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Original Article

Latent class analysis of physical activity, screen time and sleep: Association with obesity in youth

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Abstract:
Obesity is a major public health concern, that has demonstrated a considerable global increase in recent years, including in low and middle-income countries. However, there are still gaps in the literature regarding the combined influence of physical activity, screen time, and sleep on obesity in young people, particularly during the transition phase from adolescence to adulthood. This study aimed to identify latent classes based on physical activity, screen time, and sleep behaviors among youths and analyze the association of these behavioral clusters with obesity. This is a cross-sectional study, conducted as part of a school-based epidemiological survey with state-wide coverage, involving 2,925 young people aged 14 to 19 years. Information was obtained using a translated, self-administered, and previously tested version of the Global School-Based Student Health Survey (GSHS). Binary logistic regression was performed to analyze the association between the cluster of physical activity, screen time, and sleep behaviors with obesity. In total, 13.3% of the young people were obese,31.1% reported being active per week, 35.5% had low screen time per day, and 38.3% had adequate nighttime sleep. It is concluded that there was no association between the clusters of physical activity, screen time, and sleep behaviors with obesity in the analysis for the total sample and in the analyses stratified by sex.
Key Words*:* **Adolescent Behavior; Health Behavior; Motor activity; Pediatric Obesity; Sedentary Behavior.**

Introduction

Obesity is defined by the World Health Organization (WHO) as a chronic disease characterized by the excessive accumulation of fats that can negatively affect health (WHO, 2024; Zhang et al., 2024). There has been an increase in the number of obese individuals worldwide in recent years, and obesity is now considered a global public health problem (Abarca-Gómez et al., 2017; Phelps et al., 2024; WOF, 2024). Obesity among youths is also a critical factor, as the transition from adolescence to adulthood involves a series of biological, behavioral, and social changes that can affect future lifestyle habits (Viner et al., 2015). The maintenance of excess weight during this life stage increases the risk of obesity persisting into adulthood (Simmonds et al., 2016), as well as predisposing individuals to a series of chronic non-communicable diseases (Anderson & Durstine, 2019), affecting body image perception and social interactions (Dandgey & Patten, 2023).

In recent years, there has been a significant increase in the prevalence of obesity among school-aged children (Phelps et al., 2024). Globally, in 2022, approximately 390 million children and adolescents aged 5 to 19 years were overweight, including 160 million with obesity (WHO, 2024). In Brazil, by early October of the same year, more than 4.4 million youths aged 10 to 19 were monitored by the Unified Health System (SUS), and according to data from the Ministry of Health's Food and Nutrition Surveillance System, approximately 1.4 million of these adolescents were diagnosed with overweight, obesity, or severe obesity (Brazil, 2022).

A recent systematic review examined how following recommendations for physical activity, screen use, and sleep habits relates to health outcomes across different stages of life (Rollo; Antsygina; Tremblay, 2020). It has been observed that higher levels of physical activity, low screen time, and adequate sleep duration can have health implications at all stages of life and are particularly associated with a series of health indicators in young people (Rollo; Antsygina; Tremblay, 2020). On the other hand, non-adherence to such behaviors in adolescence

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seems to be associated with a higher chance of developing obesity (López-Gil et al., 2023; Rollo; Antsygina; Tremblay, 2020), although this evidence in youth is still inconclusive.

Current recommendations for physical activity, screen time, and sleep present different cutoff points for children, youths, and adults. Children and youths should engage in at least 60 minutes of moderate to vigorous physical activity daily, limit recreational screen time to a maximum of two hours, and sleep for between 8 to 10 hours per night (Tremblay et al., 2016). Differently, it is recommended that adults engage in 150 to 300 minutes of moderate-intensity physical activity or 75 to 150 minutes of vigorous-intensity exercise per week, or a combination of both; minimize recreational screen time as much as possible; and sleep for 7 to 9 hours per night (Brazil, 2021a; NSF, 2025). However, it is not clear how these recommendations are affected during the transition from adolescence to adulthood, considering that youth tend to experience a change in their life routine during this phase, which typically involves the transition from school life to university and/or professional life.

Given that physical activity, screen time, and sufficient sleep duration can interact and jointly affect health, researchers are increasingly focusing on examining how these behaviors combine and form patterns among youths. For this purpose, statistical techniques such as cluster analysis and latent class analysis have been employed (Beets; Foley, 2010; Leech; McNaughton; Timperio, 2014). Latent class analysis has been used to identify behavioral patterns among various variables in different populations and contexts (Kongsted; Nielsen, 2017). Different behavioral patterns, such as low physical activity and high screen time, have been linked to a higher risk of obesity in youths (Kim; Barreira; Kang, 2016).

Additionally, cluster analysis has been used to identify various combinations of physical activity, screen time, and sleep. These include groups with healthy levels in all three behaviors, as well as groups with unhealthy levels in all three (Chemtob et al., 2021). However, in early adolescence, youths who did not have adequate classifications had a higher chance of obesity, while in late adolescence this association was not found (Chemtob et al., 2021). Thus, it is important to identify possible associations between these behaviors and obesity in the transition phase between adolescence and adulthood.

The current study is justified by the growing increase in the prevalence of obesity among adolescents, its serious consequences for public health, as adult behaviors are shaped by the childhood environment and habits developed during this stage, and the need to understand the profile of obesogenic behaviors and the factors associated with them in order to develop strategies for prevention and health promotion. By investigating these aspects, it will be possible to identify priority intervention areas and contribute to the development of targeted health promotion programs. Furthermore, few studies have been conducted for this age group in low- and middle-income countries. This is important, as a large proportion of youths with obesity in the world live in low- or middle-income countries (Phelps et al., 2024). Understanding the patterns of these behaviors in young people and their link to obesity is crucial for creating effective strategies to promote behavioral changes in this group. Thus, the aim of the current study was to identify distinct patterns of physical activity, screen time, and sleep behaviors in youths and to examine the relationship between clusters of these behaviors with obesity.

Material & methods

This study has a cross-sectional design, conducted as part of a school-based epidemiological survey with statewide coverage, entitled: "Exposure to alcoholic beverages, tobacco and other drugs and screening for common mental disorders in youth in the state of Pernambuco: an epidemiological study to support a proposal for School - RAPS integration". The study received approval from the Human Research Ethics Committee of the Pernambuco State Hematology and Hemotherapy Foundation (opinion n°: 4,449,705/HEMOPE) and was carried out between April and October 2022. All parents or guardians were duly informed about the study, and participation was authorized by signing the Free and Informed Assent Form (TALE) and the Free and Informed Consent Form (TCLE). This study was conducted in accordance with the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (Von Elm et al., 2014).

The target population of the study comprised young people aged 14 to 19 years, of both sexes, enrolled in public state schools in Pernambuco, Brazil. All schools distributed across the Regional Education Management units were considered eligible. Due to variations in the number of students per school, the selection of participants followed a two-stage cluster sampling (schools and classes). All students from the selected classes were invited to participate.

The study included participants based on the following criteria: 14 to 19 years of age, of both sexes, and being a high school student at one of the selected state public schools. Students were excluded from the sample if they: declined to take part in any phase of the study; did not have complete data for any of the variables analyzed in this study; and who exceeded 24 hours of self-reporting of physical activity, sedentary behavior, and sleep behaviors in one day. It is worth noting that the 24-hour exclusion criterion was used to avoid overestimating the exposure time to behaviors. To determine the exclusion of data, the mathematical expression "24h - ST > PA + SB" was established. This mathematical expression requires that the total waking time (24 hours minus sleep time) be greater than the sum of physical activity time and sedentary behavior time, ensuring the validity of the data.

The information was obtained using a translated, self-administered, and previously tested version of the Global School-Based Student Health Survey (GSHS). The questionnaire was administered in the classroom, without the presence of teachers, to all students present who agreed to participate in the study. Before administration, the research objectives were explained, emphasizing that the information provided would be kept confidential and used exclusively for scientific research. The instrument demonstrated a reproducibility coefficient ranging from 0.77 to 1.0, with an average completion time of approximately 40 to 50 minutes. SPHYNX® software (Sphynx Software Solutions Incorporation, Washington, United States) was used for application of the questionnaire, on a tablet (Samsung Galaxy A7, Suwon, South Korea). After each day of data collection, the data were sent to an online server, so that at the end, the tabulation phase was completed. For objective measurements, researchers filled out a specific form that was tabulated with double entry in Microsoft Office software (Excel, version 2019).

Information on the dependent variable (obesity) was determined using the body mass index (BMI) classification categories, based on BMI percentiles adjusted for participants' age and sex (WHO, 2007). Body mass was measured using a previously calibrated electronic scale from Plenna (Sport model; São Paulo, Brazil) and height using a Plenna stadiometer (model 206; São Paulo, Brazil). Youth were classified as obese (percentiles from 95 and above) and non-obese (percentiles below 95).

The independent variables were physical activity, screen time, and nighttime sleep duration. Information on physical activity was obtained using four questions: “During a typical or normal week, on how many days do you engage in moderate to vigorous physical activities?”; “On the days you engage in moderate to vigorous physical activities, how long does this practice last per day?”; “During the last 7 days, on how many days did you engage in moderate to vigorous physical activities?”; “In the last 7 days, on the days you engaged in moderate to vigorous physical activities, how long did this practice last per day?” The average of the sum of physical activity results in a typical week and physical activity in the previous 7 days was calculated. Subsequently, the young person was categorized as more active (practicing in moderate to vigorous intensity physical activity equal to or greater than 300 min/week) or less active (practicing in moderate to vigorous intensity physical activity less than 300 min/week).

Information on screen time was obtained from six questions about youth behavior on weekdays and weekends regarding recreational use time on: TV, computer, and video games. The young people were categorized as having less screen time (≤2 hours/day) and more screen time (>2 hours/day). Unlike other studies, we chose not to use smartphone screen time considering the possibility of concurrent use with other types of screens. To analyze sleep time, two questions were used: "On days of a normal week, on average, how many hours do you sleep per day?"; "On days of a normal weekend, on average, how many hours do you sleep per day?". The variable was categorized as adequate sleep time and inadequate sleep time, with those reporting between 8 to 10 hours/day being classified as having adequate sleep time.

The data were analyzed using STATA software, version 17.0 (StataCorp LP®, College Station, Texas, United States). The descriptive analyses used were the distribution of relative and absolute frequencies. Pearson's Chi-Square test was used to examine differences between variables.

Latent class analysis was used to model the latent variable from three variables, related to physical activity, screen time, and sleep hours. The evaluation of the most parsimonious model was based on the lowest values of Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Log-likelihood (LL), and highest entropy values (Schreiber, 2017). Finally, the probability of belonging to each item (ρ) and the prevalence of classes (γ) allowed for the analysis of homogeneity and separation of model classes.

To analyze the association between the cluster of physical activity, screen time, and number of sleep hours with obesity, binary logistic regression analysis was used. The analyses were adjusted for age, race, and mother's education level. The "Enter" method was used for the inclusion and retention of variables. The quality of the logistic regression models was evaluated by the Hosmer-Lemeshow test, in which values greater than 0.05 indicated a good fit of the modeling procedure. The models were presented for the total sample, and also stratified according to sex. Variables were considered significantly associated when the p-value was less than 0.05.

Results

The descriptive analysis is presented in Table 1. The sample included young people aged 14 to 19 years, of whom 61.2% were girls. The majority lived in urban areas (74.6%), were non-white (74.7%), with mothers who had not completed high school (57.5%). Regarding weight status, approximately 10.6% were overweight, and 13.3% were obese. Approximately 31.1% reported practicing more than 300 minutes of physical activity per week, 35.5% had up to two hours of screen time per day, and 38.3% had sleep time between eight to ten hours. However, the cluster of physical activity, screen time, and sleep behaviors indicated a low proportion of youths who exhibited all three healthy behaviors (4.4%).

Table 1 - Characteristics of high school students from the state public network of Pernambuco, Brazil, 2022.

Variables	Male (n= 1,134)	Female (n= 1,791)	Total (n=2,925)	p
Age, n (%)				**<0.01**
14 years	21 (1.8)	41 (2.3)	62 (2.1)	
15 years	214 (18.9)	411 (22.9)	625 (21.4)	
16 years	314 (27.7)	501 (28.0)	815 (27.9)	
17 years	308 (27.2)	496 (27.7)	804 (27.5)	
18 years	218 (19.2)	295 (16.5)	513 (17.5)	
19 years	59 (5.2)	47 (2.6)	106 (3.6)	
Residence region, n (%)				0.18
Urban	861 (75.9)	1.321 (73.8)	2.182 (74.6)	
Rural	273 (24.1)	470 (26.2)	743 (25.4)	
Race, n (%)				0.05
White	297 (26,2)	443 (24,7)	740 (25,3)	
Non-white	837 (73.8)	1.348 (75.3)	2.185 (74.7)	
Mother's education level, n (%)				**<0.01**
Did not complete high school	636 (56.1)	1.047 (58.5)	1.683 (57.5)	
Completed high school	498 (43.9)	744 (41.5)	1.242 (42.5)	
Weight status, n (%)				**<0.01**
Normal weight	909 (80.2)	1.317 (73.5)	2.226 (76.1)	
Overweight	93 (8.2)	217 (12.1)	310 (10.6)	
Obesity	132 (11.6)	257 (14.4)	389 (13.3)	
Behaviors, n (%)				
Physical Activity	486 (42.9)	423 (23.6)	909 (31.1)	**<0.01**
Screen Time	365 (32.2)	673 (37.6)	1.038 (35.5)	**<0.01**
Sleep	426 (37.6)	694 (38.8)	1.120 (38.3)	0.52
Cluster of behaviors, n (%)				**<0.01**
Meets three recommendations	66 (5.8)	63 (3.5)	129 (4.4)	
Meets two recommendations	300 (26.5)	420 (23.5)	720 (24.6)	
Meets one recommendation	479 (42.2)	761 (42.5)	1.240 (42.4)	
Meets no recommendations	289 (25.5)	547 (30.5)	836 (28.6)	

Legend: PA: Physical Activity; SB: Sedentary Behavior; p: p-value.

To identify behavioral patterns of youths using latent class analysis, models of two to five classes were analyzed considering the dichotomous variables of physical activity, screen time, and sleep. Table 1 presents the fit parameters of the latent class models. Based on the lowest information criteria indices AIC, BIC, and LL, and higher entropy values, it was possible to verify that the two-class latent model is more parsimonious, being the most appropriate to describe the groupings of behaviors in the analyses.

Table 1 - Criteria for determining the number of latent classes.

Number of classes	AIC	BIC	LL	Entropy
Total				
2	**11325.004**	**11360.890**	**-5656.502**	**0.967971**
3	11329.664	11383.494	-5655.832	0.828080
4	11334.408	11406.181	-5655.204	0.724418
5	11332.408	11398.199	-5655.203	0.942410
Male				
2	**4476.113**	**4506.314**	**-2232.056**	**1.005675**
3	4478.108	4513.343	-2232.054	0.937820
4	4484.046	4534.381	-2232.022	0.718207
5	4486.046	4541.414	-2232.022	0.440714
Female				
2	**6728.033**	**6766.467**	**-3357.016**	**0.850955**
3	6731.845	6786.750	-3355.922	0.690412
4	6729.844	6729.259	-3355.921	0.979125
5	6741.844	6824.202	-3355.921	0.488013

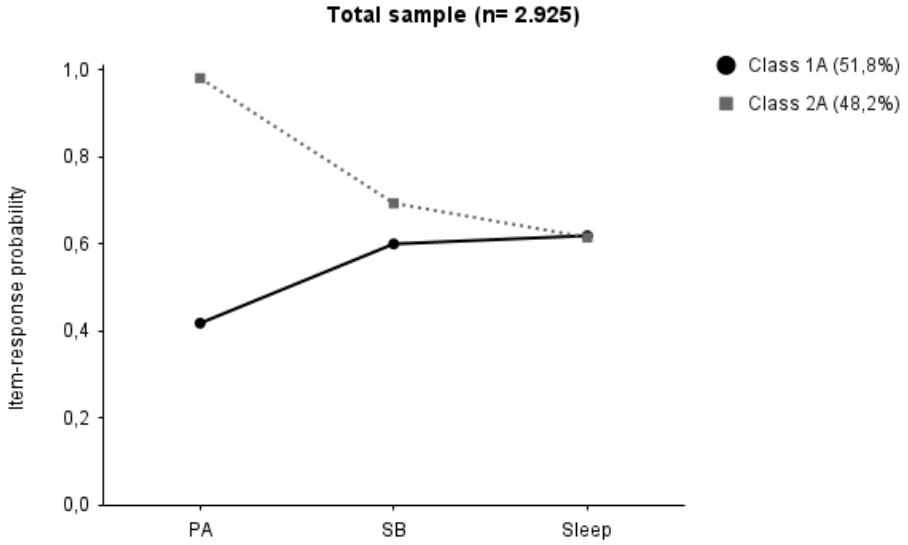
Note: The model with the chosen number of latent classes is highlighted in bold.

Legend: AIC - Akaike Information Criterion; BIC - Bayesian Information Criterion; LL: Log-likelihood.

The item-response probabilities for the latent classes are presented in figures 1, 2, and 3. Class 1A, with the highest prevalence at 51.8% of the total sample (figure 1), showed higher probabilities of presenting healthy behaviors in physical activity and screen time, being characterized by young people who are more active and have low screen time. On the other hand, Class 2A included youths with less healthy behaviors, with lower probabilities of being more active, having low screen time, and more adequate sleep, representing 48.2% of youths who are less active and have more screen time.

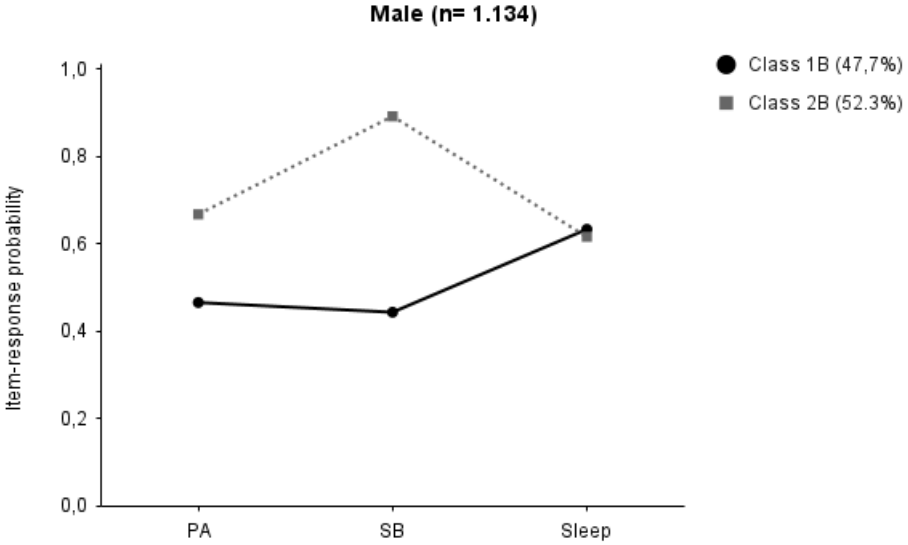
Similar patterns were observed in boys (figure 2), however, the highest prevalence in boys was found in Class 2B (52.3%), with less healthy behaviors (less active and with more screen time). The result for girls (figure 3) presented two latent classes, with the majority being in Class 1C (88.8%), showing healthy behaviors characterized by a higher probability of being more active, having low screen time, and having adequate sleep.

Figure 1 - Prevalence and item response probability of each behavior among young people in the total sample.



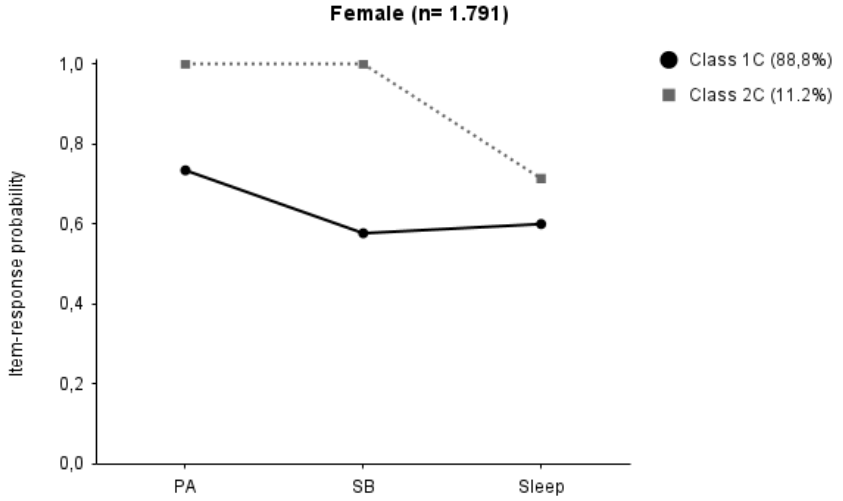
Note: Class 1A: active and non-sedentary; Class 2A: inactive and sedentary.
Legend: PA: Physical Activity; SB: Sedentary Behavior.

Figure 2 - Prevalence and item response probability of each behavior among young people in the male subsample.



Note: Class 1B: active and non-sedentary; Class 2B: inactive and sedentary.
Legend: PA: Physical Activity; SB: Sedentary Behavior.

Figure 3 - Prevalence and item response probability of each behavior among young people in the female subsample.



Note: Class 1C: active and non-sedentary; Class 2C: inactive and sedentary.
Legend: PA: Physical Activity; SB: Sedentary Behavior.

Table 2 presents the association between clusters of physical activity, screen time, and sleep behaviors and obesity. No significant associations were found between these behavioral clusters and obesity, either in the overall sample or when analyzed separately by sex.

Table 2 - Association of clusters of adherence to recommendations with obesity in young people.

	Male (n= 1,134)	**Female (n= 1,791)**	**Total (n=2,925)**
Clusters	OR (CI95%)	OR (CI95%)	OR (CI95%)
Meets three	1	1	1
Meets only two	1.39 (0.52;3.76)	0.69 (0.33;1.40)	0.91 (0.51;1.62)
Meets only one	1.97 (0.76;5.10)	0.83 (0.42;1.65)	1.19 (0.69;2.07)
Meets none	1.48 (0.55;3.99)	0.75 (0.37;1.51)	1.02 (0.58;1.80)

Note: Adjusted for age, race, and mother's education level.
Hosmer-Lemeshow test: Boys (chi-square = 381.64; p-value = 0.4095); Girls (chi-square = 429.34; p-value = 0.2912); Total (chi-square = 507.78; p-value = 0.4944).
Legend: OR: Odds Ratio; 95%CI: 95% Confidence Interval.

Discussion

The current study identified latent classes of physical activity, screen time, and sleep behaviors among youths and analyzed the existence of an association between the cluster of physical activity, screen time, and sleep behaviors with obesity. The key findings indicate that 10.6% of the young people are overweight, with 13.3% classified as obese. The prevalence of healthy behaviors related to physical activity, screen time, and sleep was low, at only 4.4% of adolescents exhibiting all three healthy behaviors simultaneously. A model consisting of only two latent classes was found, with the most prevalent class formed by youth who are more active and have less screen time. Finally, no associations were found between the simultaneity of healthy behaviors and obesity in youth.

The obesity rate in our study was higher than the results found in the 2019 National Health Survey, which identified that 6.7% of youths were obese (Brazil, 2021b). This higher rate can be explained by the fact that the global obesity prevalence has been rising in recent years, particularly in low- and middle-income countries (Phelps et al., 2024). Furthermore, global estimates indicate that, by 2035, 39% of youth could be overweight or obese (WOF, 2024). The gradual increase in obesity may be related to the growing prevalence of low levels of physical activity and preferences for sedentary behaviors (Phelps et al., 2024; Iurilli et al., 2021; Abarca-Gómez et al., 2017), giving rise to an urgent need for obesity prevention, since behaviors and patterns adopted during youth are known to persist into adulthood (Appannah et al., 2021; Inchley et al., 2020).

In the current study, 31.1% of the youths met the physical activity recommendation, a percentage similar to that observed in Canadians (Janssen; Roberts; Thompson, 2017) and North Americans (Katzmarzyk; Staiano, 2017), and higher than Chinese youth (Chen et al., 2021; Shi et al., 2020). Regarding screen time, 35.5% of young people reported using screens for an average of two hours per day, a prevalence similar to

studies in other countries (Jakubec et al., 2020; Katzmarzyk; Staiano, 2017; Shi et al., 2020). Additionally, 38.3% of youths met the sleep time recommendation, with prevalences similar to Canadian (Chemtob et al., 2021; Janssen; Roberts; Thompson, 2017), North American (Katzmarzyk; Staiano, 2017), and Chinese young people (Shi et al., 2020; Yang et al., 2022). However, only 4.4% of the youths in the current study reported simultaneously meeting all three recommendations, a value higher than that identified in Brazilian youth (3.1%) (Costa et al., 2020) and Chinese youth (1%) (Shi et al., 2020), but lower than that observed in North American youth (8.4%) (Katzmarzyk; Staiano, 2017). Given the low adherence to recommendations, it is essential to develop strategies to encourage physical activity, reduce screen time exposure, and improve sleep duration, promoting a healthier lifestyle in this population.

The LCA (Latent Class Analysis) enabled the identification of behavioral patterns considering the combination of adherence to recommendations. In the total sample and the male subsample, two latent classes of similar behaviors were analyzed, characterized as active, non-sedentary, poor sleep (Class 1A/B), and inactive, sedentary, better sleep (Class 2A/B). On the other hand, the female subsample combined healthier and less healthy behaviors in distinct classes, being active, non-sedentary, better sleep (Class 1C) and inactive, sedentary, poor sleep (Class 2C). Classes 1A, 1B, and 1C were considered as the healthiest, with higher probabilities of meeting the recommendations.

Our findings contribute to the literature by highlighting the differences in latent classes, based on combined patterns of PA, SB, and sleep. Most of the youths in the current study were included in classes with better behaviors, characterized mainly by being active and non-sedentary. Previous studies have identified that the most prevalent classes are characterized by healthier behaviors across the entire sample (Magee; Caputi; Iverson, 2013; Wang et al., 2014; Carson et al., 2015), in boys (Heitzler et al., 2011; Heikkala et al., 2014; Carson et al., 2015; Kim; Barreira; Kang, 2016), and in girls (Heikkala et al., 2014; Carson et al., 2015). Analyzing the associations between latent classes and obesity, several studies have reported that less healthy behaviors, such as physical inactivity and sedentary behavior (including high screen time), are associated with higher chances of obesity (Magee; Caputi; Iverson, 2013; Carson et al., 2015; Kim; Barreira; Kang, 2016; Mello et al., 2023). The classes of the female subsample seem to reinforce that girls are more inactive than boys, as they showed lower probabilities of meeting the physical activity recommendation. Adolescence is a risk phase for adopting inadequate behaviors, which, in addition to being harmful to health, tend to persist, resulting in worse health in adulthood (Burdette et al., 2017).

The current study did not identify an association between clusters of adherence to recommendations and obesity. Our results differ from others already published, which report a higher chance of obesity in young people who do not meet the three recommendations (Chemtob et al., 2021; Chen et al., 2021; López-Gil et al., 2023; Rollo; Antsygina; Tremblay, 2020; Yang, et al., 2022; Zhu et al., 2020). This may be related to the influence of sociocultural and economic factors, given that most of the previous research is conducted in high-income countries (López-Gil et al., 2023; Marques et al., 2023; Rollo; Antsygina; Tremblay, 2020), or with samples that include young people from different age groups, with the possibility that the relationship between these variables varies according to age (Marques et al., 2023). In addition, there may be other factors that influence, attenuate, or amplify the relationship between healthy behaviors and obesity (Antonio-Anderson et al., 2020; García Pérez & Rodríguez López, 2022).

The practical implications of this study include the possibility of addressing obesity in youth through the development of comprehensive public policies. This may include implementing school-based programs focused on promoting physical activity and reducing screen time. It could also be important to launch awareness campaigns targeting both parents and young people, highlighting the importance of maintaining healthy lifestyle habits and the dangers associated with excessive use of electronic devices and inadequate sleep time. Furthermore, campaigns that raise awareness among young people about social media content and that encourage the dissemination of messages which can promote physical activity, decrease screen time, and adequate sleep hours, as well as healthy eating behaviors associated with obesity control, could be highly effective. It is important to acknowledge the limitations of the present study. Firstly, it was not possible to establish a causal association, as the study has a cross-sectional design. The self-reported nature of the data may have been influenced by memory bias, as the time of exposure to behaviors may have been underestimated or overestimated by the youths. However, the main strength of the study is the sample size (which involves a large number of high school students from the state of Pernambuco), which allows for better direction and understanding for future actions and strategies for behavior change in this population. Furthermore, the use of latent class analysis allowed the identification of behavioral patterns based individually on each of the young people.

Conclusions

The study identified that more active young people with less screen time prevailed, while boys were less active and spent more time on screens, and girls were more active, with less screen time and adequate sleep. Furthermore, no association was found between the cluster of adherence to recommendations for physical

activity, screen time, and sleep and obesity in youth, both in the analysis of the total sample and in the sex-stratified analyses.

Conflicts of interest The authors declare that there is no conflict of interests.

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