behaviors, and short sleep durations could be associated with obesity in adolescents. While a combination of high SSB consumption and short sleep durations could be associated with obesity in adolescents, no such association was found for appropriate screen-based sedentary behaviors.

As SSB consumption is a major source for intake of free sugars, it is strongly associated with weight gain. Moreover, as the calorie intake through SSB drinking results in decreased satiety, it could induce overconsumption of foods. According to Magriplis et al. [33], consuming 10% or more of total energy from added sugars is linked to a 1.77 times higher likelihood of obesity after controlling for covariates. In the same vein, Arango-Angarita et al. [34] reported that on an average, SSB consumption of 240 mL a day was linked to approximately a 1.35% increase in obesity prevalence. Similarly, increased SSB consumption of caffeine beverages also resulted in short sleep durations [16]. Sleep duration of less than 5.9 hours a day was associated with a 1.14 fold increased likelihood of obesity in Korean adolescents [14], which might be associated with a greater intake of high-calorie diets (increased SSB consumption), with increased ghrelin levels and decreased leptin levels in the serum, and decreased activity (increased sedentary behaviors) with fatigue. In the same vein, as short sleep duration circularly led to increased SSB consumption in children, SSB consumption was considered a mediator between sleep duration and weight [16]. According to Sampasa-Kanyinga et al. [35], short sleep duration was linked to a 1.64 fold increased SSB consumption in adolescents. Similarly, individuals with short sleep durations tended to have higher energy intakes owing to increased carbohydrate snacks and SSBs [16]. Thus, with increased SSB consumption playing a mediating role, short sleep duration might be indirectly associated with adolescent obesity.

In this study, excessive screen-based sedentary behaviors (≥2 hours a day) were not associated with obesity in adolescents. In the same vein, a systematic review reported that a high dose of screen-based sedentary behaviors was associated with obesity in adolescents, while duration of screen-based sedentary behaviors was linearly not associated with their risk of obesity [9]. In addition, only TV watching was

Table 1. Prevalence of Adiposity and Lifestyle Behaviors among South Korean Adolescents (*N*=20,497)

Variables		Categories	n (%)[b]
Adiposity			
Non-obesity		Underweight	1,643 (8.2)
		Normal weight	12,073 (59.0)
Obesity		Overweight	1,629 (7.9)
		Obesity	5,152 (24.9)
Independent lifestyle behaviors			
Sugar-sweetened beverage consumption[a]		Q1 (low)	7,685 (37.4)
		Q2 (medium)	5,360 (26.4)
		Q3 (high)	7,452 (36.2)
Screen-based sedentary behaviors (hours a day)		<2	5,998 (29.4)
		≥2	14,499 (70.6)
Sleep duration (hours a day)		≥8	3,301 (15.5)
		<8	17,196 (84.5)
Combined lifestyle behaviors			
Sugar-sweetened beverage consumption	Screen based sedentary behaviors (hours a day)	Sleep duration (hours a day)	
Q1 (low)	<2	≥8	428 (2.0)
	<2	<8	1,982 (9.8)
	≥2	≥8	971 (4.7)
	≥2	<8	4,304 (20.9)
Q2 (medium)	<2	≥8	192 (0.9)
	<2	<8	1,361 (6.8)
	≥2	≥8	589 (2.7)
	≥2	<8	3,218 (16.0)
Q3 (high)	<2	≥8	273 (1.3)
	<2	<8	1,762 (8.6)
	≥2	≥8	848 (3.9)
	≥2	<8	4,569 (22.4)
Covariates			
Biological factors			
Sex		Males	10,563 (51.7)
		Females	9,934 (48.3)
Social factors			
Grade		1st	7,115 (32.5)
		2nd	7,079 (33.5)
		3rd	6,303 (34.0)
Family's socioeconomic status		Low	480 (2.2)
		Middle	18,412 (89.8)
		High	1,605 (8.0)
Psychological factors			
Depressive symptoms		Yes	5,394 (26.1)
		No	15,103 (73.9)
Daily stress		Yes	18,149 (88.5)
		No	2,348 (11.5)
Perceived body shape		Being fat	8,065 (39.1)
		In average	7,425 (36.1)
		Skinny	5,007 (24.8)
Skipping breakfast		Yes	15,974 (77.9)
		No	4,523 (22.1)
Fast food consumption[a]		Q1 (low)	14,952 (72.7)
		Q2 (medium)	4,490 (22.1)
		Q3 (high)	1055 (5.2)
Moderate and vigorous physical activity (a week)		≥3 days	7,099 (34.2)
		<3 days	13,398 (65.8)
Current cigarette consumption		Yes	1,317 (6.2)
		No	19,180 (93.8)
Current alcohol consumption		Yes	3,106 (14.9)
		No	17,391 (85.1)

[a]Q1=first quantile, Q2=second quantile, Q3=third quantile; [b]n=unweighted, %=weighted.

Table 2. Independent Effects of Lifestyle Behaviors on Obesity in Adolescents

Independent lifestyle behaviors		Obesity
		aOR (95% CI)[a]
Sugar-sweetened beverage consumption[c]	Q1 (low)	1.00
	Q2 (medium)	1.12 (1.01–1.24)[b]
	Q3 (high)	1.12 (1.01–1.25)[b]
Screen-based sedentary behaviors (hours a day)	<2	1.00
	≥2	0.98 (0.89–1.09)
Sleep duration (hours a day)	≥8	1.00
	<8	1.18 (1.02–1.35)[b]

[a]Adjusted for biological, social, and psychological factors associated with adolescents' depressive symptoms and suicidal ideation; [b]$p<.05$; [c]Q1=first quantile (reference), Q2=second quantile, Q3=third quantile; aOR, adjusted odds ratio; CI, confidence interval.

Table 3. Combination Effects of Lifestyle Behaviors on Obesity in Adolescents

Combined lifestyle behaviors			Obesity
Sugar-sweetened beverage consumption[c]	Screen-based sedentary behaviors (hours a day)	Sleep duration (hours a day)	aOR (95% CI)[a]
Q1 (low)	<2	≥8	1.00
	<2	<8	0.98 (0.75–1.17)
	≥2	≥8	1.02 (0.90–1.16)
	≥2	<8	1.18 (1.03–1.35)[b]
Q2 (medium)	<2	≥8	1.15 (0.95–1.42)
	<2	<8	1.07 (0.96–1.26)
	≥2	≥8	1.17 (0.90–1.51)
	≥2	<8	1.12 (1.02–1.22)[b]
Q3 (high)	<2	≥8	1.03 (0.89–1.30)
	<2	<8	1.15 (1.01–1.31)[b]
	≥2	≥8	1.07 (0.89–1.28)
	≥2	<8	1.40 (1.16–1.69)[b]

[a]Adjusted for biological, social, and psychological factors associated with obesity in adolescents; [b]$p<.05$; [c]Q1=first quantile (reference), Q2=second quantile, Q3=third quantile; aOR, adjusted odds ratio; CI, confidence interval.

associated with obesity of adolescents, not playing video games and using personal computers which could increase physical activity [9]. Thus, obesity development might depend on dose and type of screen-based sedentary behaviors.

Meanwhile, excessive screen-based sedentary behaviors could lead to sleep disturbances, including short sleep durations, which in turn, finally resulted in psychological distress, such as depressive symptoms [22]. Additionally, adolescents with depressive symptoms might report increased sedentary behaviors, including screen-based activities. According to Li et al. [17], short sleep durations contributed to weight gain through the mediation of psychological distress. Thus, short sleep durations due to excessive screen-based sedentary behaviors could result in psychological distress, which in turn, could lead to weight gain with increased screen-based sedentary behaviors involving activities with low energy expenditure.

Screen-based sedentary behaviors are also associated with increased SSB consumption [6,8]. Adolescents with increased screen-based sedentary behaviors might watch more online advertisements regarding sweet snacks and beverages [6]. In the same vein, while using screen-based electronic devices, SSB consumption increases, while regular meals tend to be skipped [6]. According to Gan et al. [6], while watching television, playing video games, and using mobile phones, adolescents showed higher sugar intakes, with increased consumption of sodas and energy drinks. Thus, owing to screen-based sedentary behaviors and increased SSB consumption, adolescents' calorie intake might exceed their daily requirements. In this context, a combination of high SSB consumption, excessive screen-based sedentary behaviors, and short sleep duration might be associated with an increased likelihood of obesity in adolescents.

Based on these results, significant clustering of lifestyle behaviors according to developmental stages need to be identified. According to Carson et al. [36], identifying the target

population's clustering patterns of unhealthy behaviors might be important to develop effective strategies to prevent obesity. Furthermore, while considering the clustering of lifestyle behaviors associated with obesity, integrated and tailored strategies should be developed to prevent obesity in adolescents. To prevent and manage obesity, Carson et al. [36] also emphasized the need for integrated interventions, that consider the multiple behaviors associated with it. Moreover, approaches tailored according to the clustered patterns of lifestyle behaviors were considered more effective than general approaches [27,37].

This study has significant nursing implications for crafting targeted interventions addressing specific lifestyle behaviors among Korean adolescents. Potential interventions include tailored school-based health promotion programs, culturally sensitive nutritional education, and initiatives promoting physical activity for Korean adolescents [37]. Moreover, Koo and Lee [20] recommended family-centered interventions focusing on reducing SSB consumption, limiting screen time, and improving sleep habits for preventing obesity among Korean adolescents. Nurses can also advocate policies for supporting healthy environments in schools and communities, and addressing issues, such as access to nutritious food and regulating the marketing of unhealthy products targeted at adolescents. These strategies are entirely in line with the Guidelines for the Management of Obesity in Korea (2020) [38]. By incorporating culturally sensitive methods, nurses and policymakers can develop effective interventions within the Korean context, fostering improved health outcomes and lasting behavior change among adolescents.

This study's strength was its large sample taken from national data, which enabled identifying the combined effects of lifestyle behaviors by controlling covariates. According to Williams et al. [18], obesity is developed through the influence of biological, social, and psychological factors. It means that controlling of multivariate factors (covariates) is important to identify association between significant factors and obesity. Additionally, our results might be helpful for generalizability of the need for combining interventions for clustered lifestyle behaviors to prevent obesity development among Korean high school students.

However, it also had some limitations. First, adiposity was evaluated using self-reported height and weight, which might have led to misestimation of adolescents' adiposity. Second, as self-reported values were used to evaluate frequency of SSB consumption, hours per day of screen-based sedentary behaviors, and sleep duration, future studies should use objective measurements to correctly evaluate adiposity, SSB consumption, screen-based sedentary behaviors, and sleep duration. Third, many covariates involved in this secondary data analysis were evaluated using a single question, and their answers were categorized as yes or no. To ensure validity and reliability of the measurements, further studies should evaluate covariates using structured instruments, having good validity and reliability. Finally, the prevalence of obesity and lifestyle behaviors associated with it, might be different depending on ethnicity, age, gender, familiar and community environments. Thus, future studies need to confirm this study's results by considering adolescents' biological characteristics and social environments.

CONCLUSION

The results indicate that identifying clustered patterns and combination effects of lifestyle behaviors in adolescents might be the first step toward developing effective integrated interventions for preventing obesity. In particular, strategies tailored according to the significant combining patterns of lifestyle behaviors of individual adolescents should be developed. Notably, this study reported that consumption of SSBs, screen-based sedentary behaviors, and sleep duration might be important targets to prevent adolescent obesity. Hence, integrated and tailored intervention programs should be developed by considering the combined effects of SSB consumption, screen-based sedentary behaviors, and sleep duration among individual adolescents.

ARTICLE INFORMATION

Authors' contribution

Conceptualization: all authors; Data collection, Formal analysis: all authors; Writing-original draft: all authors; Writing-review and editing: all authors; Final approval of published version: all authors.

Conflict of interest

No existing or potential conflict of interest relevant to this article was reported.

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Data availability

Please contact the corresponding author for data availability.

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