Chen *et al. BMC Public Health* (2025) 25:1877
https://doi.org/10.1186/s12889-025-23011-9

BMC Public Health

RESEARCH

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Associations of sleep, sedentary behavior, and physical activity during out-of-school time and the risk of overweight and obesity in children and adolescents: a dose-response and isotemporal substitution analysis

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Abstract

Background For students, sleep, sedentary behavior (SB), and physical activity (PA) all have a direct impact on overweight and obesity. However, out-of-school time SB, PA, and sleep have not been adequately studied for their effects on overweight and obesity. We aim to explore the correlations among PA, SB, sleep duration, and the likelihood of excess body weight in youth during out-of-school hours, focusing on dose-response relationships and isotemporal substitution effects.

Methods This study conducted a cross-sectional analysis by employing data obtained from the China Health and Nutrition Survey, spanning from 2004 to 2015. Restricted cubic spline and isotemporal substitution model were used to assess the corresponding relationships. The weighted quantile sum regression was used to study how different behaviors contribute to the risk of excess body weight.

Results There are linear dose-response relationships between sleep, SB, and moderate-to-vigorous physical activity (MVPA) during out-of-school hours and the risk of overweight and obesity in children and adolescents (all *P* for nonlinear > 0.05). Furthermore, screen-based SB shows a non-linear dose-response association with overweight/obesity. (*P* for nonlinear = 0.038). Theoretically, replacing 10 min of SB with an equal amount of sleep and PA could reduce the risk of overweight and obesity by 2.3–4.4%. Considering sleep, MVPA, and LPA during out-of-school time together, sleep contributed the most to overweight and obesity(weight = 0.6363).

Conclusions During out-of-school time, SB demonstrated a cross-sectional dose-response association with a heightened likelihood of overweight and obesity in childhood. Conversely, sleep and MVPA displayed a contrasting dose-response association with overweight and obesity risk when compared to SB. Substituting SB with sleep or PA might potentially mitigate the risk of overweight and obesity.

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Keywords Obesity, Sleep, Sedentary behavior, Physical activity, Dose-response, Out-of-school time, Children and adolescent, Isotemporal substitution

Globally, the rates of overweight and obesity have increased considerably in recent years. In 2020, the prevalence among Chinese school-aged children and adolescents was 11.1% for overweight and 7.9% for obesity [1]. There are a variety of adverse health consequences associated with excess body weight in both the immediate and prolonged periods for child, including dyslipidemia [2], type 2 diabetes [3], and cardiovascular disease [4]. Consequently, promoting healthy weight status in childhood is a promising approach to preventing obesity-related complications [5]. The management of obesity presents a significant challenge, obesity in childhood generally persists into adulthood [6]. In response to these concerning trends, the World Health Organization (WHO) has established a goal of halting the rise in childhood obesity by the year 2025 [7].

Appropriate physical activity (PA) [8], limited sedentary behavior (SB) [9], and adequate sleep duration [10] have long been recognized as effective strategies for preventing and managing childhood obesity. To foster a healthy lifestyle for youth, each conduct at least 60 min of moderate to vigorous physical activity (MVPA) is recommended [11–13]. The Canadian 24-Hour Movement Guidelines for Children and Youth include recommendations concerning PA and SB, alongside directives for screen time and sleep duration [14]. Despite numerous studies on the health effects of school-based PA programs on children and adolescents, the effects appear to be somewhat limited [15]. Recent findings revealed that just a small proportion of students adhere to the recommendations in the 24-Hour Movement Guidelines [16, 17].

Since 2002, the Chinese Ministry of Education has implemented reforms to the physical education curricula in schools throughout China, with an emphasis on encouraging consistent engagement in physical activity and fostering overall health and well-being [18]. Nevertheless, the out-of-school time is frequently disregarded and underutilized for encouraging PA and fitness among youth. The out-of-school period has the potential to significantly impact children's activity patterns [19–21]. Children and adolescents are often not restricted by school schedules during this time, giving them more freedom to choose their behavior compared to the constraints of the school day. Therefore, it is crucial to clarify how behaviors during out-of-school time (PA, SB, and sleep) relate to excessive weight among children and adolescents.

At any given moment, we can engage in only one type of behavior, and the time available throughout the day for various activities is limited, which means that changes in the time spent on one behavior will inevitably be accompanied by changes in the duration spent on other behaviors.

Compared to traditional single model or allocation model, the isotemporal substitution model can assess the impact on health outcomes by substituting one behavior with an equivalent amount of time dedicated to another behavior [22–24].

In logistic regression model, it is typically assumed that there is a linear relationship between continuous independent variables and the log-odds of the dependent variable. This assumption limits further analysis of whether a nonlinear relationship exists between the independent and dependent variables. When the data exhibits a nonlinear distribution, continuing to use logistic regression may lead to biased results [25]. Consequently, recent studies frequently employ the restricted cubic splines (RCS) model to analyze dose-response relationships [26, 27]. The RCS is a robust method for elucidating the dose-response relationship, also for verifying the association's linearity [28]. Thus far, there are no published studies that have integrated these two methodologies to explore the association between out-of-school hours behaviors and overweight and obesity in youth.

Therefore, we aim to investigate the relationships between different behaviors during out-of-school time and the risk of excess body weight in students by data derived from the China Health and Nutrition Survey (CHNS). We hypothesized that (1) substituting SB with PA or sleep would lower overweight and obesity risk and (2) dose-response associations exist between out-of-school time movement behaviors and the risk of overweight and obesity.

Methods

Study design and participants

The cross-sectional data utilized in this study was obtained from the China Health and Nutrition Survey (CHNS), an ongoing open-cohort study that spans across 15 provinces in China. Samples were drawn using a multistage, random cluster sampling procedure in each province. Recruitment efforts and sampling strategies have already been described in detail elsewhere [29], and the website (https://www.cpc.unc.edu/projects/china/data) contains the data used in this study. The CHNS has published online data from 10 survey rounds conducted between 1989 and 2015.

Questions related to sedentary behaviors have been included since 2004 to facilitate a comprehensive assessment of daily behaviors. For these reasons and to maximize the sample size, our study included only individuals aged 6–17 who took part in at least one follow-up survey round from 2004 to 2015 were included in the study. The survey obtained approval from the institutional review boards at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health (NIHH) at the China Center for Disease Control and Prevention (CCDC), with all participants providing written informed consent [30]. Trained and certified investigators used structured questionnaires to collect data from the study participants. Participants aged younger than 12 completed their questionnaires with their parents, while those older than 12 completed them independently. Participants were deemed ineligible for inclusion in the study if they exhibited missing data in any of the following categories: height, weight, PA, SB, screen time, sleep, extreme outlier values for movement behaviors data exceeding three standard deviations (SD), or implausible values such as BMI below 10 or exceed 50, sleep duration less than 5 h or greater than 14 h, or total physical activity time or any behavior time exceeding 1440 min per day. The final analysis included a total of 2,993 participants, with 4,114 observations.

Anthropometrics measurement

Participants' weight (kg) and height (cm) measurements followed standardized procedures. Using a standard scale and stadiometer, weight and height were measured with a precision of 0.1 kg and 0.1 cm, respectively.

PA, SB, and sleep assessment

The questionnaire designed to assess behaviors was developed by adapting the US Health Interview Surveys, with contributions from Professor Barry Popkin of the University of North Carolina and Professor Barbara Ainsworth of Arizona State University [31].

Out-of-school time includes the time segment spent on school days (before and after school) and the time spent throughout the entire day on weekends. Physical activities were classified into three categories: activities during out-of-school time, commuting, and housework. Activities during out-of-school time included structured and non-structured exercises such as gymnastics and various ball games, commuting activities encompassed walking and cycling, and housework activities comprising cleaning, laundry, and cooking. Daily MVPA time was calculated from the questionnaires by dividing the sum of weekday and weekend MVPA by seven. The Compendium of Physical Activities for Youth was used to estimate the Metabolic Equivalents(METs) and evaluate the intensity for different kinds of physical activities [32]. PAs intensity was classified according to MET values: 1.5 METs ≤ light physical activity (LPA) < 3 METs, 3 METs ≤ moderate physical activity (MPA) < 6 METs, vigorous physical activity (VPA) ≥ 6 METs [33].

Participants were asked to recall their screen-based SB (such as TV watching, computer use, and video games) and non-screen-based SB (such as reading, writing, and drawing) during out-of-school time. Daily SB time was calculated from the questionnaires by dividing the sum of weekday and weekend SB by seven.

In the CHNS, both daytime and nighttime sleep durations were recorded. Daytime and nighttime sleep were combined to determine the total hours of sleep per day.

Overweight and obesity assessment

Participants' BMI was calculated using their height and weight, then categorized as overweight/obese or non-overweight/obese based on specific cutoffs for age and sex [34].

Sociodemographic data assessment

Sociodemographic Characteristics included age, sex, region (north/south China), and place of residence (urban/rural). Elementary school groups and middle school groups are divided according to age, corresponding to 6–12 years old and 13–17 years old, respectively.

Statistical analysis

Continuous variables were represented using medians and interquartile ranges (25th, 75th percentiles), whereas categorical variables were displayed as frequencies and proportions (n%). LPA, MVPA, SB, sleep, and the likelihood of excess body weight were investigated with two multivariable-adjusted logistic regression models. The single model was adjusted for age, sex, place of residence, and region. The partition model was additionally adjusted for other types of activity. The restricted cubic spline model was used to examine the continuous dose-response associations between LPA, MVPA, SB, sleep duration, and overweight/obesity, with the multivariate adjustment.

In the subgroup analyses, we conducted the logistic regression models with full adjustments, stratifying by age, sex, region, and place of residence. We compared models that included and did not include cross-product terms in order to identify interactions between stratifying variables and SB. We performed isotemporal substitution analyses to investigate the impact of substituting time spent on one specific behavior with an equal amount of time on another behavior on the risk of overweight and obesity. The model incorporated sleep duration, SB, MPVA, LPA, total behavior time, and other covariates. For instance, to estimate the effect of substituting 10 min of SB with 10 min of MVPA, SB was excluded from the

Table 1 Basic characteristics of the participants

Characteristics *n* = 4114	Median (25th, 75th percentile)/*n* (%)
Age (years)	11.00(8.00,13.00)
Sex	
Boys	2052(49.9)
Girls	2062(50.1)
Region	
North	1297(31.5)
South	2817(68.5)
Place of residence	
Urban	1352(32.9)
Rural	2762(67.1)
Height (cm)	144.00(130.00,157.00)
Weight (kg)	36.20(26.70,47.00)
BMI (kg/m^2)	17.21(15.32,19.67)
Sleep duration (min/day)	540.00(480.00,600.00)
Sedentary time (min/day)	214.29(150.00,285.11)
Screen time (min/day)	94.29(60.00,150.00)
MVPA (min/day)	30.00(14.29,61.43)
LPA (min/day)	21.00(3.00,81.00)

Data are expressed as Median (25th, 75th percentile) or n (%)

Abbreviations: BMI, body mass index; MVPA, moderate to vigorous physical activity; LPA, light physical activity

model while sleep duration, MVPA, total behavior time, and other covariates were included.

To comprehensively explain the relationship between sleep, MVPA, LPA, and the risk of overweight and obesity, a weighted quantile sum (WQS) regression model [35]with a bootstrapping method over 1000 iterations was used. The WQS model enabled the calculation of weights for sleep, MVPA, and LPA, allowing for the quantification of their individual impacts on the overall outcome. Weights in WQS were restricted to a range of 0 to 1, ensuring that a cumulative sum of 1 was achieved. WQS assumed that each effect in the mixed component was in the same direction [36, 37]. All statistical analyses and graphics are based on R language software 4.1.0, and statistical significance was set as *P*-value less than 0.05.

Results

Characteristics of the participants

In a sample of 4114 observations, consisting of 2052 boys and 2062 girls, the mean age was 11.00 (8.00, 13.00) years, with 67.1% residing in rural areas. Table 1 displays the study population's basic characteristics.

Sleep, SB, PA, and the risk of obesity and overweight

According to the data presented in Table 2, in the single model, each additional 10 min per day spent on SB showed an association with an increased risk of obesity and overweight. (OR = 1.012, 95%CI: 1.005, 1.020), whereas the same amount of time allocated to sleep and MVPA was associated with a decreased risk of obesity and overweight (OR = 0.968, 95%CI: 0.953, 0.982 for sleep; OR = 0.977, 95%CI: 0.957, 0.998 for MVPA). Similarly, in the partition model, every 10 min per day spent on SB was relevant to the increased risk of obesity and overweight (OR = 1.013, 95%CI: 1.006, 1.020), while the time spent on sleep or MVPA was associated with the reduction risk of obesity and overweight (OR = 0.968, 95%CI: 0.954, 0.983 for sleep; OR = 0.976, 95%CI: 0.958, 0.994 for MVPA). Furthermore, when SB was categorized into screen-based SB and non-screen-based SB, an escalation in both types was linked to a higher risk of overweight and obesity (OR = 1.012, 95%CI: 1.002, 1.022 for screen-based SB; OR = 1.015, 95%CI: 1.005, 1.025 for non-screen-based SB).

A dose-response relationship was identified between sleep duration, SB, MVPA, and the risk of obesity and overweight. (Fig. 1A-F). Sleep, SB, and MVPA were linearly associated with the risk of obesity and overweight (all *P* for nonlinear > 0.05). However, screen SB was nonlinearly associated with obesity/overweight (*P* for nonlinear = 0.038). In particular, an elevated duration of screen-based SB exceeding 130 min per day was found to demonstrate a significant association with increased likelihood of overweight and obesity.

Subgroup analyses

In the subgroup analyses, we observed a significant interaction between sleep duration and the risk of overweight and obesity in participants from different regions (*P* for interaction = 0.037) (Fig. 2A). The protective effect of sleep against excess body weight is more pronounced in individuals living in the southern region. Similarly, we noted a significant interaction between SB and overweight and obesity in participants of different sexes (*P* for interaction = 0.026), with the corresponding associations being more pronounced among boys (Fig. 2B). Furthermore, we identified a significant interaction between LPA and regions (*P* for interaction = 0.002) or place of residence (*P* for interaction = 0.026) (Fig. 2F). The

Table 2 Relationship between sleep, SB, MVPA, and risk of overweight and obesity

Model	Sleep OR(95% CI)	SB OR(95% CI)	Screen SB OR(95% CI)	Non-screen SB OR(95% CI)	MVPA OR(95% CI)	LPA OR(95% CI)
Single	0.968(0.953,0.982)*	1.012(1.005,1.020)*	1.008(0.999,1.018)	1.016(1.006,1.026)*	0.977(0.957,0.998)*	0.989(0.972,1.007)
Partition	0.968(0.954,0.983)*	1.013(1.006,1.020)*	1.012(1.002,1.022)*	1.015(1.005,1.025)*	0.976(0.958,0.994)*	0.990(0.973,1.008)

The single model was adjusted for age, sex, place of residence, and region; the partition model was adjusted for age, sex, place of residence, region, and other types of movement behavior. * *P* < 0.05

Abbreviations: CI, confidence interval; OR, odds ratio

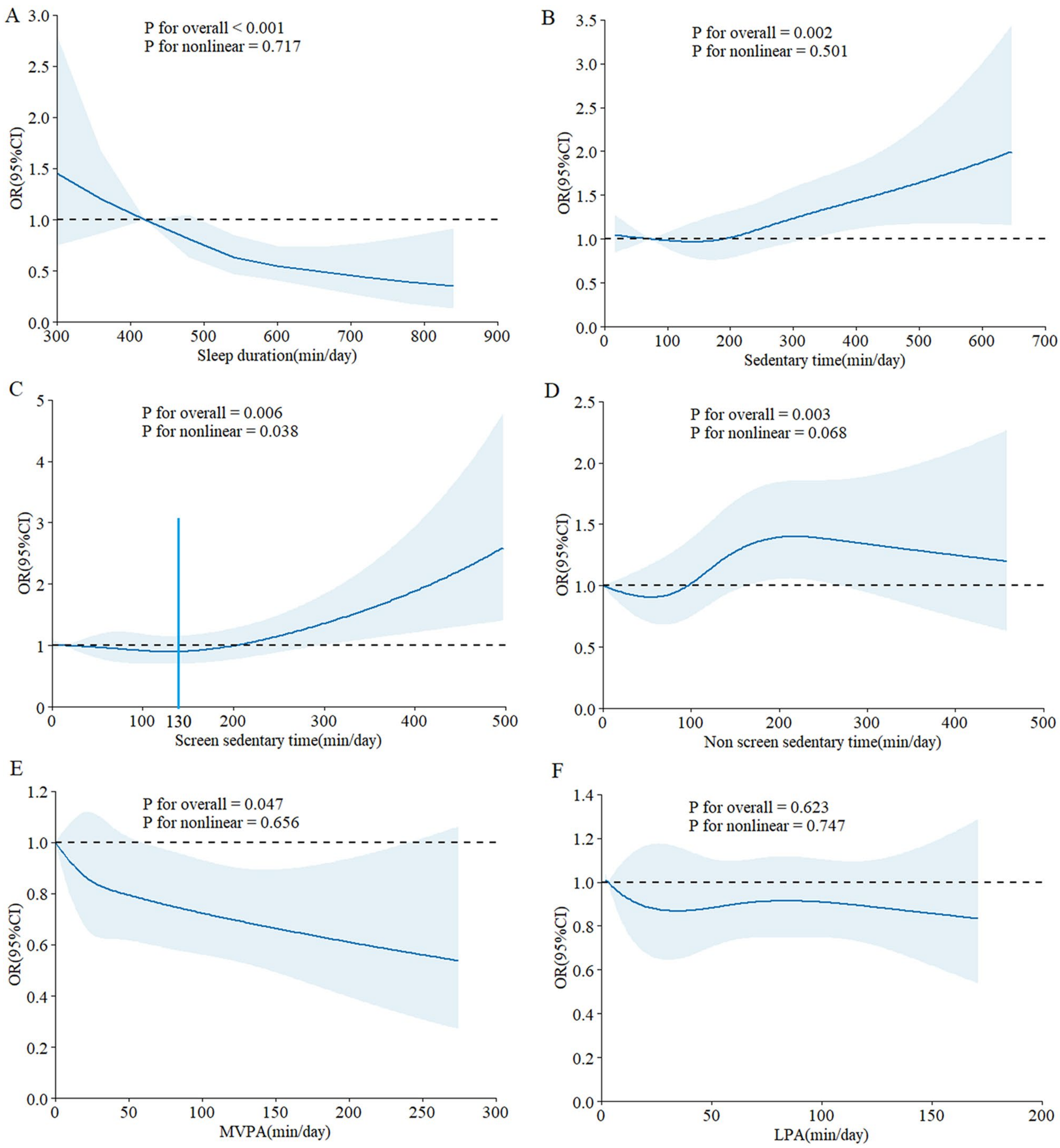

Fig. 1 Dose-response associations between sleep (**A**), SB (**B**), screen SB (**C**), non-screen SB (**D**), MVPA (**E**), LPA (**F**), and the risk of obesity and overweight. The solid line and blue shading represent OR and 95% CI. Models were adjusted for age, sex, place of residence, region, and other types of movement behavior

corresponding associations were more evident among participants from the south region and rural areas.

Isotemporal substitution analyses

Overall, substituting SB with an equivalent duration of sleep, MVPA, or LPA was found to demonstrate favorable effects on obesity prevention (Fig. 3). Specifically, each 10-minute substitution of reducing SB by adding sleep resulted in a 4.4% reduction in the risk of overweight and obesity (OR = 0.956, 95%CI: 0.940, 0.972). Similarly, each 10-minute substitution of reducing SB by adding MVPA or LPA was associated with a 3.7% and 2.3% reduction in the risk of overweight and obesity, respectively (OR = 0.963, 95%CI: 0.944, 0.983 for MVPA;

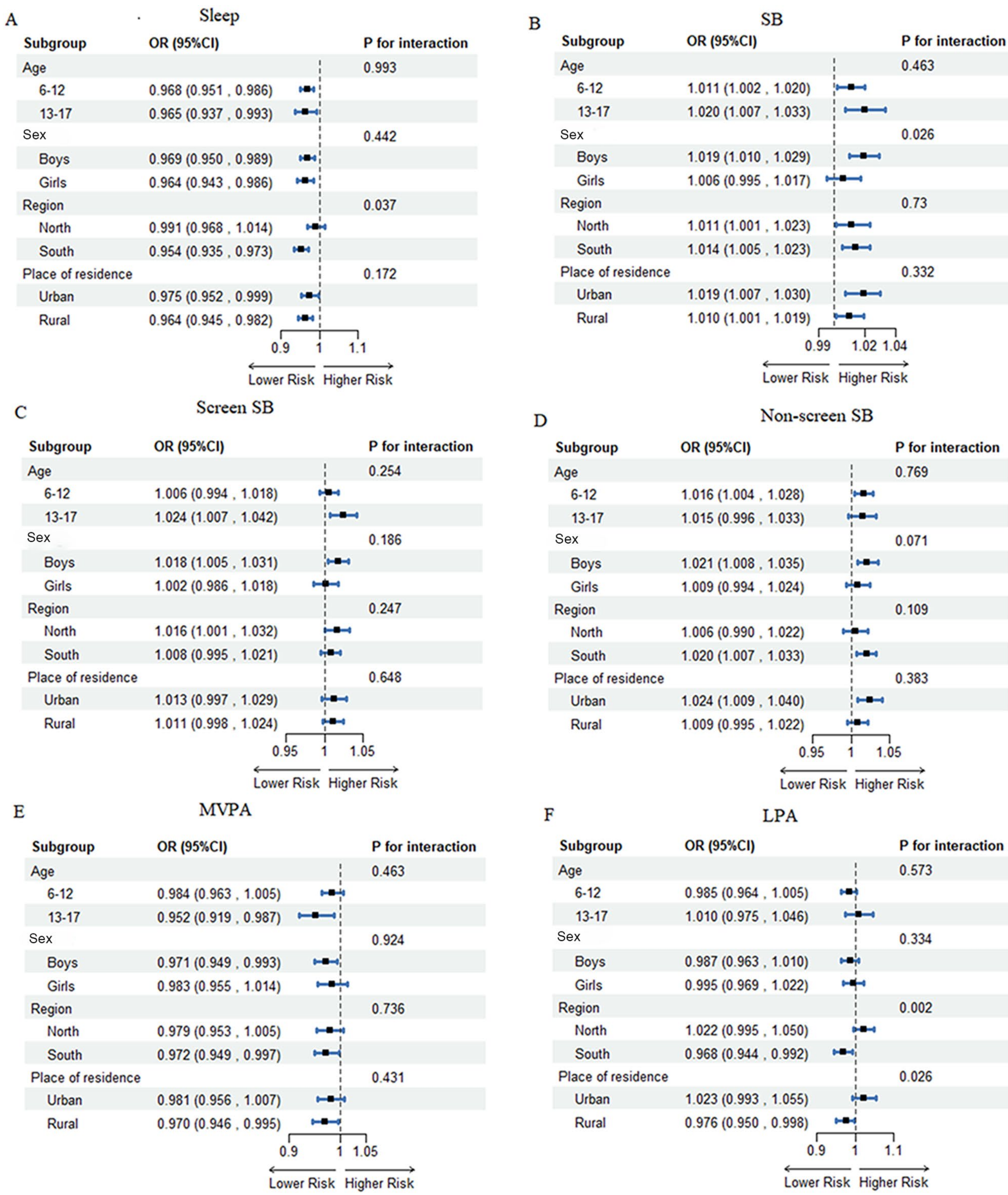

Fig. 2 Odds ratio of the risk of overweight and obesity per 10-minute increase in sleep (**A**), SB (**B**), screen SB (**C**), non-screen SB (**D**), MVPA (**E**), and LPA (**F**). Models were adjusted for age, sex, place of residence, region, and other types of movement behavior

OR = 0.977, 95%CI: 0.959, 0.996 for LPA). Furthermore, upon conducting stratified analyses, it was determined that substituting 10 min of SB with an equivalent amount of time was associated with a 4.9% decrease in the risk of sleep replacement (OR = 0.951, 95%CI: 0.929, 0.973), a 4.2% decrease in the risk of MVPA replacement (OR = 0.958, 95%CI: 0.933, 0.985), and a 3.4% decrease in the risk of LPA replacement (OR = 0.966, 95%CI: 0.941,

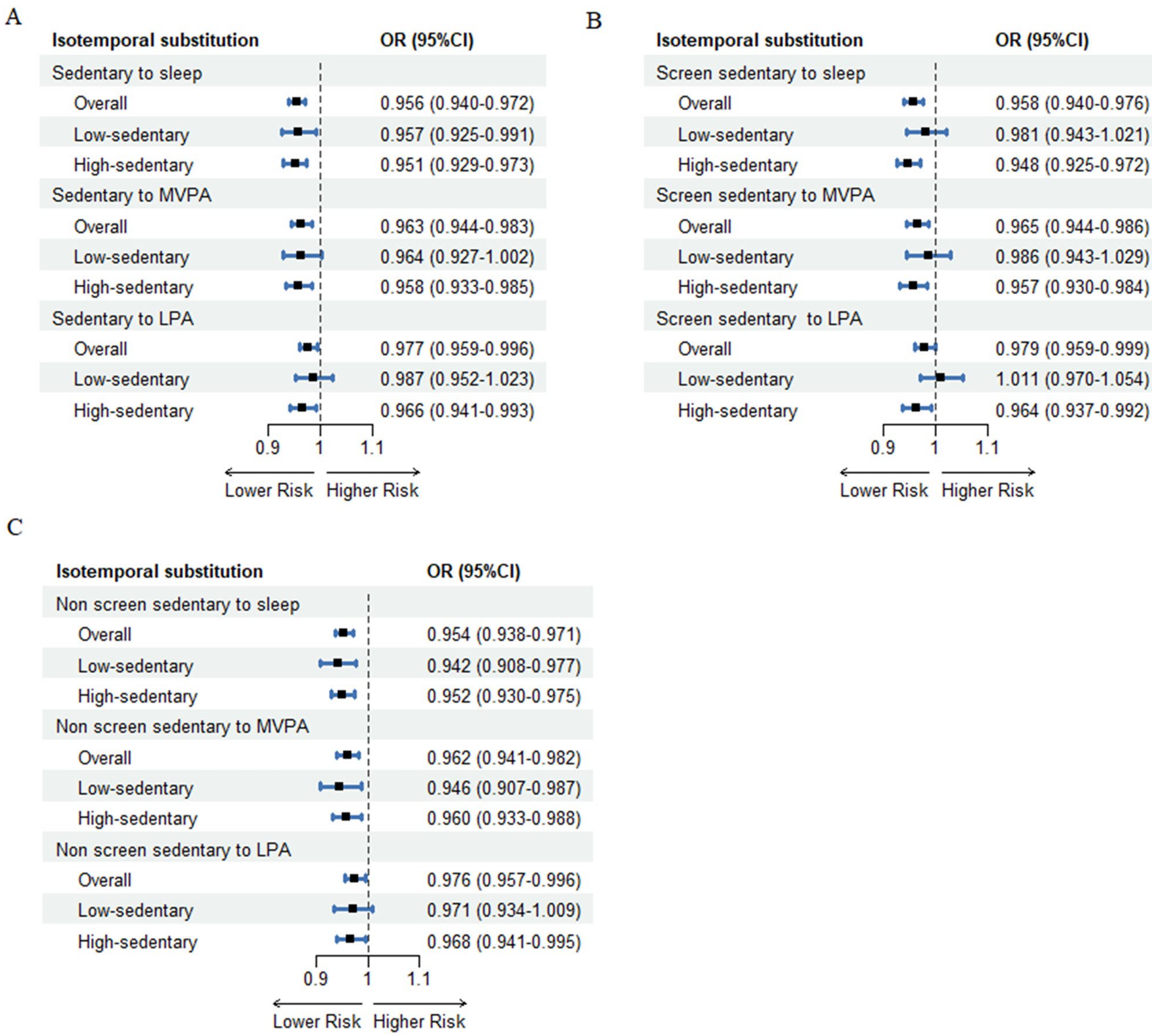

Fig. 3 Substitution of 10 min of SB (**A**), screen SB (**B**), non-screen SB (**C**) to sleep, and PA on the risk of overweight and obesity. Low-sedentary and high-sedentary subgroups were determined by the median of SB. Models were adjusted for age, sex, place of residence, region, and other types of movement behavior

0.993) among individuals with high levels of SB. Moreover, SB replaced by sleep or PA are both beneficial for obesity prevention, whether it's screen-based or non-screen-based. Stratified analysis results indicate that for the high sedentary group, the benefits of replacing screen time with sleep or PA are more pronounced compared to replacing non-screen sedentary behavior. Conversely, replacing non-screen sedentary behavior with sleep or physical activity in the low-sedentary group appears to be more pronounced.

WQS analyses

The results of the WQS showed that the mixture effects of sleep, MVPA, and LPA, on overweight and obesity was statistically significant (Table S2). In the model, all WQS indexes were weighed in the following order: sleep(0.6363), LPA (0.2156), and MVPA (0.1480), indicating that sleep was the most influential determinant among the examined factors (Fig. 4).

Discussion

The results of this study suggest that sleep, SB, and MVPA during out-of-school hours have a cross-sectional dose-response association with overweight and obesity among Chinese students aged 6–17 participating in the CHNS. Theoretically, replacing SB with the same amounts of sleep or PA was cross-sectional related to a reduced risk of excess body weight in this population.

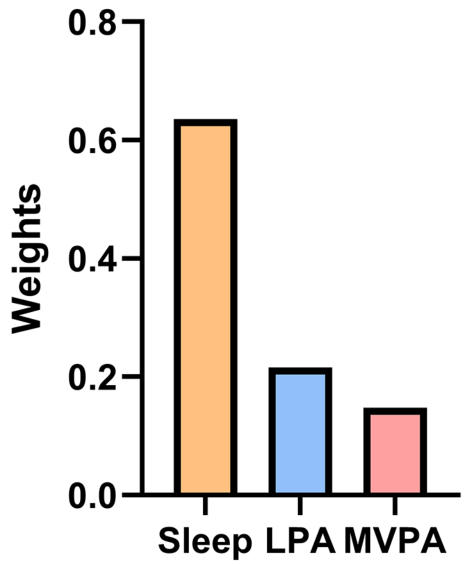

Fig. 4 Weights of each type of activity in the WQS model regression index. The models were adjusted for age, sex, place of residence, and region

Furthermore, during the whole out-of-school time, compared to PA, sleep may have a greater impact on preventing overweight and obesity.

The links between lack of PA, excessive SB, insufficient sleep, and obesity have been reported in previous studies [38–41]. However, they have rarely focused on the association between these behaviors during out-of-school time and obesity, and the dose-response relationship has not been provided. Using a multistage, random cluster processed sample of Chinese children and adolescents, The present study examines the dose-response association between sleep, SB, and PA during out-of-school time and overweight/obesity in school-aged youth. Our study revealed a notable dose-response relationship between out-of-school time sleep duration, SB, MVPA, and the risk of overweight and obesity among Chinese school-aged children and adolescents. These findings are consistent with some previous studies [42–44]. Furthermore, we observed a non-linear dose-response relationship between screen-based SB and the risk of excess body weight. Specifically, when screen-based SB is below 130 min per day, there is no significant change in the risk of overweight and obesity. In contrast, screen-based SB for more than 130 min per day significantly increases the risk of overweight/obesity. Our findings are consistent with the 24-Hour Movement Guidelines [14], which advocate for youth to restrict their daily screen time to no more than 2 h. Sedentary behavior and screen time frequently result in a reduction in physical activity, thus lowering energy expenditure derived from physical activity. Additionally, increased screen time may cause higher food intake during screen-related activities and decreased sensations of fullness while eating [45, 46], leading to increased energy intake and, thereby, greater fat accumulation. However, the mechanisms underlying the nonlinear relationship between screen time and overweight/obesity have not been clearly elucidated in existing research, necessitating further exploration in the future. Furthermore, while this study identified a non-linear dose-response relationship between screen time and overweight/obesity after controlling for certain covariates, the interpretation of these findings should be cautious, as several potential confounding factors, including diet and parental influence, were not accounted for in this analysis. Further research is required to confirm these findings.

Most current studies investigating the impact of replacing SB with PA on obesity predominantly use continuous variables such as BMI, body fat percentage, or waist circumference as outcome measures, with few utilizing binary outcome measures (such as obese or non-obese). Dumuid et al. [47]reported that substituting MPA for SB for 30 min/day was cross-sectionally associated with participants in New Zealand. It was found that substituting 60 min/day of SB with an equivalent duration of MVPA led to a reduction in body mass index across all age cohorts, with the reduction in BMI ranging from −1.26 to -1.43 units [48]. Similarly, our study found that replacing 10 min of SB with MVPA or LPA decreased the risk of overweight and obesity by 3.7% or 2.3%. Additionally, our research revealed that replacing 10 min of SB with sleep was linked to a 4.4% decrease in overweight and obesity risk. This finding differs from the results of some other studies [47, 49, 50]. This discrepancy may be attributed to different measurement methods (self-report or objective measurement), outcome measures, and characteristics of the study participants (e.g., race, region). Moreover, replacing SB with sleep and PA lowers the risk of overweight and obesity, regardless of whether it is screen-based or non-screen-based SB. This further confirms the potential benefits of substituting sedentary behavior. One of the characteristics of obesity is chronic inflammation, which frequently results in a reduction in muscle mass and a slowing of muscle protein synthesis [51]. Physical activity can improve this chronic inflammatory state by decreasing levels of Interleukin-6 (IL-6) and Tumor Necrosis Factor-alpha (TNF-α) [52], thereby reducing the risk of obesity through the enhancement of metabolic function. Additionally, studies have demonstrated that leptin levels decrease following PA, whereas ghrelin levels increase [53]. These changes may help control appetite, thereby reducing excessive fat accumulation. Recent studies have discovered that PA can modify specific genes and microRNAs linked to obesity, which may be a potential mechanism by which PA aids in the prevention of obesity [54, 55].

Subgroup analysis reveals that the protective impact of increased sleep and LPA on the incidence of overweight and obesity is more prominent in the southern population. This could be attributed to climatic differences between northern and southern China, with higher temperatures in the south often leading to shorter sleep durations compared to the north [56, 57]. As a result, increasing sleep duration appears to have a more pronounced protective effect against overweight and obesity in the southern population. The weaker preventive effect of LPA on weight gain among children and adolescents in northern China may be associated with variations in dietary patterns. Earlier studies have suggested that the dietary patterns in northern China are more likely to contribute to obesity compared to those in southern China [58]. However, due to the extremely high proportion of missing dietary data among the subjects in this study, it is challenging to further examine the impact of dietary factors. This issue warrants further exploration in future research. We also found that the relationship between increased SB and the incidence of overweight and obesity is more pronounced in boys. This may be attributed to boys generally being more active than girls, with higher levels of PA overall [59]. Therefore, the reduction in energy expenditure associated with boys substituting PA with SB is more substantial.

The significant mixture effect of sleep, MVPA, and LPA on overweight and obesity suggested that the combination of three types of behaviors was conducive to reducing overweight and obesity risk, with sleep contributing the most to this association. This finding aligns with existing research that underscores the significance of sleep [60]. Insufficient sleep impairs energy metabolism, contributing to an excess of calorie consumption and an increased risk of overweight and obesity [61, 62]. This is attributed to sleep deprivation, which can elevate ghrelin levels and reduce leptin levels, resulting in heightened appetite [63]. Furthermore, research has demonstrated that sleep deprivation may elevate oxidative stress in the brain, which is linked to anxiety-like behaviors, subsequently reducing physical activity [64]. Inadequate sleep may also contribute to fatigue, which in turn leads to reduced physical activity and increased sedentary behavior [65]. The aforementioned findings suggest that sleep may impact physical activity, sedentary behavior, and energy metabolism via multiple mechanisms, thereby influencing the onset and progression of obesity. Therefore, for preventing and controlling obesity, besides increasing physical activity, ensuring an adequate duration of sleep may also have significant potential.

There are several strengths to this study. First, it is the first study to date to examine the dose-response relationship and isotemporal substitution effects between SB, PA, sleep, and overweight/obesity during out-of-school time among children and adolescents. Second, the WQS model was applied to investigate the combined impact of sleep, MVPA, and LPA on overweight and obesity, also estimating the individual impact weights for each type of behavior. Third, the CHNS data were gathered with strict adherence to quality control protocols, thereby enhancing the credibility of the findings. Although a recent study also examined the risk of overweight or obesity in children and adolescents using the CHNS database [66], its primary focus was to analyze the relationship between adherence to the 24-Hour Movement Guidelines and overweight or obesity. In contrast, the present study focuses on the associations between sleep, sedentary behavior, and physical activity during out-of-school time and the risk of overweight and obesity. It analyzes the isotemporal substitution effect and dose-response relationship, further elucidating the impact of varying intensities of physical activity on the risk of overweight and obesity in children and adolescents.

However, this study has some shortcomings. A limitation of this study is that the exposure variables were gathered through self-reported questionnaires, which may be subject to recall bias and social desirability bias, potentially resulting in misclassification of the behaviors. Moreover, despite this study adjusting for several potential confounding factors and analyzing specific interaction terms, unmeasured factors or those excluded from the adjustment due to a significant portion of data being missing may still impact the findings. For instance, factors like diet, parental influence, and school environment were not included in this study either because they were not measured or had exceedingly high missing rates, necessitating further investigation in future research. While the CHNS survey covers 15 provinces in China, certain provinces are excluded, which limits the data's capacity to comprehensively represent the entire population of children and adolescents in China, including variations in socioeconomic status, regional diversity, and cultural characteristics. This limitation restricts the generalizability of the study's findings.

Finally, this study is a cross-sectional observational design, so it might be difficult to establish causal relationships. Additional investigation utilizing longitudinal data is necessary to find causal relationships.

Conclusion

Our findings suggest a dose-response associations between out-of-school time SB, MVPA, sleep, and the likelihood of overweight and obesity in children and adolescents. Elevated SB during out-of-school time seems to be linked with a greater risk of overweight and obesity, while sufficient sleep and PA might be associated with a lower risk of overweight and obesity. Besides, substituting SB with sleep or PA might aid in mitigating the likelihood of being overweight and obese. Apart from increasing PA or decreasing SB, ensuring sufficient sleep is a factor that should not be neglected in the prevention of childhood and adolescent obesity. Nonetheless, given the cross-sectional design of this study, it is important to recognize the exploratory nature of these findings and the need for additional research to validate these associations.

Abbreviations

BMI	Body mass index
RCS	Restricted cubic spline
SD	Standard deviation
CHNS	China Health and Nutrition Survey
SB	Sedentary behavior
PA	Physical activity
LPA	Light physical activity
MVPA	Moderate-to-vigorous physical activity
WQS	Weighted quantile sum
METs	Metabolic Equivalents

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-23011-9.

Supplementary Material 1

Acknowledgements
We thank all the participants and their parents for their cooperation in CHNS.

Author contributions
Z.C.: Conceptualization, Methodology, Data analysis, Validation, Writing - original draft, Writing - review & editing. P.C.: Conceptualization, Methodology, Writing- review & editing, Supervision. L.Z.: Conceptualization, Methodology, Resources, Validation, Writing - original draft, Writing - review &editing, Supervision.

Funding
This work was supported by the National Social Science Fund of China (No. 23ATY007).

Data availability
All the data in the present analysis is available at CHNS website https://www.cpc.unc.edu/projects/china/data.

Declarations

Ethics approval and consent to participate
The ethics approval was obtained by the review board from the University of North Carolina at Chapel Hill, National Institute for Nutrition and Food Safety, China Center for Disease Control. All parents gave written informed consent for their children's participation in the survey.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 28 June 2024 / Accepted: 30 April 2025
Published online: 21 May 2025

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