Patterns of screen-based sedentary behavior and physical activity and associations with overweight among Norwegian adolescents: a latent profile approach

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ABSTRACT

Background: Physical activity and screen based sedentary behaviors are both related to energy balance and to risk for becoming overweight. The aim of this study is to find out if these behaviors cluster together in order to find out whether groups of adolescents have particularly unfortunate levels of both physical activity and screen-based sedentary behaviors. ***Methods:*** Data are from the Norwegian 2005/2006 sample of the international "Health Behaviour in School-aged Children (HBSC) study; A WHO cross-National Survey". Data were collected through questionnaires from 13-, 15- and 16-year-olds. The final sample included 4848 adolescents. Gender-stratified latent profile analysis was used to identify the different profiles. ***Results:*** Six profiles were identified for both boys and girls. Less than 30% of adolescents were found to have behavioral patterns which were associated with higher risk for overweight relative to the most healthy behavioral profile. Physical activity and screen-based sedentary behaviors cluster together in different ways suggesting independence between the behaviors. Low levels of physical activity was the most important predictor for overweight among boys. Screen-based sedentary behaviors were more important predictors of overweight among girls. ***Conclusions:*** Physical activity and screen-based sedentary behaviors are independent behaviors and may cluster together in manners which lead to low energy expenditure and subsequent increased risk for overweight among adolescents.

INTRODUCTION

Overweight and obesity among school-aged children is a serious and growing health concern in virtually all parts of the world (1). Childhood and adolescent overweight is a particularly serious problem as it is associated with increased risk for numerous health complications such as diabetes II (2), pediatric hypertension (3), as well as psychosocial outcomes such as fewer friends (4) and lower quality of life (5) relative to non-overweight children.

The development of overweight and obesity is caused by an unfavorable energy balance where energy consumption is greater than energy expenditure (6). Consequently the balance between high energy expenditure behaviors such as physical activity (PA) and low energy expenditure behaviors such as sedentary behaviors (SB) should influence adolescents' weight status.

Indeed, there is strong and conclusive evidence linking physical activity to overweight (7). For sedentary behaviors however, associations are in best case weak and in some studies even statistically insignificant (8). The only sedentary behavior that has been found to be consistently associated with weight-status is TV viewing (9). However, a meta-analysis by Marshall and colleagues revealed that these associations are generally weak and most likely of little clinical significance (8).

Screen-based sedentary behaviors (SBSB) represent a prevalent (10) and distinguishable type of SB which are likely to influence the energy balance both through low energy expenditure as well as through their associations with eating less healthy types of food (11-13) and meal skipping (14,15).

Most adolescents perform both physical activity and various SBSB. However, these behaviors are weakly correlated (8,16) suggesting that PA and SBSB may be combined in several different patterns within individuals. Consequently, different combinations of high or low levels of PA or SBSB may interact and lead to higher or lower risk for overweight relative to the levels of the individual behaviors.

Consequently, the weak associations between overweight and TV viewing which were identified in Marshall and colleagues' meta-analysis (8) may conceal sub-groups with stronger or weaker associations between behaviors and overweight.

In order to investigate such sub-groups it is necessary to change from a variable-oriented approach to an individual-oriented approach when analyzing data. Variable-oriented approaches expresses the relationship between variables in terms of assessments of association or difference. Individual differences are considered random and thus negligible in these types of analysis (17). This implies that if individual differences are not random, then variable-oriented analyses will provide biased results. In contrast, person-oriented approaches aim to describe groups of individuals with relatively homogenous characteristics and do not depend upon assumptions of normal distributions and homoscedasity (18).

Previous studies which have used person-oriented approaches have identified sub-groups of adolescents with different behavioral patterns. Among boys, patterns of both above average PA and SBSB have been found (19-21) while various behavior profiles such as high PA/low SBSB and low PA/ high SBSB levels have been identified for both genders (19,22-24).

We were only able to identify three studies that have investigated the relationship between overweight and patterns of physical activity and sedentary behavior using cluster analytic approaches.

TeVelde and colleagues (19) investigated if the risk for overweight differed across clusters of PA, SBSB and watching TV during dinner. They found sedentary behavior to be the main factor distinguishing between higher and lower risk for overweight among girls, whereas both physical activity levels and sedentary behavior levels distinguished boys' risk for being overweight. Seghers and Rutten (24) also attempted to distinguish the prevalence of overweight between behavioral profiles based upon PA, SB and food habits, but were not able to find significant differences between the groups due to the small sample and low statistical power. Finally, Monda and Popkin (22) found that, irrespective of levels of SBSB, physical activity distinguished between clusters with different risk for overweight among Chinese youth. In sum, this research provides somewhat mixed results about whether physical activity and SBSB patterns influence individuals' weight status.

In order to address the lack of consistency of the reviewed results, the aim of the current study was to investigate the associations between PA, SBSB and overweight among Norwegian adolescents, and to assess the prevalence of different behavioral profiles based upon these behaviors. Finally the study will assess whether adolescents with different behavioral profiles differ in risk for overweight.

The research questions which will be investigated:

1. How are SBSBs and PA associated with overweight among Norwegian adolescents?
2. What are the most common patterns/combinations of physical activity and SBSBs?
3. Do adolescents with different behavioral patterns differ in risk for overweight?

METHODS

The study was based on data from the Norwegian sample of the 2005/2006 Health Behaviour in School-Aged Children (HBSC) study (25). HBSC is an international WHO collaborative study with cross-sectional surveys performed every fourth year among 11-, 13- and 15-year-olds (the Norwegian sample also includes 16-year-olds). The samples were designed to be nationally representative with the primary sampling unit being the school class (response rate 58%) or the school where school class information was not available. The final sample consisted of 6447 students, indicating an 84% response rate on the individual level.

The 11-year old students were omitted from the final sample due to over 20% missing BMI responses for both boys and girls. Thus, the final sample included 4848 of which 52% were boys and 48% were girls. For more information on the HBSC study, see Currie et al. (25) and Roberts et al. (26). The study was approved by The National Committees for Research Ethics in Norway and Norwegian Social Science Data Services.

The student's parents received information about the study, and passive consent from parents was obtained. Students received relevant information about the purpose of the survey, and were informed that all answers were anonymous and that they were free to withdraw at any time. Data was collected in the school classrooms by the teachers who followed a standardized procedure ensuring student anonymity.

Measures

Levels of leisure time vigorous physical activity (VPA) was assessed through the following item: *After school: How many HOURS per week do you do sports or other exercise until you become out of breath and/or sweaty*? This item is likely to reflect the time spent in vigorous activity as the intensity indicated suggests that it involves some higher intensity physical activity, requiring at least as much effort as brisk or fast walking (27). The question has been found to have acceptable to good test-retest reliability and at least partial validity, as higher activity levels corresponded with higher aerobic fitness (28). In order to increase the interpretability of the results, the responses were recoded. "None" was coded, 0, "about 30 minutes" was coded .5, "1hr" was coded 1, "2-3hrs" was coded 2.5, "4-6hrs" was coded 5, and finally "≥ 7hrs" was coded 7.

Moderate to vigorous physical activity (MVPA) was measured by the item "Over the past 7 days how many days were you physically active for a total of at least 60 minutes?" The responses were coded "none" (0), "one" (1), "two" (2) etc. Prochaska and colleagues (29) found this question to be reliable and to have acceptable validity in comparison with accelerometer data.

Levels of *screen-based sedentary behaviors* were assessed through six items: "About how many hours a day do you usually watch television (including videos) in your free time?"; "About how many hours a day do you play PC-games or TV-games (Playstation, Xbox, GameCube etc.) in your free time?" About how many hours a day do you usually use a computer for chatting on-line, internet, emailing, homework etc. in your free time? Each question asked about time spent in the behaviors on week days and on weekend days. The following nine response options were the same for all six questions: “None at all” (0), “About half an hour a day” (.5), “About 1 hour a day” (1), “About 2 hours a day” (2), “About 3 hours a day” (3), “About 4 hours a day” (4), “About 5 hours a day” (5), “About 6 hours a day” (6), “About 7 or more hours a day” (7).

Cumulative scores for hours of weekly use of the three different behaviors were computed by weighing the weekday and weekend responses according to the number of days per week to which they referred. The item referring to TV viewing has been investigated for test-retest reliability and relative validity relative to a 7-day TV-diary. No systematic difference was identified between test and retest, but adolescents reported higher levels of TV viewing relative to the TV diaries with the average discrepancy being approximately one hour per day for boys, and half an hour for girls (30). The item reflecting PC-use has been found to have good reliability and validity (12,31).

Socioeconomic status (SES) was assessed by the family affluence scale FAS II (32). The FAS II is a formative index consisting of four items: “Does your family own a car, van or truck?”, “Do you have your own bedroom for yourself?”, “During the past 12 months, how many times did you travel away on holiday with your family?”, “How many computers do your family own?” FAS II has been thoroughly validated and has demonstrated good criterion validity across a range of studies (32,33).

Weight status was calculated using self reported weight and height. Body mass index score (BMI) was calculated (kg/m^2) and individuals were categorized as overweight or normal weight according to age and gender specific cutoffs corresponding to adult reference levels of 25 (34).

Statistical Analyses

The clusters were constructed by means of latent profile analysis (LPA) in Latent Gold (version 4). LPA is analogous to latent class analysis (LCA), but with continuous rather than dichotomous indicators (35).

LPA is conceptually similar to the K-means cluster analysis which was used in the reviewed cluster analytic approaches (19,22,24,36). The main purpose of LPA is thus to allocate subjects to sub-groups where within group variance is minimized and between-groups variation is maximized. However, in contrast to the conventional modeling approaches, LPA is based upon maximum likelihood (ML) estimation that provides several advantages. Most importantly, the model selection in LPA is less arbitrary as both relative fit indices and statistical tests are provided to determine which cluster solution fits the data better. Other advantages of LPA modeling is that cluster assignment is based upon the individuals probability of belonging to a given class and the opportunity to include active covariates in the analysis. This allows for improved estimation as the information about associations between the covariates and the latent variable is used to maximize the likelihood of the model (37).

Finally, the ML estimation does not require listwise deletion as it operates with the MAR assumption where any missingness related to the variables included in the model are statistically accounted for (37,38). This retains more statistical power and reduces the probability of getting biased estimates as a consequence of systematic missing responses (39).

The estimation of the LPA model was conducted through the following steps. First, the datafile was split in two random halves. TV, PC, Gaming, VPA and MVPA were used as indicators for the latent classes while age and FAS was used as active covariates. This implies that the associations between the latent profiles and overweight are controlled for age and FAS effects. Overweight status was used as a distal outcome and was thus included in the analysis as an indicator as recommended in the LPA/LCA literature (37). The model was estimated for the range of 1 to 8 latent classes and the solutions relative fit was compared according to the Bayesian information criterion (BIC) (40). The BIC indicated that the eight class solution showed the best fit. However, neither the seven or eight class solutions did replicate in the other half of the sample. Consequently, a six class solution was chosen for both boys and girls as these fit better to the data relative to the 5 class both in terms of BIC and the conditional bootstrap ($p< .000$ for both girls and boys). Importantly, these solutions replicated into very similar clusters in both halves of the sample. Finally, the entire sample was used to estimate a six cluster solution for both boys and girls separately.

The naming of the latent classes in low moderate, high and very high levels of and SBSB refers to relative amounts of time and were used to simplify interpretation of the differences between the clusters. The standard errors were adjusted for clustering effect according to the primary sampling unit (school class).
In order to reduce the likelihood of obtaining a local solution representing a sub-optimal model, the number of random sets of starting values for the estimation algorithm was increased from the default 10 to 200 random starts and 100 iterations (41).

The odds-ratios for being overweight were calculated by assigning all individuals to the class to which they had the highest posterior probability of belonging to. This procedure as well as the logistic regression model (table 2) was performed in mplus (version 4.0) (42) with using full information maximum likelihood (FIML) estimation which is a full information estimator where missing responses are assumed to be missing is random (MAR) conditional on the variables included in the model (38).

RESULTS

Table 1 shows the demographic characteristics of the sample and the distribution of normal weight, overweight and missing BMI responses. More boys were

Table 1. Gender, age and FAS across overweight categories.

	Missing BMI	Normal weight	Overweight	total	chi	P
Boys	13.8%	74.1%	12.1%	2520	32.20	0.000
Girls	16.4%	76.2%	7.4%	2328		
13 years	19.7%	72.4%	7.8%	1585	49.61	0.000
15 years	14.0%	75.2%	10.9%	1534		
16 years	11.7%	77.5%	10.8%	1729		
Low FAS	14.5%	74.7%	10.9%	1511	9.17	0.057
Medium FAS	14.6%	74.8%	10.6%	1648		
High FAS	14.6%	77.4%	8.0%	1613		
Total	729	3641	477	4848		

Note the total N does not correspond with FAS due to some missing FAS values

Table 2. Means, standard deviations and correlations for SBSB and PA.

	Boys			Girls							
	Mean	SD	N	Mean	SD	N	1.	2.	3.	4.	5.
1. TV	2.49	1.53	2292	2.6	1.43	2174		.25**	.29**	–0.06	–.13**
2. Games	2.11	1.86	2307	0.54	1.08	2198	.33**		.26**	0.01	–.08**
3. PC	1.94	1.75	2315	2.1	1.63	2172	.30**	.37**		–.08**	–.05*
4. MVPA	3.80	2.04	2351	3.5	1.94	2201	–.06**	–.18**	–.06**		.58**
5. VPA	3.68	2.49	2434	3.09	2.30	2263	–.09**	–.20**	–.09**	.63**	

** Correlation is significant at the 0.01 level (2-tailed).
Girls correlations are shown above the diagonal and boys correlations are shown below the diagonal.
ANOVA tests indicated that all means were significantly different across gender ($p<.05$)

found to be overweight whereas more girls had missing data for BMI. Across age, there was an increase of adolescents who were found to be normal-weight. However, there was also an increase in the prevalence of overweight between the 13 year-olds and the 15 year-olds and a decrease in number of missing BMI responses with increasing age. Fewer in the high FAS categories were found to be overweight relative to the medium and low FAS categories.

Table 2 shows the means, standard deviations and correlations between the physical activity and SBSB variables. Boys were found to spend more time than girls in MVPA, VPA and gaming, and girls reported spending more time watching TV and using the computer for non-gaming purposes. All SBSBs were found to correlate moderately with each other (r between .25 and .37). Both VPA and MVPA were weakly and negatively correlated with the different SBSBs (except gaming and MVPA for girls which was not significant).

Table 3 shows odds-ratios and 95% confidence intervals for boys and girls. There was a significant gender interaction for the association between gaming and overweight where odds of being overweight increases pr hour for girls, but not for boys. Each hour extra spent in VPA was associated with reduced odds for being overweight for both boys and girls. MVPA however, was only significant predictor for overweight in boys. Time spent in all SBSBs were significantly associated with increasing odds for overweight in girls but not in boys.

Table 4 shows size, and profile and overweight prevalence of the different latent profiles for boys. Odds ratios and 95% confidence intervals for being overweight for each group are presented relative to the *moderate SBSB/very high PA*. The moderate SBSB/very high PA cluster comprised 24% of the sample and was characterized by the highest levels of physical activity along with moderate amounts (between 1.5 and 2.5 hrs/day) of the various SBBSB's. 11% of the adolescents in this group were found to be overweight. The

Table 3. Odds ratios and 95% confidence intervals for overweight by SBSB and PA.

	Boys		Girls	
	OR	95% CI	OR	95% CI
MVPA $_1$	**0.94**	(0.91 to 0.97)	0.97	(0.94 to 1.02)
VPA $_2$	**0.95**	(0.92 to 0.98)	**0.96**	(0.93 to 0.99)
TV $_3$	1.04	(1.00 to 1.09)	**1.08**	(1.02 to 1.14)
GAME $_3$*	1.03	(0.99 to 1.07)	**1.12**	(1.04 to 1.20)
PC $_3$	1.03	(0.99 to 1.07)	**1.10**	(1.01 to 1.19)

Note: Estimates are controlled for age and FAS
*indicates a significant gender interaction.
$_1$ = number of weekly days of 60 min cumulative MVPA,
$_2$ = number of weekly hrs of VPA, $_3$ = number of daily hrs.

Table 4. Size of cluster, mean values of behaviors, prevalence of overweight and OR and 95% confidence intervals for being overweight relative to the Moderate SBSB/ very high PA cluster for boys.

	size	TV	Game	PC	MVPA	VPA	% OW	95% CI	OR	95% CI
Moderate SBSB/very high PA	24%	2.30	1.68	1.73	5.72	7.00	11%	(0.08 to 0.14)	1.00	
Moderate SBSB/ high PA	25%	2.41	1.85	1.86	4.17	5.00	11%	(0.09 to 0.13)	1.00	(0.82 to 1.22)
Moderate SBSB/ moderate PA	23%	2.46	2.08	1.85	3.31	2.50	14%	(0.11 to 0.17)	1.18	(0.97 to 1.44)
Low SBSB/ low PA	12%	1.88	1.32	0.91	2.71	0.61	16%	(0.10 to 0.22)	**1.35**	(1.07 to 1.70)
High SBSB/ low PA	14%	3.10	3.26	2.66	1.78	0.44	22%	(0.16 to 0.29)	**1.62**	(1.30 to 2.01)
Very high SBSB/ low PA	2%	5.25	7.00	6.99	2.78	1.44	26%	(0.12 to 0.40)	**1.82**	(1.18 to 2.81)

Table 5. Size of cluster, mean values of behaviors, prevalence of overweight and OR and 95% confidence intervals for being overweight relative to the Moderate SBSB/ very high PA cluster for girls.

	Size	TV	Game	PC	MVPA	VPA	% OW	95% CI	OR	95% CI
Moderate SBSB/ very high PA	13%	2.28	0.19	2.00	5.51	7.00	5%	(0.02 to 0.07)	1.00	
Moderate SBSB/ high PA	20%	2.33	0.13	1.81	4.26	5.00	8%	(0.05 to 0.10)	1.26	(0.92 to 1.71)
Moderate SBSB/ moderate PA	27%	2.43	0.21	1.98	3.33	2.50	7%	(0.05 to 0.09)	1.18	(0.87 to 1.60)
Moderate SBSB/ low PA	11%	2.95	0.69	1.91	2.34	0.56	9%	(0.04 to 0.14)	1.36	(0.95 to 1.94)
Moderate SBSB (no gaming)/ low PA	18%	2.80	0.00	2.36	2.21	0.56	12%	(0.08 to 0.15)	**1.59**	(1.17 to 2.17)
High SBSB/ moderate PA	11%	3.46	3.00	3.09	3.68	2.94	17%	(0.11 to 0.23)	**2.01**	(1.45 to 2.78)

Moderate SBSB/high PA group was the largest group including 25% of the sample. Adolescents in this group reported 4.17 days per week of (60 min) MVPA and 5 hrs/week of VPA. The prevalence of overweight in this group was also 11%. The *Moderate SBSB/ moderate PA* cluster comprised 23% of the sample, reported 3.31 days/week of MVPA and 2.5hrs/week of VPA. 14% of this group was found to be overweight. The *Low SBSB/low PA* cluster was about 12% of the sample. They reported watching TV about 1.88 hrs/day and less time in both gaming and PC use. Adolescents in this cluster also reported 2.71 days/week of MVPA and less than half an hour (.44hrs) of weekly VPA. 16% of the adolescents in this cluster were found to be overweight. Adolescents in the *High SBSB/low PA* cluster spent more than three hours daily on both TV and gaming and more than 2.5 hrs/ day on gaming. This cluster had the lowest levels of physical activity with less than 2 days/week of MVPA and less than 15 minutes/week (.22hrs) of VPA. 22% of the adolescents in this cluster were overweight. The Very high SBSB/low PA was the smallest cluster containing only 2% of the sample. This group reported the highest levels of SBSB with more than 5hrs/daily of TV and about 7hrs/day for both computer use and gaming. Physical activity levels were also low in this group and the prevalence of overweight was the highest with 26%. Relative to the Moderate SBSB/very high PA, the Low SBSB/low PA, High SBSB/low PA and Very high SBSB/low PA clusters had significant higher odds of being overweight.

Table 5 shows size, and profile and overweight prevalence of the different latent profiles for girls. Odds ratios and 95% confidence intervals for being overweight for each group are presented relative to the *moderate SBSB/very high PA*. The *moderate SBSB/very high PA* cluster comprised 13% of the sample of which 5% was found to be overweight. Adolescents in this cluster reported 5.5 days/week of MVPA, 7hrs weekly of VPA and moderate levels of SBSB (here defined as between 2-3hrs TV, 0-1hrs gaming, and 1.5-2.5hrs of PC). Adolescents in the *moderate SBSB/ high PA* cluster reported over 4 days/week MVPA and 5hrs/week of VPA. This cluster contained 20% of the sample and had an 8% prevalence of overweight. The *moderate SBSB/moderate PA* cluster reported 3.3 days of MVPA and 2.5hrs of VPA/week, comprised 27% of the sample of which 7% were overweight. 11% of the sample were in the *moderate SBSB/low PA* cluster. These adolescents were characterized by 2.3 days of MVPA and about half an hour of VPA. 9% of this cluster were classified as overweight. The *moderate SB (no gaming)/low PA* cluster comprised 18% of the sample and had similar levels of both SBSB and PA as the *moderate SB/low PA* cluster except they reported no gaming behavior. 15% of the adolescents in this cluster were overweight. The *high SBSB/moderate PA* cluster had the highest prevalence of overweight (17%). Adolescents in this cluster were characterized by more than 3hrs/day in all SBSBs, about 3.7 days of MVPA and 2.94hrs/week of VPA. The *moderate SB (no gaming)/low PA* and High SBSB/moderate PA clusters had increased odds of being overweight relative to the *moderate SBSB/very high PA* cluster.

DISCUSSION

This study aimed to identify behavioral patterns based upon the time adolescents spend in SBSBs and physical activity and how these differ in terms of prevalence and risk of overweight. The main findings suggest that less than 30% of adolescents have behavioral patterns based upon SBSB and PA which are associated with higher risk of overweight. Among boys, low levels of physical activity were the distinguishing factor for increased risk of overweight irrespective of time spent in SBSB. For girls, SBSB was found to be a more important predictor of overweight.

The clusters which had relatively higher risk for overweight were different between the genders. PA was the key predictor of overweight among boys, both in the crude associations and in distinguishing the relative risk for overweight across clusters. For girls on the other hand, the group with the highest risk for overweight had moderate levels of PA (mean levels of MVPA of 3.68 and 2.94hrs/week of VPA), but relatively high levels of SBSB (<3 hrs/day for all three SBSBs). The crude associations also suggest a dose-response relationship between the amount of time girls spend in the various SBSBs and overweight (and also with VPA).

Despite the general similarities to the results from the variable-centered approach (crude associations in table 2), the person-centered approach (latent profiles) provides more additional important information about the clustering of risk factors, and prevalence of the high-risk behavioral patterns.

Gender differences in associations with overweight suggested that girls who reported relatively high levels of SBSB were found to have increased risk for overweight despite average or high levels of physical activity. This corresponds well with other cluster-analytic studies (19,43) and suggests that the assessment of PA and SBSB as individual risk factors may conceal the interplay between these qualitatively different behaviors among subgroups in the population.

Our results suggested that physical activity was the most important behavioral correlate for overweight among boys. However, this is not entirely in line with the results of te Velde and colleagues (19) as they also found increased risk for overweight in clusters with high levels of SBSB and average levels of PA. Wong and Lathersdale (43) only found increased risk for overweight among the low active-high sedentary boys (relative to high active-low sedentary), making it impossible to attribute the increased risk to either physical activity or sedentary behavior alone.

In sum, our findings suggest that overweight girls tend to spend more time in SBSBs relative to normal-weight girls and overweight boys are less physically active. Longitudinal studies suggest that both PA and SBSB are causal predictors of overweight status (44). However, there is also speculation that overweight or obese adolescents may choose more sedentary behavioral patterns as well. Vanderwater and colleagues (45) suggest that overweight girls in particular may turn to electronic media due to social isolation. Regardless of the direction of causality, there is a need for behavior change in the high-risk groups of individuals as increasing activity levels or decreasing levels of SBSB would be likely to increase energy expenditure, lead to lower risk of overweight and thus lower health risk for these individuals.

The descriptive data did reveal some gender differences in both PA and SBSB. In line with previous studies boys were found to be more physically active than girls (46-48) and to spend more time playing video or PC games (10,49,50). However, our results showing that girls spend more time watching TV and using PC's for non-gaming purposes are not entirely in correspondence with dose estimates from an international review and meta-analysis (10) as this suggests that there were no gender differences in either TV viewing or PC use. This lack of correspondence could possibly be a reflection of changes in secular trends (as our data is more recent), or it may reflect that gender differences in these behaviors are different in Norway relative to the international tendencies found by Marshall and colleagues.

The variation in composition of high and low levels of PA across similar levels of SBSB provides further support for the assumption of independence of these behaviors (8,16,48). This independence is evident as girls who spent the most time in SBSB have about average levels of PA and boys who spend the least amount of time in SBSB also have low levels of PA. The combination of low SBSB/low PA also highlights the fact that many adolescents spend their leisure time on behaviors that are not included in the current analyses. An implication of these findings is that assessments of single or even multiple SBSBs are not likely to be valid indicators for overall sedentariness.

However, the independence between behaviors is likely to hold only up to a certain threshold after which there will simply not be any time left over for other behaviors. The boys High SBSB/ low PA cluster exemplify this as the time these boys spend in SBSBs is likely to preoccupy virtually all of their free time.

Implications of these findings is that interventions aimed at increasing the time adolescents spend in both MPVA and VPA and reduce time spent in SBSB may have the potential to attenuate the increase in overweight and obesity. Numerous interventions aimed at increasing physical activity and a systematic review by van Sluijs et al. (51) suggests that effective interventions should be multi-component, including school and family or community involvement.

However, any interventions aiming to reduce SBSB or SB in general is likely to have more of an influence on adolescents overweight-status if the sedentary behaviors are replaced by more active behaviors and not just another type of SB. Interventions should also aim at reducing SB during daytime when they are more likely to compete for time with more physically active behaviors (36). Also, although SBSBs are characterized by lower energy expenditure, some of them are also important to children and adolescents' development. Thus, watching educational TV shows or using computers for homework or creative purposes should not necessarily be discouraged as long as it is incorporated in an otherwise healthy lifestyle.

Some limitations of this study should be mentioned. First, the cross-sectional design does not allow for conclusions about causality. However, irrespective of whether adolescents are overweight because of their behavioral patterns, or if they choose the different behavioral patterns because of their weight status, the results are still of importance as they identify high risk groups which could benefit from targeted interventions.

Secondly, we know from previous research that adolescents tend to under-report their weight (52-55). However, Goodman and Strauss (56) suggested that self-reported measures indeed are “feasible, useful measures for large studies of risk factors associated with excess weight among adolescents and that data collected in such a fashion can be used to reliably categorize subjects as overweight (95% or over BMI) or not” (pp 140).

Thirdly, missing responses for BMI are also a challenge for most survey-based studies. However, the prevalence of missing responses in this study was quite small relative to other comparable studies (19). Also as this study used ML estimation, it was therefore not necessary to do listewise deletion of observations and all available information was thus used to provide more accurate estimates (38).

The strengths of this study include a nationally representative sample, improved methods of analysis from previous studies both in the use of latent profile analysis over the conventional approaches to cluster analysis (57), and in the handling of missing responses (38,39).

Future research should attempt to replicate some of the cluster solutions presented in the current study using confirmatory analysis to find whether they are stable across samples.

Developing ways to assess multitasking, both the prevalence and different types of multitasking is important in the future studies of SBSBs. Jeong and Fishbein (58) found that most adolescents do several things at one time when using the computer. This tendency may have caused some bias in the current estimates and in other similar studies as adolescents may double-report the time they spend in the various SBSBs.

Future studies should also attempt to identify the modifiable determinants of SBSB. While the determinants and correlates of PA has been extensively studied (46), very little is known about motivational and structural factors which may influence adolescent use of SBSB.

In conclusion, this study identified sub-groups of adolescents with qualitatively different behavioral profiles consisting of different levels of PA and SBSB. These suggest that no single sedentary behavior or even multiple SBSBs should be used as indicators of overall sedentariness. Gaming behavior was a key distinguishing factor between boys and girls’ behavioral patterns as the behavior was found to be performed by boys across all behavioral patterns, but only a small proportion of girls reported gaming behavior. About 30% of adolescents were found to have high-risk behavioral patterns involving higher odds for overweight. Levels of physical activity was found to distinguish between high and lower risk for overweight among boys while screen-based sedentary behavior was found to be a more important correlate for overweight among girls.

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