Concurrent Associations of Physical Activity and Screen-Based Sedentary Behavior on Obesity Among US Adolescents: A Latent Class Analysis

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ABSTRACT

Background: Independent associations of physical activity (PA) and sedentary behavior (SB) with obesity are well documented. However, little is known about the combined associations of these behaviors with obesity in adolescents. The present study examines the prevalence of concurrent levels of PA and SB, and their associations with obesity among US adolescents.

Methods: Data from a total of 12,081 adolescents who participated in the Youth Risk Behaviors Survey during 2012–2013 were analyzed. A latent class analysis was performed to identify latent subgroups with varying combined levels of subjectively measured PA and screen-based SB. Follow-up analysis examined the changes in the likelihood of being obese as determined by the Center for Disease Control and Prevention Growth Chart between latent subgroups.

Results: Four latent subgroups with varying combined levels of PA and SB were identified across gender. The likelihood of being obese was significantly greater for the subgroups featuring either or both Low PA or High SB when compared with High PA/Low SB across genders (odds ratio [OR] ranges, 2.1–2.7 for males and 9.6–23.5 for females). Low PA/High SB showed the greater likelihood of being obese compared to subgroups featuring either or both High PA and Low SB (OR ranges, 2.2–23.5) for female adolescents only.

Conclusions: The findings imply that promoting sufficient levels of PA while reducing SB should be encouraged in order to reduce obesity risk among adolescents, particularly for males. The risk of obesity for female adolescents can be reduced by engaging in either high levels of PA or low levels of SB.

Key words: screen time; exercise; BMI; YRBS

INTRODUCTION

Obesity is a global pandemic that has been identified as one of the leading causes of preventable morbidity and mortality.¹⁻³ The prevalence of obesity in adolescents has increased significantly in the last few decades,⁴ and this may directly lead to a future risk of developing chronic diseases, such as diabetes or metabolic syndrome later in life.⁵,⁶ A body of literature has identified physical activity (PA) as a potential modifiable lifestyle behavior that can reduce risk of obesity (and improve health profiles) among adolescents.⁷,⁸ Specific PA guidelines have been established to promote PA in youth (eg, ≥60 minutes of moderate and vigorous-intensity PA [MVPA] per day with ≥3 days of muscle-strengthening PA).⁹

Recently, the environmental and behavioral changes in modern society have extended a paradigm of health determinants to sedentary behavior (SB),¹⁰ which are characterized by a prolonged sitting or reclining posture requiring low level of energy expenditure (<1.5 METs), such as watching TV or using a computer.¹¹,¹² A great deal of evidence has been accumulated demonstrating SB as a health risk factor associated with a variety of chronic diseases across the lifespan.¹³ Specifically, excessive exposure to screen-based media is significantly associated with weight gain and increased risk of developing obesity among adolescents.¹⁴,¹⁵

PA and SB have become the major focus areas for preventing and explaining the risk of obesity among adolescents. Although some research has shown an
interdependent relationship between these two behaviors, suggesting a possible tradeoff between one and the other,\textsuperscript{16,17} it is generally understood that PA and SB are distinct behaviors with different internal/external determinants\textsuperscript{18} that may explain unique variance of obesity risk.\textsuperscript{17,19,20} This line of thought has led researchers to examine the potential combined effects of PA and SB on the risk of obesity.\textsuperscript{21–24} To date, although direct comparison of studies is challenging due to variations in measurement of PA and SB (ie, subjective vs objective measurements), results have been unclear, with some studies showing additive effects,\textsuperscript{22,24} some showing independent effects,\textsuperscript{20} and others showing effects only for PA.\textsuperscript{25,26}

One factor that might lead to inconsistent results may be the way in which PA and SB are combined to identify concurrent levels of PA and SB. A majority of large-scale observational studies, in which subjective measures of PA and SB are commonly preferred, have used a variable-centered approach that directly combines one or few implicit variables of PA and SB (eg, meeting aerobic PA guidelines and being in a low quartile of TV time) rather than relying on empirical evidence.\textsuperscript{27} This approach may introduce redundant classification errors, which may not be comprehensive enough to fully reflect various components of PA and SB simultaneously. Such limitations can be potentially overcome using latent class analysis (LCA), a person-centered approach identifying latent subgroups of a population with varying response patterns of multiple observed variables. LCA has been successfully employed in a previous PA study\textsuperscript{27}; however, that study failed to adequately control for the possible influence of covariates on estimating the latent subgroups and in evaluating links with obesity in LCA model, which might produce biased estimates of population parameters.

The overarching goal of this study was to develop and examine a comprehensive LCA model examining the concurrent associations of PA and SB with obesity among United States (US) adolescents. Specific goals were to identify latent subgroups with varying concurrent patterns of PA and screen-based SB and to examine the association of latent subgroups with different level of PA and screen-based SB with obesity status among a national representative sample of US adolescents.

METHODS

Survey data and study sample
Data for this study came from the 2013 national Youth Risk Behavior Survey (YRBS), a biennial cross-sectional survey conducted by the Center for Disease Control and Prevention (CDC). The 2013 YRBS employed a three-stage cluster sampling design to obtain a national representative sample of adolescents in 9th to 12th grades attending public and private schools in the United States. In the first stage of sampling, the primary sampling units (PSUs; ie, counties) were organized into 16 strata based on their metropolitan statistical area status (ie, urban and rural) and the percentages of minority (black and Hispanic) students in the PSUs. The 54 PSUs were sampled with probability proportional to the total size of school enrollment in the PSU. In the second stage of sampling, secondary sampling units (SSUs; ie, schools) were categorized into two strata based on the size of schools. 193 schools with any of grades 9–12 were selected using probability proportional to school enrollment size. In the third stage of sampling, one class per grade was selected in each SSU (two classes per grade in SSUs with high minority enrollment) by varying selection methods from school to school (eg, random sampling, selecting from required courses such as English, or selecting during a particular time of day such as first or second period classes). All students in a sampled classroom were eligible for the survey.

The survey is primarily used to monitor a variety of health risk behaviors among youth, including PA and screen-based SB, using a standard questionnaire. Local parental permission was obtained from the participating schools prior to survey administration, and the protocol of the national YRBS was approved by the CDC’s Institutional Review Board. The response rates at the school and student levels were 77% and 88%, respectively, and adjustment for student and school non-response was made when calculating the weights of students in participating schools. The detailed protocol of the 2013 national YRBS can be found elsewhere.\textsuperscript{28}

A total of 13 583 adolescents completed a questionnaire in the 2013 national YRBS. Of these, the adolescents who provided valid responses on study variables were included. Those with missing values in gender, grade, body mass index (BMI), and three questions asking about healthy diet behaviors were excluded (\(n = 1460\)). In addition, 42 adolescents with \(\geq 3\) missing values among five questions asking about PA and screen-based SB were further excluded from the analysis. The final analytic sample consisted of 12 081 adolescents (6109 males), which represents 88.94% of the original sample.

Measures

Self-reported PA and screen-based SB
The adolescents were asked to disclose the frequency of PA behaviors, including MVPA, sports team participation (STP), and muscle-strengthening exercise (MSEx). MVPA was determined by the question asking the number of days they had been physically active (ie, any kind of PA that increased heart rate and made breathe hard some of the time) for a total of at least 60 minutes per day during the past 7 days. The adolescents were dichotomized into either sufficient MVPA (S-MVPA) or insufficient MVPA (I-MVPA) categories based on the PA guideline for youths (\(\geq 60\) minutes of MVPA per day).\textsuperscript{9} The number of sports teams (in the school or community group) in which the adolescents participated during the past 12 months was used for categorizing
adolescents into either Active-STP (≥1 STP/year) or No-STP categories. In addition, the number of days engaging in MSEP (eg, push-ups, sit-ups, or weight lifting) during the past 7 days was obtained for categorizing adolescents into either sufficient-MSEP (S-MSEP) or insufficient-MSEP (I-MSEP) categories in accordance with the PA guideline for youths (≥3 days a week).²⁹

Two questions asking about screen-based SBs provided the number of hours watching TV and using a computer for non-school work on an average school day (eg, time spent playing video or computer games; using all other screen-based technologies, such as smartphone or tablet; or Internet-related activities, such as social networking). Excessive exposures to TV and computer were determined using a criteria of ≥3 h per day for each behavior, respectively.²⁹,³⁰

Body mass index

Body mass index (BMI) calculated using self-reported height (cm) and weight (kg) was used to determine obesity. Adolescents were considered obese if BMI (kg/m²) was at or above 95th percentile according to the CDC sex-specific BMI-for-age growth chart.³¹

Study covariates

Demographic characteristics, including gender, grade (9th–12th), and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or others) were obtained. In addition, information on healthy dietary behaviors was obtained from the questions asking about the frequency of having breakfast, consuming fruits and vegetables, and drinking soda during the past 7 days, as these diet behaviors may be confounding factors influencing the relationship of PA and screen-based SB with obesity.³²

Statistical analysis

LCA is a family of finite-mixture models representing the population heterogeneity by unobservable subpopulations. We first fitted a series of unconditional LCA models with differing number of latent subgroups (k; 1 through 6) in order to identify the model that best represents the heterogeneity of response patterns of PA and screen-based SB across a given number of latent subgroups. The model with the best model-data fits was determined using 1) the relative fit indices, including the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and sample size adjusted BIC (SABIC), where a lower value indicates a better model; 2) Lo-Mendell-Rubin adjusted likelihood ratio test (LMR-LRT), which compares the models with k and k − 1 latent subgroups; and 3) average classification probability (ACP) ranging between 0 and 1, in which a higher value indicates greater certainty in classification. In particular, BIC was preferred when comparing models based on results from a recent simulation study,³³ and the practical interpretability of latent subgroups was also considered.³⁴

The follow-up conditional LCA model with a distal outcome was fitted to examine 1) the likelihood of being classified as a respective latent subgroup based on grade and race/ethnicity; and 2) the likelihood of being obese based on a latent subgroup membership after controlling for grade, race/ethnicity, and healthy diet behaviors. All LCA analyses were stratified by gender to obtain gender-specific estimates, as there are gender disparities in PA and screen-based SB among adolescents.

LCA models were weighted for the three-stage sampling design of the 2013 national YRBS to obtain the population parameters of US adolescents. A robust full-information maximum likelihood algorithm was used for parameter estimations in order to account for missing responses in PA and screen-based SB. SAS version 9.3 (SAS Institute, Cary, NC, USA) and Mplus version 7.2 (Muthén & Muthén, Los Angeles, CA, USA) were used for data management and LCA analyses.

RESULTS

Descriptive statistics

Table 1 presents the descriptive statistics of study variables among US adolescents. There were significant gender disparities in the prevalence of PA and healthy dietary behaviors: male adolescents were more likely to be physically active and to have healthy dietary behaviors than female adolescents. In particular, more than half of US adolescents had either S-MVPA (57.6%; SE = 0.9), Active-STP (59.8%; SE = 1.3), or MSEP (57.8%; SE = 2.2). However, the prevalence of obesity was also greater for male adolescents (16.6%; SE = 0.8) compared to their female counterparts (10.8%; SE = 0.6). Additionally, no gender differences in the prevalence of screen-based SBs were observed.

Latent class analysis

The model-data fit indices for unconditional LGA models with differing number of latent subgroups are presented in Table 2. The results showed that the heterogeneity of response patterns of PA and screen-based SB was best represented by four latent subgroups with the lowest BICs (43 920.0 and 41 682.3 for males and females, respectively), relatively high ACP (0.75 for both genders), and practical interpretability of item-response patterns of each latent class.

The item-response probabilities for each PA and screen-based SB item across latent subgroups are presented in Table 3. Higher probabilities in PA items indicates higher likelihood of being physically active (ie, engaging in MVPA, STP, and MSEP); whereas higher probabilities in screen-based SB items (ie, TV hours and computer hours) indicates higher likelihood of being engaged in excessive levels of SB. The results highlighted that latent subgroups are best characterized as the High PA/High SB (probability ≥0.5 for all of PA and screen-based SB items), High PA/Low SB (probability ≥0.5 and <0.5 for PA and screen-based SB items, respectively).
Using a national representative sample of US adolescents, we found that the heterogeneity of PA and screen-based SBs in the High PA/High SB subgroup was more pronounced compared to Low PA/Low SB and Low PA/High SB subgroups. The findings suggest that the likelihood of being obese across latent subgroups after controlling for grade, race/ethnicity, and healthy dietary behaviors is presented in Table 5. Compared to the High PA/Low SB subgroup, all other subgroups were more likely to be obese for both genders. In particular, the Low PA/High SB subgroup showed higher odds of being obese compared to the Low PA/Low SB subgroup (OR 2.2; 95% CI, 1.3–3.5) when compared to non-Hispanic white adolescents.

**DISCUSSION**

The findings for predicting the likelihood of being obese across latent subgroups after controlling for grade, race/ethnicity, and healthy dietary behaviors are presented in Table 5. Compared to the High PA/Low SB subgroup, all other subgroups were more likely to be obese for both genders. In particular, the Low PA/High SB subgroup showed higher odds of being obese compared to the Low PA/Low SB subgroup (OR 2.2; 95% CI, 1.3–3.5) when compared to non-Hispanic white adolescents.

**Table 1. Descriptive statistics of study variables among US adolescents**

| Class | Total (n = 12,081) | Male (n = 6,109) | Female (n = 5,972) | P-valuea |
|-------|-------------------|-----------------|-------------------|----------|
| Grade | % | SE | % | SE | % | SE |
| 9th | 26.8 | 0.6 | 27.0 | 0.8 | 26.7 | 0.8 | 0.6 |
| 10th | 25.5 | 0.6 | 26.0 | 0.9 | 25.0 | 0.8 | |
| 11th | 24.0 | 0.5 | 23.7 | 0.5 | 24.4 | 0.7 | |
| Race/ethnicity | Non-Hispanic white | 56.4 | 3.5 | 56.8 | 3.5 | 56.1 | 3.7 | 0.7 |
| | Non-Hispanic Black | 13.2 | 1.8 | 12.8 | 1.8 | 13.6 | 1.9 | |
| | Hispanic | 20.3 | 2.2 | 20.3 | 2.3 | 20.3 | 2.3 | |
| | Others | 10.1 | 1.1 | 10.2 | 1.1 | 10.1 | 1.1 | |

**Table 2. Determining the number of latent subgroups using the unconditional LGM**

**MVPa, moderate and vigorous physical activity; I-MSEX, insufficient-MSEX; I-MVPA, insufficient-MVPA; MSEX, muscle-strengthening exercise; S-MSEX, sufficient-MSEX; S-MVPA, sufficient-MVPA; STP, sports team participation; SE, standard error; TV, television.**


dThe model with an optimal number of latent subgroups from the 1-class models.

eThe model-data fit indices from the conditional LGM with covariates adjustment and distal outcome. All estimates are weighted by a three-stage cluster sampling design of 2013 national YRBS.
adolescents can be best captured by four latent subgroups for both genders. Conceptually, it is reasonable to assume that the choice to engage in SB may decrease PA and vice-versa, as they are aligned at opposite ends of the behavioral spectrum. A growing body of literature, however, confirms the independent relationship between these two behaviors, with specific evidence for MVPA and SB, and our findings generally support this claim. In particular, our unique analytic approach focusing on intra-individual variations in multiple

structured PA and SB indicators provided empirical evidence of the most likely subgroups with varying concurrent patterns of PA and SB among adolescents. The results revealed that the response probabilities for PA and SB indicators are likely interrelated within each domain but not across domains, yielding distinct and independent patterns of PA and SB across latent subgroups (High PA/Low SB, High PA/High SB, Low PA/Low SB, and Low PA/High SB).

### Table 3. The estimated item-response probabilities of PA and screen-based SB across the latent subgroups

| Male | Female |
|------|--------|
|  | Latent Class 1 | Latent Class 2 | Latent Class 3 | Latent Class 4 | Latent Class 1 | Latent Class 2 | Latent Class 3 | Latent Class 4 |
| **% (SE)** | | | | | | | | |
| High PA/Low SB | 20.3 (1.3) | 38.6 (1.4) | 7.7 (0.5) | 33.5 (0.9) | 17.6 (1.1) | 23.1 (1.2) | 26.4 (1.4) | 33.0 (1.4) |
| High PA/High SB | 0.8* | 0.9* | 0.1 | 0.2 | 0.7* | 0.9* | 0.0 | 0.2 |
| Low PA/Low SB | 0.9* | 0.9* | 0.1 | 0.2 | 0.6* | 0.8* | 0.3 | 0.4 |
| Low PA/High SB | 0.7* | 0.1 | 1.0* | 0.2 | 0.6* | 0.1 | 0.6* | 0.1 |
| **Physical activity** | | | | | | | | |
| **Active-STP (≥ 1 STP)** | | | | | | | | |
| 0.8* | 0.9* | 0.1 | 0.2 | 0.7* | 0.9* | 0.1 | 0.2 |
| **Screen-based sedentary behaviors** | | | | | | | | |
| TV hours (≥ 3 hours/day) | 0.7* | 0.1 | 1.0* | 0.2 | 0.6* | 0.1 | 0.6* | 0.1 |
| Computer hours (≥ 3 hours/day) | 0.6* | 0.2 | 0.7* | 0.48 | 0.6* | 0.2 | 0.6* | 0.3 |

Active-STP, active sports team participation; PA, physical activity; S-MVPA, sufficient moderate or vigorous physical activity; S-MSex, sufficient muscle-strengthening exercise; SB, sedentary behavior; SE, standard error; TV, television.

*Estimated probability ≥0.50 for a respective item.

All estimates are from the conditional LGA model adjusted by grades and race/ethnicity, and are weighted by a three-stage cluster sampling design of 2013 national YRBS.

### Table 4. Correlates of latent class memberships with grades and race/ethnicity

|  | High PA/Low SB | Low PA/Low SB |
|---|---|---|
| **Males** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Grade | | | | | | |
| 9th | 17.1 (8.8, 33.5) | 12.33 (4.5, 33.5) | 3.11 (1.7, 5.6) | | | |
| 10th | 2.6 (1.7, 3.8) | 2.14 (1.3, 3.5) | 1.33 (0.98, 1.8) | | | |
| 12th | 3.7 (2.5, 5.7) | 1.74 (0.6, 5.0) | 1.76 (1.3, 2.4) | | | |
| Race/ethnicity | | | | | | |
| Non-Hispanic white | 1.0 (0.6, 1.6) | 1.05 (0.6, 2.0) | 1.22 (0.8, 1.9) | | | |
| Non-Hispanic Black | 0.9 (0.6, 1.4) | 1.11 (0.6, 2.1) | 1.22 (0.9, 1.7) | | | |
| Hispanic | 0.9 (0.6, 1.3) | 1.51 (0.9, 2.6) | 1.41 (1.0, 1.9) | | | |
| Others | | | | | | |
| Grade | | | | | | |
| 9th | 11.0 (5.2, 23.1) | 11.59 (4.9, 27.7) | 1.34 (0.3, 5.3) | | | |
| 10th | 4.9 (3.0, 8.0) | 3.59 (2.1, 6.2) | 1.28 (0.7, 2.3) | | | |
| 12th | 2.8 (1.4, 5.9) | 3.17 (1.8, 5.5) | 1.45 (0.7, 2.9) | | | |
| Race/ethnicity | | | | | | |
| Non-Hispanic white | | | | | | |
| Non-Hispanic Black | 0.8 (0.5, 1.2) | 0.73 (0.5, 1.1) | 1.21 (0.8, 1.8) | | | |
| Hispanic | 0.7 (0.4, 0.98) | 1.05 (0.6, 1.7) | 2.16 (1.3, 3.5) | | | |
| **Females** | | | | | | |
| Grade | | | | | | |
| 9th | | | | | | |
| 10th | | | | | | |
| 12th | | | | | | |
| Race/ethnicity | | | | | | |
| Non-Hispanic white | | | | | | |
| Non-Hispanic Black | | | | | | |
| Hispanic | 0.6 (0.3, 1.3) | 1.09 (0.6, 1.9) | 2.51 (1.7, 3.8) | | | |

CI, confidence interval; OR, odds ratio; PA, physical activity; SB, sedentary behavior.

High PA/Low SB was used as a reference group.
All estimates are from the conditional LGA model with covariate adjustment and distal outcome, and are weighted by a three cluster sampling design of 2013 national YRBS.
The findings highlight gender disparity with regards to PA and SB. Gender differences in healthy behaviors have been continuously reported across all age groups. Specifically, it has been well-documented that female adolescents have lower levels of PA and higher levels of SB compared to male adolescents; however, a preponderance of evidence has been accumulated for a single variable of PA and SB separately, limiting our understanding of possible gender disparity in concurrent prevalence of PA and SB among adolescents. The present findings extend the literature by describing the gender differences in the latent subgroups identified based on the combined patterns of PA and SB. The largest portion of male adolescents were categorized into the High PA/Low SB (38.6%; SE = 1.4) subgroup, while the Low PA/Low SB (33.0%; SE = 1.4) subgroup was the largest for female adolescents. More importantly, the Low PA/High SB subgroup, which is potentially the highest risk group for health, was significantly larger for females (26.4%; SE = 1.4) compared to males (7.7%; SE = 0.5). Considering that PA and SB are important health determinants in later life, public efforts to develop and implement gender-specific intervention strategies to promote PA and reduce SB should be made.

As previously mentioned, the independent associations of PA and SB with obesity have been frequently examined among adolescents; however, findings are mixed and limited, in part, to extending our understanding of combined effects on the risk of obesity. For example, a study examining the independent relationships of objectively measured PA and self-reported TV hours with obesity among 2200 adolescents from 10 European cities demonstrated that excessive TV watching (>4 hours per day) was a significant predictor of increased likelihood of being obese even after adjusting for PA levels. Another study also reported a stronger association of screen time with overweight and obesity than PA among 2200 Australian adolescents. In contrast, PA has frequently been reported as the only risk factor of obesity among adolescents; however, efforts to develop and implement gender-specific intervention strategies to promote PA and reduce SB are important health determinants in later life.

The present findings provide empirical evidence to support the complexity of combined effects of PA and SB for explaining the risk of obesity in this population. The use of an advanced statistical method based on LCA allowed us to classify the population by the response patterns of multiple PA and screen-based SB indicators and to include the distal outcome of obesity directly into the model while adjusting for covariates, including gender, race/ethnicity, and healthy diet behaviors. For both genders, the High PA/Low SB subgroup showed significantly lower likelihood of being obese compared to other subgroups; however, the relative magnitudes of such effects were greater for females compared to male adolescents. This may imply that increasing PA and reducing SB are equally important to reduce obesity risk among adolescents, in that significant health benefits will likely be obtained by having healthy behaviors for both PA and SB, with greater likelihood for preventing obesity being expected for females than males. Our findings are generally aligned with those of a previous report that both low PA and excessive TV hours are important risk factors for being overweight in adolescents, with stronger associations observed in female adolescents.

Our analyses also indicated that there could be some differences in the concurrent effects of PA and SB on obesity between genders. Specifically, the odds of being obese were not significantly different between the High PA/High SB, Low PA/High SB, and Low PA/Low SB subgroups for males, while female adolescents in the Low PA/High SB subgroup showed a significantly greater likelihood of being obese compared to their female counterparts in the Low PA/Low SB and High PA/High SB subgroups. These findings imply that for male adolescents to reduce the risk of obesity, which would be a significant health benefit, they must have both high levels of PA and low levels of SB. Pertaining to adolescent females, having either high levels of PA or low levels of SB may reduce risk of being obese to a greater degree than engaging in both low levels of PA and high levels of SB. Our findings demonstrating distinct combined associations of PA and SB with the risk of obesity across gender may also partially explain the prevalence of obesity being lower in female adolescents (10.8%) than in males (16.6%).

Taken together, these findings suggest that gender-specific PA and SB recommendations and intervention strategies might be necessary. Although it is difficult to make a concrete explanation of such gender differences due to the limited resources in this survey, one possible reason could be related to the differences in calories expended and consumed during the engagements of PA and SB, respectively, between genders. Energy imbalance is regarded as a common cause of obesity, and gender differences in the response of energy expenditure during daily PA have been previously reported. Moreover, the likelihood of having unhealthy foods while engaging in screen-based SB is reportedly increased, with female adolescents being more likely to consume unhealthy foods than males.

The interpretation of the present findings should account for several limitations. First, the 2013 national YRBS is a cross-sectional survey that precludes assessment of the casual relationships among study variables. As noted above, a longitudinal study examining the trajectories of PA and SB in relation to time-variant determinants as well as the changes in obesity would be a promising way to better understand the complex nature of PA, SB, and the influence of those behaviors on risk of obesity among adolescents. Second, while our findings were controlled for demographic characteristics and healthy diet behaviors, we were not able to control for additional potential confounding factors, such as previous weight status, due to the limited data available in the YRBS. Third, the indicators of PA and SB are subjectively measured and are limited to address only some aspects of PA (ie, MVPA, STP, and MSEX) and SB (ie, watching TV...
and using a computer). This might lead participants to overestimate their actual levels of PA and SB, which are subject to recall bias.\(^4\) Furthermore, obesity status was determined based on self-reported height and weight. The objectively measured adiposity levels, PA, and SB across specific contexts would be warranted in future studies in order to strengthen the external validity of the findings.

In conclusion, US adolescents can be classified into four latent subgroups based on the response patterns of PA and screen-based SB. The estimated latent subgroups showed significantly different likelihoods of being obese between each other, indicating the complex associations of PA and SB with the risk of obesity. For both genders, both PA and SB are important lifestyle behaviors related to obesity. More specifically, the High PA/Low SB subgroup, who had the highest probability of compliance with current PA and screen-based SB recommendations, had significantly lowest odds of being obese, with greater odds for female adolescents than males. In addition, female adolescents may expect to have some health benefits by complying with either PA or SB recommendations, while male adolescents should be encouraged to comply with both PA and SB recommendations in order to achieve significant health benefits. The present findings imply the need for developing gender-specific PA and/or SB intervention strategies to maximize health benefits of reducing the risk of obesity among adolescents.

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**REFERENCES**

1. Flegal KM, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and obesity using standard body mass index categories: A systematic review and meta-analysis. JAMA. 2013;309:71–82.
2. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: Systematic review. Int J Obes (Lond). 2011;35:891–8.
3. Swinburn BA, Sacks G, Hall KD, McPherson K, Finegood DT, Moodie ML, et al. The global obesity pandemic: Shaped by global drivers and local environments. Lancet. 2011;378: 804–14.
4. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999–2010. JAMA. 2012;307:483–90.
5. Biro FM, Wien M. Childhood obesity and adult morbidities. Am J Clin Nutr. 2010;91:1499S–505S.
6. Eriksson JG, Forsén T, Tuomilehto J, Osmond C, Barker DJ. Early adiposity rebound in childhood and risk of Type 2 diabetes in adult life. Diabetologia. 2003;46:190–4.
7. Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, et al. Evidence based physical activity for school-age youth. J Pediatr. 2005;146:732–7.
8. Janssen I, Leblanc AG. Review Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Phys Act. 2010;7:40.
9. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC: US Department of Health and Human Services 2008 (2008): A1-H14. 2008.
10. Katzmarzyk PT. Physical activity, sedentary behavior, and health: Paradigm paralysis or paradigm shift? Diabetes. 2010;59:2717–25.
11. Pate RR, O’Neill JR, Lobelo F. The evolving definition of “Sedentary”. Exerc Sport Sci Rev. 2008;36:173–8.
12. Sedentary Behavior Research Network. Letter to the Editor: Standardized use of the terms of “sedentary” and “sedentary behaviors”. Appl Physiol Nutr Metab. 2012;37:540–2.
13. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. Appl Physiol Nutr Metab. 2010;35:725–40.
14. Boone JE, Gordon-Larsen P, Adair LS, Popkin BM. Screen time and physical activity during adolescence: Longitudinal effects on obesity in young adulthood. Int J Behav Phys Act. 2007;4:26.
15. Hands BP, Chivers PT, Parker HE, Beilin L, Kendall G, Larkin D. The associations between physical activity, screen time and weight from 6 to 14 yrs: The Raine Study. J Sci Med Sport. 2011;14:397–403.
16. Epstein LH, Roemmich JN, Paluch RA, Raynor HA. Physical activity as a substitute for sedentary behavior in youth. Ann Behav Med. 2005;29:200–9.
17. Carson V, Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: A cross-sectional study. BMC Public Health. 2011;11:274.
18. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: The population-health science of sedentary behavior. Exerc Sport Sci Rev. 2010;38:105–13.
19. Maher C, Olds TS, Eisenmann JC, Dollman J. Screen time is more strongly associated than physical activity with overweight and obesity in 9- to 16-year-old Australians. Acta Paediatr. 2012;101:1170–4.
20. Ekelund U, Brage S, Froberg K, Harro M, Andersson SA, Sardinia LB, et al. TV viewing and physical activity are independently associated with metabolic risk in children: The European Youth Heart Study. PLoS Med. 2006;3:e488.
21. Sisson SB, Broyles ST, Baker BL, Katzmarzyk PT. Screen time, physical activity, and overweight in US youth: National Survey of Children’s Health 2003. J Adolesc Health. 2010;47:309–11.
22. Eisenmann JC, Bartee RT, Smith DT, Welk GJ, Fu Q. Combined influence of physical activity and television viewing on the risk of overweight in US youth. Int J Obes (Lond). 2008;32:613–8.
23. Laurson KR, Eisenmann JC, Welk GJ, Wickel EE, Gentile DA, Walsh DA. Combined influence of physical activity and screen...
time recommendations on childhood overweight. J Pediatr. 2008;153:209–14.

24. Laurson KR, Lee JA, Gentile DA, Walsh DA, Eisenmann JC. Concurrent associations between physical activity, screen time, and sleep duration with childhood obesity. ISRN Obes. 2014;2014:204540.

25. Patrick K, Norman GI, Calfas KJ, Sallis JF, Zabinski MF, Rupp J, et al. Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. Arch Pediatr Adolesc Med. 2004;158:385–90.

26. Chaput JP, Lambert M, Mathieu ME, Tremblay MS, O’Loughlin J, Tremblay A. Physical activity vs sedentary time: Independent associations with adiposity in children. Pediatr Obes. 2012;7:251–8.

27. Patnode CD, Lytle LA, Erickson DJ, Sirard JR, Barr-Anderson DJ, Story M. Physical activity and sedentary activity patterns among children and adolescents: A latent class analysis approach. J Phys Act Health. 2011;8:457–67.

28. Kann L, Kinchen S, Shanklin SL, Flint KH, Kawkins J, Harris WA, et al. Youth risk behavior surveillance—United States, 2013. MMWR Surveill Summ. 2014;63 Suppl 4:1–168.

29. American Academy of Pediatrics. Committee on Public Education. American Academy of Pediatrics: Children, adolescents, and television. Pediatrics. 2001;107:423–6.

30. Council on Communications and Media, Strasburger VC. Children, adolescents, obesity, and the media. Pediatrics. 2001;107:423–6.

31. Kuzcmarcki RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, et al. CDC growth charts: United States. Adv Data. 2000;314:1–27.

32. Wing RR, Goldstein MG, Acton KJ, Birch LL, Jakicic JM, Sallis JF Jr, et al. Behavioral science research in diabetes lifestyle changes related to obesity, eating behavior, and physical activity. Diabetes Care. 2001;24:117–23.

33. Nylund KL, Asparouhov T, Muthén BO. Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. Struct Equ Modeling. 2007;14:535–69.

34. Muthén B. Statistical and substantive checking in growth mixture modeling: Comment on Bauer and Curran (2003). Psychol Methods. 2003;8:369–77.

35. Taveras EM, Field AE, Berkey CS, Rifas-Shiman SL, Frazier AL, Colditz GA, et al. Longitudinal relationship between television viewing and leisure-time physical activity during adolescence. Pediatrics. 2007;119:e314–9.

36. Azevedo MR, Araújo CL, Reichert FF, Siqueira FV, da Silva MC, Hallal PC. Gender differences in leisure-time physical activity. Int J Public Health. 2007;52:8–15.

37. Barreira TV, Schuna JM Jr, Mire EF, Broyles ST, Katzmarzyk PT, Johnson WD, et al. Normative steps/day and peak cadence values for United States children and adolescents: National Health and Nutrition Examination Survey 2005–2006. J Pediatr. 2015;166:139–43.

38. Rey-López JP, Ruiz JR, Vicente-Rodríguez G, Gracia-Marco L, Manios Y, Sjöström M, et al; HELENA Study Group. Physical activity does not attenuate the obesity risk of TV viewing in youth. Pediatr Obes. 2012;7:240–50.

39. Ekelund U, Yngve A, Brage S, Westerterp K, Sjöström M. Body movement and physical activity energy expenditure in children and adolescents: How to adjust for differences in body size and age. Am J Clin Nutr. 2004;79:851–6.

40. Kim Y, Park I, Kang M. Convergent validity of the International Physical Activity Questionnaire (IPAQ): Meta-analysis. Public Health Nutr. 2013;16:440–52.