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Adherence to sleep guidelines reduces risk of overweight/obesity in addition to 8-5-2-1-0 guidelines among a large sample of adolescents in the United States

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ABSTRACT

Objectives: To examine whether adherence to US sleep, dietary, screen time, and physical activity (*8-5-2-1-0)* guidelines is associated with reduced risk of overweight/obesity in adolescents.
Design: Multivariable log-binomial regressions were estimated using the 2017 Youth Risk Behavior Surveillance System data.
Results: Of the 8194 adolescents aged 13 years and older, only 0.6% (49) met all guidelines. Meeting the recommended 8 hours of sleep per day was associated with reduced risk of overweight/obesity (risk ratio [RR]: 0.90; confidence interval [CI]: 0.81-0.99). Having ≤2 hours of screen time per day was associated with reduced risks of overweight/obesity (RR: 0.85; CI: 0.77-0.95). One hour of daily physical activity was associated with reduced risk of overweight/obesity (RR: 0.80; CI: 0.73-0.87). No significant associations were found between daily consumption of ≥5 fruits and vegetables or consumption of zero sugar-sweetened beverages and overweight/obesity. The *8-5-2-1-0* constitutes an improved prediction model to explain the risk of overweight/obesity among adolescents compared with the *5-2-1-0* model ($F_{1,36} = 4.80$; $P = .035$).
Conclusions: Findings from this study suggest that meeting recommendations for sleep, screen time, and physical activity is associated with decreased risk of overweight/obesity in a large sample of adolescents. These are important factors to consider in the prevention and treatment of overweight/obesity in adolescents.

Introduction

Nationwide studies in the United States (US) showed that prevalence of obesity has risen among children and adolescents aged 2 to 19 years. Between 1999 and 2016, there was a positive linear trend in overweight/obesity: among children, 39% of those 2 to 5 years old, 36% of those 6 to 8 years old, and 35% of those 9 to 11 years old had overweight/obesity.[1] The occurrence of overweight/obesity was even higher among adolescents: 59.3% of those 12 to 15 years old and 62% of individuals 16 to 19 years old had overweight/obesity.[2] This is particularly problematic because although childhood and adolescent obesity is a precursor for adult obesity across age categories, the magnitude of the association varies considerably across age groups. Children who have obesity at age 7 have a 41% chance of becoming an adult with obesity, and adolescents aged 13 to 19 years have a 90% chance of becoming an adult with obesity.[3]

To prevent and reduce overweight/obesity among adolescents, primary care and school-based interventions[4–6] have been implemented to encourage the recommended guidelines for behaviors evidenced to reduce the risk for overweight/obesity including diet, physical activity, and screen time.[7–17] See Table 1.

In 2006, the Maine Youth Overweight Collaborative launched the "Let's Go! 5-2-1-0," a youth obesity prevention program that

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Table 1
US guidelines for pediatric populations

Guidelines	Federal entity/professional societies	Period
8: Sleep at least 8 h/24 h	National Sleep Foundation	2015[29]
	American Academy of Sleep Medicine	2016[17]
	American Academy of Pediatrics	2016[11]
5: Consume at least 5 servings of FV/24 h	American Academy of Pediatrics	2006,[10] 2007[18]
	US Department of Agriculture	2010,[18]
	Department of Health and Human Services	2015[19]
2: Limit screen time to no more than 2 h/24 h	American Academy of Pediatrics	2001[13]
1: Attain 1 h of physical activity/24 h.	US Department of Health and Human Services	2008[12]
0: Consume 0 SSB/24 h	American Academy of Pediatrics	2006,[10] 2007[18]

summarized national recommendations in a mnemonic message: 5 servings of fruit and vegetables (FV), 2 hours of screen time, 1 hour of physical activity, and 0 sugar-sweetened beverages (SSB) daily.[18] Nationwide, obesity prevention programs have used this program due to its simple and succinct message.[18] Studies using population-based data that have examined adherence to the *5-2-1-0* guidelines (all the guidelines except for sleep) found that only a very small proportion of adolescents aged 12 to 19 years meet all 4 guidelines.[18–20] Few studies have examined the associations between meeting the 5-2-1-0 guidelines and health outcomes.

In addition to the diet, physical activity, and screen time behaviors included in the 5-2-1-0 recommendations, poor sleep has also been associated with risk of obesity potentially through impaired glucose regulation and effect on other behaviors.[21,22]

A systematic review and meta-analysis of observational cohorts, cross-sectional and case-control studies from the US and 8 other countries established a negative association between sleep duration and overweight/obesity among children and adolescents from birth to 18 years. Each hour increase in sleep duration was associated with a 9% reduced risk of being overweight/obese.[23] A growing body of evidence suggests that sleep is an important factor to consider in the prevention and treatment of obesity and should be given as much attention and resources as nutrition and physical activity.[24–26] Recent efforts in Canada and Australia have added sleep to physical activity and screen time recommendations to create 24-hour movement guidelines.[27] Unfortunately, sleep insufficiency—getting less than 8 hours of sleep per night—has become common among adolescents, especially on weekdays.[28] Current sleep recommendations by the American Academy of Pediatrics, the American Academy of Sleep Medicine, and the National Sleep Foundation for adolescents aged 13-18 years is at least 8 hours of sleep per day.[10,16,29]

Specific aims

Our first aim was to evaluate whether—and the extent to which—adherence to the sleep guideline is associated with a reduced risk of overweight/obesity in adolescents. We hypothesized a negative and significant association between adherence to sleep guideline and overweight/obesity in adolescents. Our second aim was to determine whether—and the extent to which—adherence to each of the individual *5-2-1-0* guidelines is associated with a reduced risk of overweight/obesity. Our third aim was to determine whether—and the extent to which—adherence to each of the individual *8-5-2-1-0* guidelines is associated with a reduced risk of overweight/obesity. We hypothesized that adolescents meeting each of the *5-2-1-0* and *8-5-2-1-0* guidelines would have reduced risk of overweight/obesity. We further hypothesized that adding sleep to the *5-2-1-0* model (ie, *8-5-2-1-*0) will lead to a better model prediction.

Methods

Study population

This study used the 2017 Youth Risk Behavior Surveillance System data (YRBS), a national survey conducted by the Centers for Disease Control and Prevention (CDC). The 2017 YRBS self-administered survey of 14,765 individuals used a 3-stage, cluster-sample design to obtain a nationally representative population of US students in grades 9 to 12. Overall response rate (students and schools) was 60%. The YRBS sample is designed to produce estimates that are accurate within ±5% at a 95% confidence level.

Participants less than 13 years of age (n = 59) were excluded, as the 8–hour per day guideline for sleep applies to adolescents ≥13 years of age. After accounting for missing data on all selected variables, the analytic sample for this study was comprised of 8194 individuals.

Overweight/obesity

The dependent variable of interest was derived from body mass index (BMI) percentiles. On the YRBS, adolescents self-reported their height and weight. Adolescents were classified as having overweight/obesity when their BMI was ≥85th percentile according to CDC BMI age- and sex-specific percentiles.[30] A total of 2477 adolescents (30.2%) in the sample were considered to have overweight/obesity.

8-5-2-1-0 Measures

For sleep duration, participants were asked: “On an average school night, how many hours of sleep do you get?” Responses were categorized into <8 hours and ≥8 hours to create the measure to indicate adherence to the sleep guideline.

For FV consumption, students were asked: “During the past 7 days, how many times did you … (1) Drink 100% fruit juices such as orange juice, apple juice or grape juice? And eat (2) Fruit? (3) Green salad? (4) Carrots? (5) Potatoes?—excluding French fries, fried potatoes, or potato chips—(6) Other vegetables? The answer categories for each item were transformed into a daily scale. Answers to questions 1 through 6 were then combined to identify those who consumed ≥5 FV per day and those who consumed less.

For screen time behavior, students were asked: “On an average school day how many hours do you … (1) watch TV? and (2) play video or computer games or use a computer for something that is not schoolwork?” Hours of screen time were summed and dichotomized as ≤2 = 0 and >2 = 1 to indicate adherence or not to the ≤2-hour-screen-time per day recommendation by the American Academy of Pediatrics guidelines for children and adolescents.

For physical activity (PA), students were asked: “During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day? Add up all the time you spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time.” Responses were dichotomized as ≥1 hour 0 to 6 days vs ≥1 hour 7 days to obtain the recommended guideline for PA of at least 60 minutes every day.

SSB consumption was captured by the following questions: (1) “During the past 7 days, how many times did you drink a can, bottle, or glass of soda or pop, such as Coke, Pepsi, or Sprite?” and (2) “During the past 7 days, how many times did you drink a can, bottle, or glass of a sports drink such as Gatorade or PowerAde?” Students were grouped as those who answered I did not drink soda, pop, or a sports drink during the past 7 days vs those who reported consuming SSB any time in the past 7 days.

Two adherence score variables were created to indicate (1) adherence to the *5-2-1-0* guidelines and (2) adherence to the *8-5-2-1-0* guidelines.

Confounders

Putative confounders were demographic variables: age (13-18 years^{+}), sex (female/male), and race/ethnicity. Binge-drinking intensity (largest number of alcoholic drinks in a row respondent consumed in past 30 days) and cigarette use (number of days respondent smoke cigarettes in the past 30 days) were also considered due to their established associations with the dependent variable and each of the main *8-5-2-1-0* predictors.

Mean age may be slightly underestimated because individuals aged >18 years were grouped under the category ≥18 years. Labeling of race/ethnicity categories in YRBS was as follows: Asian, black or African American, Hispanic/Latino, white, multiple Hispanic, multiple non-Hispanic, American Indian/Alaska Native, Native Hawaiian, and other Pacific Islanders. American Indian/Alaska Native and Native Hawaiian/other Pacific Islanders were grouped with multiple non-Hispanic as "other" because of their lower numbers.

Statistical analysis

Stata/SE 15.1 was used for statistical descriptive and regression analyses. YRBS' complex survey design (sampling weights, cluster sampling, and stratification) was accounted for in all analyses, and valid percentages were weighted.

To test the primary hypothesis, both simple and multivariable log-binomial regressions were fitted to explore nonadjusted and adjusted (for age, sex, race/ethnicity, and alcohol and cigarette use) associations between adherence to the sleep guideline and risk of overweight/obesity. To test the second and third hypotheses, log-binomial regressions were fitted to examine the relationship between each of the guideline behaviors and risk of overweight/obesity. Because the outcome overweight/obesity was common (30.2%), the estimated associations between exposure and outcome were calculated as risk ratios (RRs) in lieu of odds ratios. Logistic regression yields an odds ratio rather than a RR; however, the more frequent the outcome (>10%) in a study population, the more the odds ratio overestimates the RR when it is more than 1 or underestimates it when it is less than 1.[31] Furthermore, in addition to RRs being more intuitive to interpret than odds ratios, RRs are collapsible; that is, the size of the RR will not change if adjustment is made for a variable that is not a confounder.[32] Because our models included several main predictors along with potential confounders, we opted for RRs to compare risks for overweight/obesity among exposure groups. To test whether adding sleep to the *5-2-1-0* model will lead to a significant fit in the model, the Wald test was used.

Analyses were conducted on complete cases, and statistical significance was a priori determined at $\alpha = .05$. This research was reviewed and determined to be exempt by the University of Arkansas for Medical Sciences Institutional Review Board (#207535).

Results

Descriptive analysis: adherence to 8-5-2-1-0 guideline

In the study population, the average age was 16 years (standard error of 0.03). Approximately 3 in 10 adolescents (30.2%) met criteria for overweight/obesity. About 1 in 4 adolescents (26%) adhered to the 8 hours or more of sleep recommendations; 15.3% reported consuming ≥5 FV per day; 39.4% reported adhering to ≤2 hours of recommended daily screen time; 27% reported having the recommended 1 hour or more of PA a day; and 58.2% did not consume SSB. Only 1.6% of adolescents met the *5-2-1-0* guidelines, and less than 1% of adolescents (0.6%) met all the *8-5-2-1-0* guidelines. See Table 2.

Table 2
Descriptive analysis: overweight/obesity and adherence to *8-5-2-1-0* guidelines among adolescents aged 13 years or more in the US

	n = 8194 % (95% CI)[a]
Measures	
Weight classification based on BMI percentile	
Overweigh/obese (BMI percentile ≥85th)	30.2 (28.6-32.0)
8-5-2-1-0 Guidelines	
Sleep duration (daily)	
≥8 h (healthy sleep)	26.0 (24.5-27.6)
FV consumption (daily)	
≥5 U	15.3 (14.1-16.7)
Screen time (daily)	
≤2 h	39.4 (37.0-41.9)
Physical activity	
≥1 h, 7 d/wk	27.0 (25.0-29.1)
SSB consumption (daily)	
0 U/wk	58.2 (55.1-61.2)
Met all *8-5-2-1-0*	0.6 (0.44-0.86)
Met all *5-2-1-0*	1.6 (1.27-2.05)
Demographics	
Sex	
Male	48.8 (46.1-51.5)
Female	51.2 (48.5-53.9)
Age	Mean 16.0
Race/ethnicity[c]	Standard error 0.03[b]
Asian	3.5 (2.6-4.7)
Black	10.7 (8.2-13.8)
Hispanic/Latino	8.8 (6.7-11.6)
White	58.5 (53.0-64.0)
Other	18.8 (15.3-20.6)

Source: 2017 National Youth Risk Behavior Survey.
[a] Valid percentages are weighted to account for complex survey design.
[b] We recorded this categorical variable as continuous. Mean age may be slightly underestimated because individuals aged >18 years were grouped under the ≥18-year category.
[c] Labeling of race/ethnicity categories in the National Youth Risk Behavior Surveillance System is as follows: Asian; black or African American; Hispanic/Latino; white; multiple Hispanic; multiple non-Hispanic; American Indian/Alaska Native; Native Hawaiian/PI. We regrouped the last 4 categories as "other."

Adherence to sleep guidelines and risk of overweight/obesity

Table 3 depicts both nonadjusted (models 1-a, 2-a, and 3-a) and adjusted (models 1-b, 2-b, and 3-b) RR with 95% confidence intervals (CIs) to gauge strength of associations and the statistical uncertainty of estimates controlling for confounders (age, sex, race/ethnicity, and alcohol and cigarette use).

In nonadjusted models, adolescents who slept ≥8 hours—as compared to those who slept less—had 13% decreased risk of having overweight/obesity (RR: 0.87; CI: 0.79-0.96; $P = .006$). In adjusted

Table 3
Adherence to individual *8-5-2-1-0* guideline and risk of overweight/obesity: RR and 95% CIs

	Hypothesis 1				Hypothesis 2				Hypothesis 3			
	Model 1-a	*P* values	Model 1-b[a]	*P* values	Model 2-a	*P* values	Model 2-b[a]	*P* values	Model 3-a	*P* values	Model 3-b[a]	*P* values
	RR (95% CI)		RR (95% CI)		RR (95% CI)		RR (95% CI)		RR (95% CI)		RR (95% CI)	
Adherence to sleep guideline												
≥8 h	**0.87** (0.79-0.96)	.006	**0.87** (0.77-0.97)	.013					**0.89** (0.82-0.98)	.015	**0.90** (0.81-0.99)	.035
≤8 h: reference category	-	-	-	-					-	-	-	-
Adherence to FV guideline												
≥5 FV					**1.17** (1.03-1.23)	.004	1.08 (0.99-1.18)	.098	**1.16** (1.05-1.29)	.005	1.08 (0.98-1.18)	.094
<5 FV: reference category					-	-	-	-	-	-	-	-
Adherence to screen time guideline												
≤2 h screen time					**0.87** (0.79-0.96)	.005	**0.84** (0.75-0.95)	.005	**0.88** (0.80-0.96)	.008	**0.85** (0.77-0.95)	.006
>2 h screen time: reference category					-	-	-	-	-	-	-	-
Adherence to physical activity guideline												
≥1 h 0 to 6 d/wk					**0.79** (0.72-0.85)	<.001	**0.78** (0.71-0.85)	<.001	**0.79** (0.73-0.86)	<.001	**0.80** (0.73-0.87)	<.001
≥1 h 7 d/wk: reference category					-	-	-	-	-	-	-	-
Adherence to no-consumption of SSB guideline												
No SSB/d					**0.92** (0.86-0.99)	.035	0.95 (0.85-1.05)	.297	**0.92** (0.85-0.99)	.032	0.94 (0.85-1.05)	.275
≥1 SSB/d: reference category					-	-	-	-	-	-	-	-

Source: 2017 National Youth Risk Behavior Survey.
Point estimates with $P < .05$ are bolded.
[a] Models 1-b, 2-b, and 3-b are adjusted for age, sex, race/ethnicity, and alcohol and cigarette use.

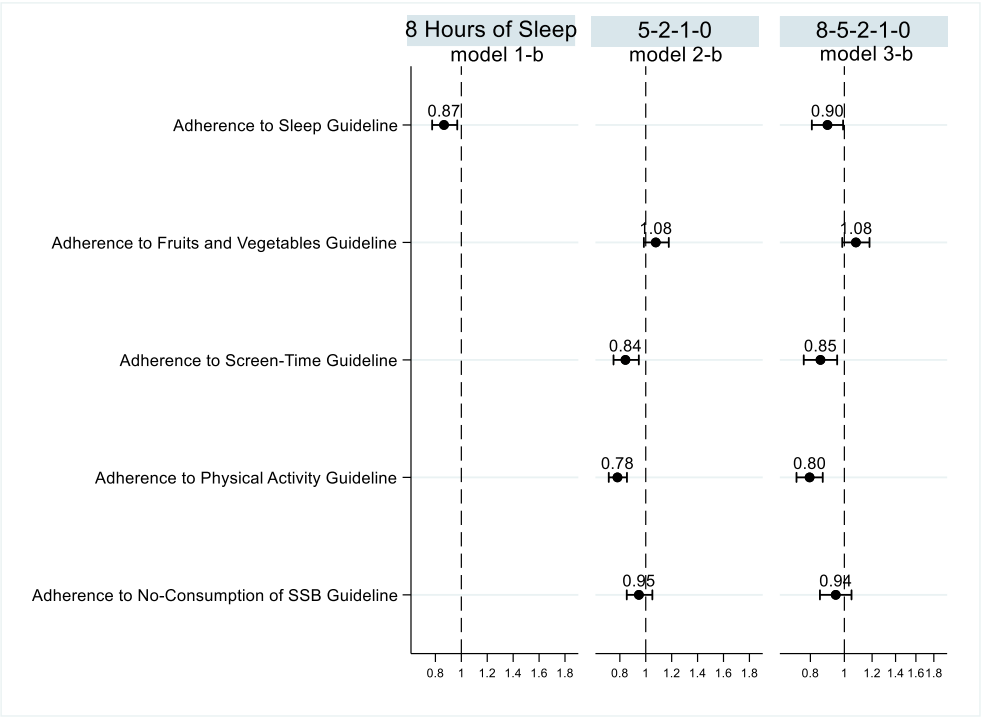

Fig. 1. Adherence to individual *8-5-2-1-0* guideline and risk of overweight/obesity: adjusted RR and 95%C.[a] Source: 2017 National Youth Risk Behavior Surveillance System. [a]Models (1b, 2-b, and 3-b in Table 3) adjusted for age, sex, race/ethnicity, and alcohol and cigarette use are depicted. RR with 95% CIs overlapping 1 are not statistically significant at $\alpha = .05$.

multivariable models, the relationship remained similar (RR: 0.87; CI: 0.77-0.97; $P = .013$). See models 1-a and 1-b in Table 3 and Figure 1.

Adherence to 5-2-1-0 and 8-5-2-1-0 guidelines and risk of overweight/obesity

In the nonadjusted *5-2-1-0* model (2-a), adolescents adhering to the screen time guideline had 13% reduction in the risk of overweight/obesity compared to adolescents not adhering to the guideline (RR = 0.87; CI: 0.79-0.96; $P = .005$). Similarly, adhering to the PA guideline was associated with a 21% reduction in risk of overweight/obesity compared with those not adhering to the guideline (RR = 0.79; CI: 0.72-0.85; $P < .001$).

In the adjusted *5-2-1-0* model (2-b), adolescents adhering to the screen time guideline had an 16% reduction in their risk of overweight/obesity (RR: 0.84; CI: 0.75-0.95; $P = .005$), and those adhering to the PA guideline had a reduction of 22% in their risk of overweight/obesity as compared with those not adhering to the guideline (RR: 0.78; CI: 0.71-0.85; $P < .001$). No statistically significant associations between adherences to ≥5 FV and 0 SSB guidelines and risk for overweight/obesity were detected in this population in adjusted model. See model 2-b in Table 3 and Figure 1.

When sleep was added to the *5-2-1-0* model (ie, the *8-5-2-1-0*), adhering to ≥8 hours of sleep was still associated with reduced risk of overweight/obesity (RR = 0.89; CI: 0.82-0.98; $P = .035$) in the nonadjusted *8-5-2-1-0* model. Adolescents who reported having ≤2 hours of screen time per day had a 12% lesser risk of overweight/obesity (RR: 0.88; CI: 0.80-0.96; $P = .008$). Adherence to the recommended 1 hour of daily PA was associated with a 21% reduced risk of overweight/obesity (RR: 0.79; CI: 0.73-0.86; $P < .001$). In the nonadjusted model, a significant association was seen between adherence to ≥5 FV and 0 SSB consumption (RR: 1.16; CI: 1.05-1.29; $P = .005$ and RR = 0.92; CI: 0.85-0.99; $P = .032$); however, these associations were no longer statistically significant after adjusting for confounding effects. See model 3-a and 3-b in Table 3 and Figure 1.

In the adjusted *8-5-2-1-0* model, adolescents who slept ≥8 hours per day had a reduction of 10% in their risk of overweight/obesity (RR = 0.90; CI: 0.81-0.99; $P = .035$). Adhering to screen time and PA guidelines was also associated with a reduced risk of overweight/obesity (RR: 0.85; CI: 0.77-0.95; $P = .006$ and RR: 0.80; CI: 0.73-0.87; $P < .001$). See model 3-b in Table 3 and Figure 1.

After running the log-binomial regression for model 3-b, the Wald test was used to examine whether adding sleep would lead to better prediction (ie, a better model fit). Including sleep resulted in a statistically significant improvement in the fit of the model ($F_{1,36} = 4.80$; $P = .035$).

Discussion

This study was undertaken to determine if adherence to adolescent sleep guideline was associated with a reduced risk of overweight/obesity and to determine if adherence to each of the *5-2-1-0* and *8-5-2-1-0* guidelines was also associated with a reduced risk of overweight/obesity in adolescents aged 13 years and older. Because adherence to adolescent sleep guideline has never been explored in relation to adherence to *5-2-1-0* from population-based data, we further investigated whether the *8-5-2-1-0* would result in a better model prediction.

This study found that 26% of adolescents aged 13 years and older met the sleep guideline. Similarly, other studies reporting on sleep among adolescents (grades 9-12) found that 72.7% reported sleeping less than 8 hours on school nights.[33] As hypothesized, those who met the sleep guideline had a significant decrease in their risk of being overweight/obesity. This result corroborates strong evidence on the negative association relationship between sleep duration and adolescent overweight/obesity.[23,24,26,34,35] However, these studies have, for the most part, not taken into account the potential influence of these

4 (*5-2-1-0*) risk factors typically found to be strongly correlated with weight.

Meeting all *5-2-1-0* guidelines for adolescents was relatively rare (1.6%). This finding is consistent with previous research from national data that has found that only a very small percentage of adolescents met all 4 of the *5-2-1-0* targets.[18,19,36] Most studies that have looked at the associations between *5-2-1-0* behaviors and overweight/obesity have mainly been based on primary care and school-based interventions with mixed findings.[6,36,37] The Maine Youth Overweight Collaborative intervention demonstrated significant provider and office system improvements; however, no significant changes in BMI *z* scores of youth aged 5-18 years in intervention vs control were seen over time.[7] When *5-2-1-0* associations with BMI were examined in preschool-aged children, only screen time was independently associated with an increase in BMI *z* scores,[18] whereas another study on fourth and fifth graders (n = 72) found significant effects between FV intake, PA levels, and change in BMI percentile.[39] The latter study did not, however, take into account the nested structure of the data or the correlation structure likely to occur with repeated measurements in its analysis. This article makes a significant contribution to the literature, as no prior studies of *5-2-1-0* behaviors have examined the independent association of these factors and risk of overweight/obesity based on a sample of US adolescents aged 13 years and older.

Only 0.6% of the adolescents in our study population adhered to all *8-5-2-1-0* guidelines. Despite national guidelines on sleep for adolescents and clear evidence on the association between short sleep duration and increased risk of obesity, adherence to sleep guideline (8 hours or more per day) *in conjunction* with each of the *5-2-1-0* guidelines that has not been explored prior to this study.

There were mixed results in meeting each of the *8-5-2-1-0* guidelines and risk of having overweight/obesity. Contrary to the hypothesis, no associations were found between overweight/obesity and consumption of ≥5 FV or 0 consumption of SSB in adjusted models. Other studies have found a lack of relation between intake of FV (alone or combined) and BMI in large prospective cohorts of children and adolescents in the US.[38,39] Systematic reviews on the relationship of FV intake with adiposity (eg, BMI, BMI *z* score) found mixed results for FV intake and risk of obesity among children and adolescents, and attributed the differences to research quality.[40] Lack of association between SSB and BMI in adolescents has also been found.[41] The results of this study contradict the initial findings of a recent randomized trial to assess the effect of SSB on weight gain among overweight/obese adolescents. The trial found an increase in BMI smaller in the experimental group than in the control group after a 1-year intervention but not at the 2-year follow-up.[42] Potential explanation for these findings may be that FV or SSB intake alone, independent of total energy intake and healthy food accessibility, may not be the best indicators of obesity risk in this population.

Overall, the findings from this study suggest that meeting recommendations for sleep, screen time, and PA was independently associated with decreased risk of overweight/obesity. Recent cross-sectional studies on the associations between adherence to sleep, screen time, and PA guidelines—24-hour movement guidelines—in 12 countries found that children aged 9 to 11 meeting the recommendations had lower odds of obesity (defined according the World Health Organization criteria) and lower BMI *z* scores as compared to those not meeting the 24-hour movement recommendations.[43] However, independent associations between sleep, screen time, and PA were not investigated among adolescents. A 2018 study that looked at the association between adhering to these movement behaviors guideline and global cognition in US children aged 8 to 11 years found that 51% of participants met the sleep recommendation, 37% met screen time, 18% met the physical activity recommendation, and only 5% met all 3 guidelines.[44]

The finding of the *8-5-2-1-0* as an improved model to predict overweight/obesity in adolescents is compelling with potentially far-reaching public health implications. As sleep is a potentially modifiable behavior, the findings from this study can inform overweight/obesity prevention and weight loss interventions in both school and clinical settings, and inform policy makers at national levels to advocate for healthier sleep hygiene, deploy concerted efforts to curtail the current epidemic of sleep deprivation in adolescents, and continue to actively promote adherence to screen time and physical activity guidelines.

Strengths and limitations

The results of this study should be appraised in light of some limitations. The first limitation concerns retrospective self-report data on weight and *8-5-2-1-*0 behaviors. A recent meta-analysis on self-reported data to screen children and adolescents for overweight/obesity status revealed that use of self-reported measures to obtain BMI has good overall performance with moderate sensitivity and high specificity, and it is a viable alternative when direct BMI measure is not available.[45] Although the CDC have determined that self-reports of dietary and PA behaviors are affected by both cognitive and situational factors, the YRBS has been found to be a reliable survey overall.

One limitation in using the YRBS as secondary data is the lack of control over the framing and wording of the survey items. The 2017 YRBS survey consists of 99 questions, several of which rely on participants to "recall-and-count" past experiences.[46] This approach likely introduces some degree of bias and inaccuracy (eg, by overreliance on participant's memories for recent events and not fully accounting for behavioral variability over time).

Although no studies have assessed the validity of self-reported sleep duration among adolescents based on the YRBS data, a systematic review and meta-analysis in children and adolescents have shown a strong correlation of sleep time assessed by questionnaires for weeknights and a moderate correlation for weekend nights compared with sleep time assessed by accelerometers.[47]

Another limitation pertains to the cross-sectional nature of the YRBS data. The findings do not speak to the causes of obesity/overweight as a function of guideline adherence. Our study is vulnerable to reverse causation bias, as overweight/obesity may have preceded and caused some of the exposures (eg, overweight/obesity could affect sleep or PA). The study could also be limited by the risk of selection bias, as absenteeism may be higher among adolescents with obesity.

Although we accounted for important confounders, socioeconomic status (SES) was not controlled for because this confounder is not measured in YRBS. Because SES has been found to be significantly associated with both adolescent obesity and each of the *8-5-2-1-0* associated factors, it is plausible that the strength of the associations observed become attenuated once SES is included as a covariate in regression models. Depression is another example of a potential confounder that is not included in the model. In the YRBS, depression is assessed by a single item that refers to a 12-month time frame (ie, "in the past 12 months") that is much longer than time frame used for the other variables.

Despite these limitations, this study provides several significant contributions to the body of evidence on adolescent overweight/obesity. First, this study is based on a large sample of adolescents, strengthening its potential to inform public health interventions and policy. Secondly, this study addresses important gaps in the literature because it is the first population-based study to add sleep to the model and investigate *8-5-2-1-0* behaviors and

their association with overweight/obesity in adolescents. By documenting an independent association between adherence to the recommended 8 hours of sleep and reduced risk of being overweight/obesity in adolescents, this study supports growing evidence on the importance of sleep in the prevention of overweight/obesity among adolescents; it also underscores the importance of an integrated approach that considers sleep along with other overweight/obesity prevention strategies (adhering to screen time and PA guidelines).

Recommendations for future research

Researchers can build upon these findings by conducting longitudinal studies with objective measures of adiposity, dietary recall, physical activity, screen time, and sleep and additional distal and proximal confounders to establish directionality and causality. Additional research is needed to examine the effect of household SES in relation to the influence of *8-5-2-1-0* on overweight/obesity. Studies that incorporate mediation and moderation to uncover possible underlying mechanisms by which adherence to *8-5-2-1-0* guidelines may influence overweight/obesity in adolescents are also warranted.

Disclaimer

Analysis, interpretation, and/or conclusions based on the Youth Risk Behavior Surveillance data are solely those of the authors and do not represent those of the CDC, which are responsible for the data.

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