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Combined aerobic and muscle-strengthening activity guidelines and their association with obesity in US adolescents

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Abstract

Most of the evidence on physical activity for maintaining a healthy weight in adolescents is based solely on aerobic physical activity alone, with little attention given to the muscle strength component. This study aimed to investigate the associations between aerobic activities and muscle-strengthening activities (MSA) and overweight/obesity among a representative sample of adolescents. Data from the United States-based Youth Risk Behavior Surveillance System for the 2011–2019 cycle were used in this cross-sectional study. Adolescents self-reported their adherence to aerobic and MSA guidelines, as well as their height and weight. Overweight and obesity were defined using the age- and sex-specific criteria of the Centers for Disease Control and Prevention, with a body mass index (BMI) ≥85th and ≥95th percentiles, respectively. We examined the associations between adherence to physical activity guidelines (reference: not meeting either of the physical activity guidelines) and overweight/obesity or obesity using binary logistic regressions. These analyses were adjusted for race/ethnicity, sex, age, screen time, sleep duration, tobacco, alcohol, fruit, vegetables, and soda consumption. A total of 42 829 adolescents (48.98% girls) were included in the study. Of these, 22.23% met both guidelines for physical activity, 30.47% had overweight/obesity, and 14.51% had obesity. Compared with meeting neither guideline, meeting both aerobic and MSA guidelines was associated with lower odds of having overweight/obesity (odds ratio [OR] = 0.64, 95% confidence interval [CI], 0.60 to 0.68) and obesity (OR = 0.52, 95% CI 0.48 to 0.56). These results were consistent across years of assessment, sex, and race/ethnicity. In conclusion, our results highlight the importance of MSA, which is often overlooked in physical activity recommendations in many studies, in combating childhood obesity in the United States.

KEYWORDS

excess weight, muscle strength training, obesity, overweight, physical activity guidelines, population based

1 | INTRODUCTION

Childhood and adolescent obesity have become an epidemic in the United States (US) and are known to significantly impact both physical[1] and psychological health.[2] According to the National Health and Nutrition Examination Survey, the prevalence of overweight and obesity among US children and adolescents aged 2–19 years was 16.1% and 19.3% in 2017–2018,[3] respectively. A combination of genetic, social, and environmental factors, as well as lifestyle preferences such as physical activity levels and sedentary behaviors and cultural factors, appear to be major contributors to the increasing prevalence of obesity worldwide.[4,5]

Physical inactivity, which refers to not engaging in the recommended level of regular physical activity, is a leading factor in the development of numerous chronic diseases, including obesity.[6] Studies have suggested that increased physical activity can help protect against overweight/obesity by increasing energy expenditure.[7] However, most of the evidence on physical activity for maintaining a healthy weight in adolescents is based solely on aerobic physical activity alone (i.e., 60 min per day of moderate-to-vigorous physical activity [MVPA]),[8,9] with little attention given to the muscle strength component. The Physical Activity Guidelines for Americans published by the US Department of Health and Human Services[9] and the WHO[10] both recommend that adolescents aged 5–17 years participate in specific exercises/activities related to building muscle strength (i.e., muscle-strengthening activities [MSA], such as push-ups, sit-ups or weight training) at least three times per week, in addition to 60 min of MVPA per day. Despite these guidelines, a recent meta-analysis showed that only one out of five adolescents met the combined aerobic and MSA guidelines.[11]

Scientific evidence has shown that both MSA[12,13] and muscular fitness (such as muscle strength, muscle power, and muscular endurance)[14,15] are independently important for adolescent health, such as body composition and cardiometabolic health. For example, previous studies have already indicated a negative association between aerobic activities[16,17] and MSA[13] and obesity in adolescents. Despite being recommended globally, there are limited studies exploring the association between compliance with both concurrent aerobic and MSA guidelines and overweight/obesity among adolescents compared to those reporting compliance with aerobic physical activities alone. Therefore, the aim of this study was to examine the associations between meeting both aerobic and MSA guidelines and overweight/obesity among a representative sample of US adolescents.

2 | METHODS

2.1 | Study sample and data collection

The national Youth Risk Behavior Survey (YRBS) is a biannual cross-sectional, nationally representative, school-based survey designed to study health-related behaviors among US public and private school students in Grades 9–12 across all 50 states and the District of Columbia. These behaviors include smoking, alcohol and drug use, and diet. Detailed information about the YRBS study design, methods, survey measures, and procedures can be found at https://www.cdc.gov/healthyyouth/data/yrbs/index.htm (accessed on January 5, 2023).

For each year of data analyzed, students with missing physical activity, body mass index (BMI), and sociodemographic and/or lifestyle characteristics were excluded from the study. Ultimately, we examined 42 829 adolescents who provided valid responses on all study variables (Figure 1).

2.2 | Measures

Adolescents self-reported their height and weight, from which BMI was calculated and converted to percentiles using the Centers for Disease Control and Prevention BMI growth charts.[18] The validity of adolescents' self-reported height and weight has been previously documented in other US representative samples ($r = 0.92$).[19] Overweight and obesity were defined as BMI values at or above the age- and sex-specific ≥85th and ≥95th percentiles, respectively.

To assess whether adolescents met physical activity guidelines, they were asked: "During the past 7 days, on how many days were you physically active for a total of at least 60 min per day? (Include 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)". The response options ranged from 0 to 7 days. For MSA, adolescents were asked: "During the past 7 days, on how many days did you do exercises to strengthen or tone your muscles, such as pushups, sit-ups, or weightlifting?" The response options ranged from 0 to 7 days. Adolescents were considered to have met both guidelines if they reported engaging in aerobic activities for 7 days and MSA for 3 or more days, as recommended by the US Department of Health and Human Services.[9] Overall, the YRBS has acceptable reliability in measuring healthy lifestyle behaviors in adolescents.[20]

2.3 | Covariates

The different response options on the variables related to lifestyle were used to dichotomize adolescents into two groups (meeting definition or not) for the following nine

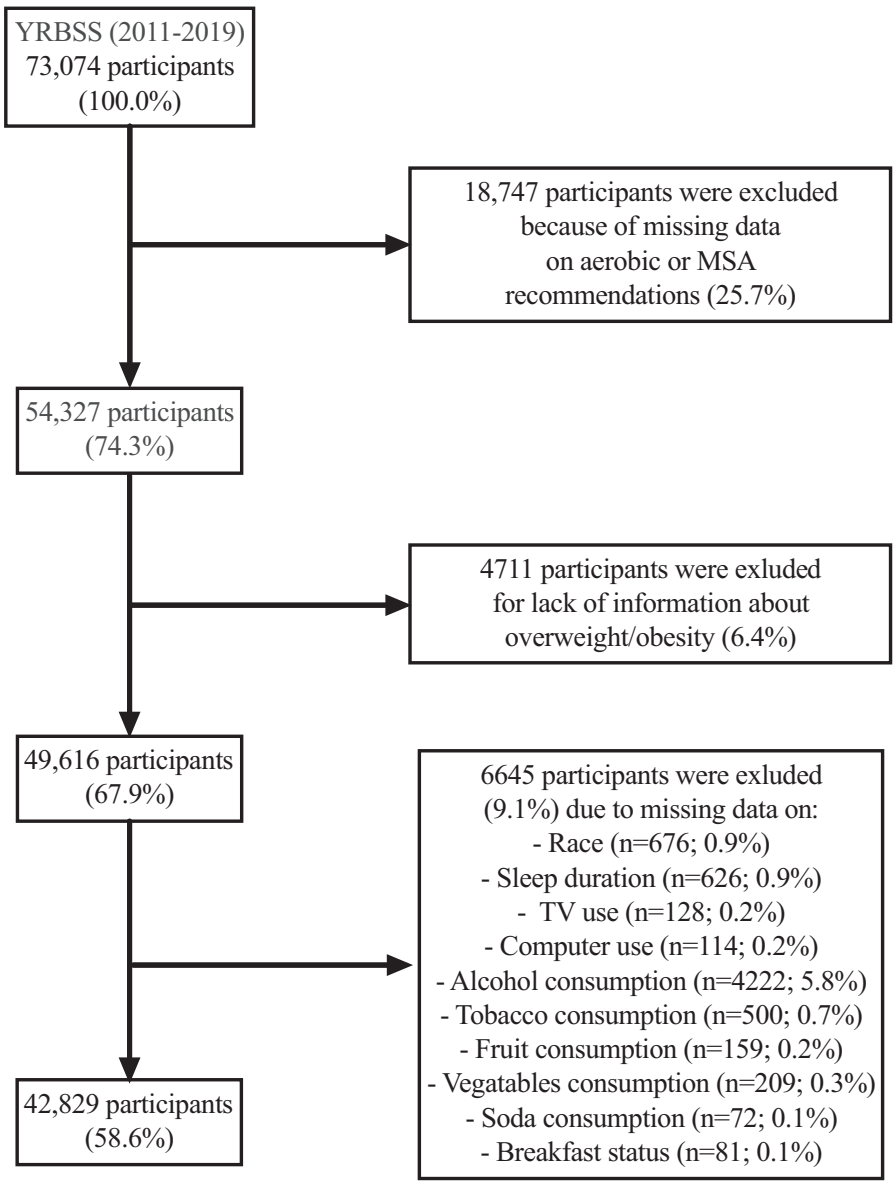


FIGURE 1 Youth Risk Behavior Surveillance System 2011–2019 participant flow diagram. MSA, muscle-strengthening activity.

items: (1) TV on average school day (yes/no); (2) playing video/computer game on average school day (yes/no); (3) sleep duration ≥8 h (yes/no); (4) tobacco consumption in the past 30 days (yes/no); (5) alcohol consumption in the past 30 days (yes/no); (6) fruit consumption during the past 7 days (yes/no); (7) vegetables consumption during the past 7 days (yes/no); (8) diet soda or pop consumption during the past 7 days (yes/no); and (9) daily breakfast (yes/no). In addition, the following demographic variables were also included as covariates: age group (>16 years old/≥16 years old), sex (male/female), and race/ethnicity (White, Black or Afro American, Hispanic/Latino, or all other races).

2.4 | Statistical analysis

All analyses were performed in R (Version 4.1.1) (R Core Team) and R Studio (Version 2021.09.2) (Posit). The national YRBS data are already adjusted for the sample size through weighting. This means that the weighted count of respondents matches the unweighted count of respondents. Consequently, there is no necessity to modify the weights when merging multiple national YRBS datasets. We assessed the associations between physical activity guideline adherence (exposure variable; reference = meet neither physical activity guidelines) and overweight/obesity or obesity (dependent variables) using logistic regressions. To examine the robustness of the analyses, we further conducted all analyses stratified by race/ethnicity, sex, age, and year of assessment. Additionally, dose–response analyses were also conducted to verify how aerobic activity days or MSA days were associated with overweight/obesity. Covariates in the models were age, race/ethnicity, television and video/computer use, tobacco use, alcohol use, fruit and vegetable intake, sugar-sweetened intake soda consumption, breakfast,

and sleep duration. In addition, to reduce possible selection bias by a listwise deletion method, we conducted further analyses using multiple imputation methods. To perform these analyses, we examined the data for any missing values using the *mice* package.[21] The missingness of the data was assumed to be random and, therefore, the *mice* package was used to replace those missing values through multiple imputations using chained equations. To ensure sufficient accuracy, a total of 42 data sets with multiple imputations were generated, following the suggestion of setting the number of imputations (m) to be greater than 100 times the highest fraction of missing information.[22] Five iterations were performed for each imputation, following the recommendation to apply a small number of iterations.[21] Furthermore, assumptions of healthy convergence, imputed distribution, and plausibility were checked.

3 | RESULTS

The sample characteristics are presented in Table 1. The study included 42 829 US adolescents, of whom 48.98% were girls. In terms of physical activity, 52.05% met the MSA guideline only, 26.66% met the aerobic activity guideline only, and 22.23% met both guidelines. Regarding BMI status, 14.51% of the sample had obesity, and 30.47% had overweight/obesity.

The results of the study are presented in Figure 2, which shows the odds ratio (OR) and 95% confidence interval (CI) for overweight/obesity and obesity by meeting physical activity guidelines. Overall, the group of adolescents who met both aerobic and MSA guidelines had the lowest OR for both overweight and obesity (adjusted OR = 0.64, 95% CI: 0.60 to 0.68, $p < 0.001$) and obesity (adjusted OR = 0.52, 95% CI 0.48 to 0.56 $p < 0.001$) compared to the other categories (Figure 2). Furthermore, the results were consistent across all the waves of assessment conducted between 2011 and 2019 (Figure S1). Furthermore, the full analyses through the listwise deletion method and multiple imputations by chained equations are shown in Tables S1–S4, respectively. These analyses showed that the results held regardless of the method used.

The results from stratified analyses by race/ethnicity, sex, and age group are presented in Figure 3. Race/ethnicity exhibit a modifying effect on this association for both overweight/obesity (p for interaction = 0.023) and obesity (p for interaction = 0.024). In terms of sex, as the p-values obtained were 0.064 (for overweight/obesity) and 0.069 (for obesity), we proceeded to perform a sensitivity analysis stratified by sex. This analysis confirmed the consistency of results across both boys and girls (Tables S5–S8). In addition, we found that age group did not modify the association between meeting the physical activity guidelines and the odds of having overweight/obesity or obesity (p for interaction 0.673 and 0.736, respectively) (Figure 3).

Finally, dose–response analyses were used to verify how aerobic activity days or MSA days were associated with

TABLE 1 Characteristics of the study participants ($N = 42\,829$).

Variables	M (SD)/*n* (%)
Age (years old)	
≤12	9 (0.02)
13	32 (0.07)
14	4332 (10.11)
15	10 003 (23.36)
16	10 924 (25.50)
17	11 035 (25.77)
≥18	6494 (15.16)
Sex	
Boys	21 850 (51.02)
Girls	20 979 (48.98)
Race	
White	20 596 (48.09)
Black or Afro American	5975 (13.95)
Hispanic/Latino	11 642 (27.18)
All other races	4616 (10.78)
Lifestyle	
Sleep duration (≥8 h)	7618 (17.79)
TV use (no use on average school day)	6827 (15.94)
Video/computer use (no use on average school day)	7905 (18.46)
Alcohol consumption (none day)	28 154 (65.74)
Tobacco consumption (none day)	38 731 (90.43)
Fruit consumption (daily)	38 447 (89.77)
Vegetables consumption (daily)	25 932 (60.55)
Soda consumption (none day)	10 528 (24.58)
Daily breakfast (yes)	15 423 (36.01)
Physical activity guidelines	
Aerobic physical activity (days)	4.00 (2.50)
MSA (days)	2.92 (2.51)
Meeting aerobic recommendations	11 417 (26.66)
Meeting MSA recommendations	22 292 (52.05)
Meeting both recommendations	9523 (22.23)
Anthropometric data	
Overweight or obesity[a]	13 051 (30.47)
Obesity[a]	6214 (14.51)

Abbreviations: MSA, muscle-strengthening activities; PA, physical activity.
[a]According to the Centers for Disease Control and Prevention criteria.[18]

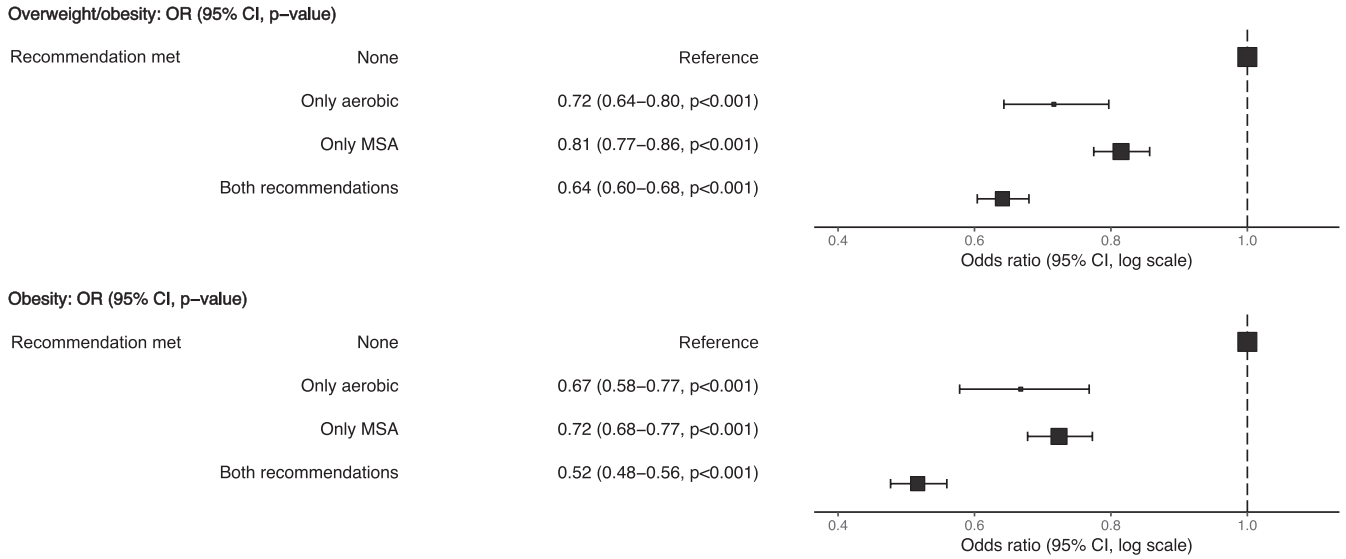
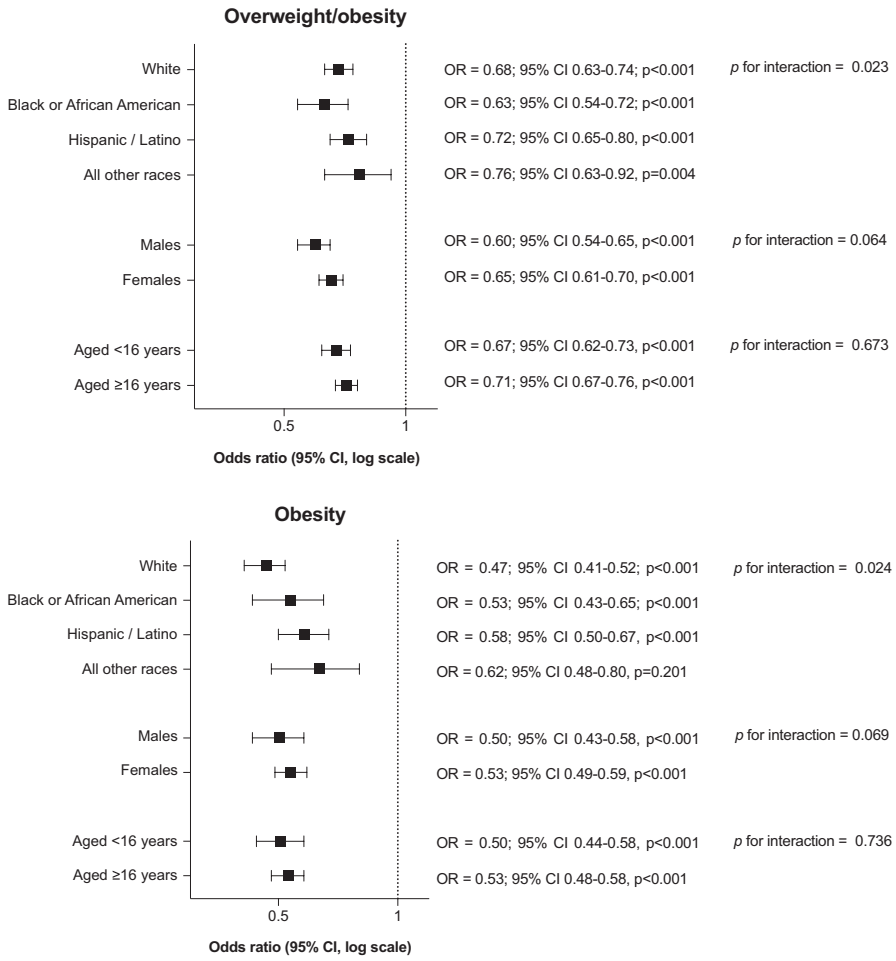


FIGURE 2 Adjusted odds ratios describing the association between the prevalence of physical activity guidelines and the odds of having overweight/obesity or obesity. Reference (1.0): meeting no guidelines. Adjusted for race/ethnicity, sex, age, screen time, sleep duration, tobacco, alcohol, fruit, vegetables, and soda consumption.

FIGURE 3 Adjusted odds ratios describing the association between the prevalence of physical activity guidelines and the odds of having overweight/obesity or obesity, stratified by race/ethnicity, sex, and age group. Reference (1.0): meeting no guidelines. Adjusted for race/ethnicity, sex, age, screen time, sleep duration, tobacco, alcohol, fruit, vegetables, and soda consumption (excluding the variable by which the analyses were stratified in each case).



overweight/obesity or obesity (Figure S2). Compared to those who did not engage in any physical activity, participants who participated in a greater number of days per week (ranging from 1 to 7 days) of aerobic activity or MSA exhibited a lower probability of having overweight/obesity or obesity in an almost linear manner. The only exception was for those who

only engaged in 2 days of aerobic activity, as they showed a slightly nonsignificant higher probability of having overweight/obesity (OR = 1.05, 95% CI: 0.98 to 1.12, $p = 0.146$).

4 | DISCUSSION

To our knowledge, this study is the first to investigate the association between meeting aerobic and MSA guidelines and obesity in adolescents. Our findings suggest that meeting both guidelines is associated with the lowest prevalence of overweight/obesity and obesity, independent of the year of assessment and several potential confounding factors, when compared with other physical activity guideline adherence categories.

Previous research has highlighted the benefits of aerobic activity and MSA on overweight and obesity in adolescents, but these activities have often been studied separately. The relationship between aerobic activity and obesity in children and adolescents has been extensively studied, including among US adolescents.[23] A systematic review has suggested that higher levels of physical activity[8] can yield greater health benefits and that regular MVPA can help people maintain a stable weight and reduce the risk of overweight/obesity, according to the Physical Activity Guidelines for Americans.[9] However, a separate narrative review reported that total physical activity, as measured by doubly labeled water, heart rate methods, and accelerometry, may not be a primary determinant of body fat gain in children and adolescents.[24] Another review suggests that the direct impact of aerobic activity on weight control should not be overemphasized and that physical activity at higher intensities or incorporating MSA may be necessary.[25] In addition, our results align with experimental studies[26,27] which have shown that concurrent aerobic and strength training can improve weight management and reduce the risk of adverse outcomes in adolescents with inactive lifestyles, overweight, or obesity. We also found that the association between meeting both guidelines and obesity was slightly stronger among White adolescents.

On the other hand, the American Academy of Pediatrics reports that muscle strength training can produce many health benefits, including improvements in body composition among children and adolescents.[12] A meta-analysis of prospective studies suggests that higher levels of muscular fitness are associated with lower adiposity later in life.[14] Another recent study of US adolescents found that meeting MSA guidelines was associated with a lower probability of having obesity.[13] One possible explanation for these findings is that combining MSA with aerobic activity can increase lean body mass more than either aerobic[26] or resistance[28] activities alone, which in turn could increase metabolic rate and total energy expenditure.[29] Overall, our study suggests that meeting both aerobic and MSA guidelines could be an effective strategy for reducing overweight/obesity and obesity prevalence among adolescents. We also observed that race/ethnicity moderated the association between meeting physical activity recommendations and the likelihood of having overweight/obesity. Nonetheless, there is an inverse relationship between meeting physical activity guidelines and having lower odds of having overweight/obesity or obesity across all race/ethnicity groups examined. These results may be influenced by variations in stigmatization and discrimination related to excess weight, diverse cultural perceptions of physical activity, and socioeconomic disparities.[30]

The 2011–2019 YRBS study had several strengths, including the use of large, nationally representative samples of US adolescents. However, our findings need to be interpreted with caution due to some limitations. First, this study had a cross-sectional design, which means we cannot determine if there is a causative link between lack of physical activity and obesity or which direction the causation would be. Second, the YRBS. Survey data were self-reported and may be subject to biases such as social desirability and recall, leading to an unknown amount of underreporting or overreporting. However, the reliability and validity of these data have been documented elsewhere.[31] Third, only adolescents were included in the present study, and future research should include other population subgroups. Finally, there are unmeasured confounding and mediating variables, such as illness or disease, that were not considered in our analysis.

In conclusion, our results highlight the importance of MSA, which is often overlooked in physical activity recommendations in many studies, in combating childhood obesity in US. This study provides evidence that meeting both aerobic and MSA guidelines is associated with lower odds of having overweight/obesity and obesity in adolescents compared to meeting neither or one guideline. From a clinical perspective, this study suggests that fitness coaches or doctors can incorporate personalized strength and aerobic training for adolescents in order to enhance muscle strength and reduce excess weight. Consequently, it is necessary to conduct future longitudinal studies to ascertain the temporal relationships between adherence to aerobic and MSA guidelines and obesity indicators.

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CONFLICT OF INTEREST STATEMENT

The authors declared no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

PERSPECTIVE

While the cross-sectional design of our study limits our ability to establish a causative link between physical activity and obesity, our findings suggest that large-scale physical activity interventions that incorporate concurrent aerobic and MSA may be beneficial in preventing and managing obesity among adolescents in the US.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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