

Adherence to the 24-hour movement guidelines and associations with myopia, poor vision, and axial length among children and adolescents in Beijing, China: a cross-sectional study

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Abstract

Background

The combined influence of sleep, recreational screen time, and moderate-to-vigorous physical activity on visual health in children and adolescents remains insufficiently understood.

Methods

We conducted a cross-sectional analysis of 3,957 participants aged 6–17 years from the Beijing Children and Adolescent Health Cohort (2022–2023). Sleep duration, recreational screen time, and moderate-to-vigorous physical activity were assessed by questionnaire and classified according to the Canadian 24-hour movement guidelines. Multivariable logistic regression was used for myopia and poor vision, and multivariable linear regression for mean bilateral axial length. Models were adjusted for age, sex, body mass index, parental myopia, parental education, and sugar-sweetened beverage intake. Age-stratified analyses were performed.

Results

Meeting the recreational screen-time recommendation was associated with lower odds of myopia (adjusted odds ratio [aOR], 0.60; 95% confidence interval [CI], 0.50–0.72), and meeting the sleep recommendation was associated with lower odds of poor vision (aOR, 0.82; 95% CI, 0.71–0.94). Each additional recommendation met was associated with lower odds of myopia (aOR, 0.77; 95% CI, 0.69–0.85) and poor vision (aOR, 0.84; 95% CI, 0.78–0.92). Meeting all 3 recommendations was associated with lower odds of myopia (aOR, 0.53; 95% CI, 0.35–0.79) and poor vision (aOR, 0.57; 95% CI, 0.40–0.79). No overall association with axial length was observed; sleep-related adherence was associated with shorter axial length among adolescents.

Conclusions

Among children and adolescents in Beijing, adherence to the 24-hour movement recommendations, particularly the recreational screen-time and sleep recommendations, was associated with more favorable visual health. Longitudinal studies are needed to establish temporality and causality.

Background

Myopia has become a major public health issue among children and adolescents worldwide. A systematic review and meta-analysis projected that the global number of children and adolescents with myopia will exceed 740 million by 2050 [1]. Myopia not only affects learning and daily life but may also progress to high myopia and increase the risk of retinal disease and glaucoma [2]. The burden of myopia

among children and adolescents in China is substantial, and myopia prevention and control have become a priority in school and child health management [3]. Poor vision reflects impaired uncorrected distance vision and is commonly used in vision screening. During childhood and adolescence, axial length is an important structural marker of ocular development. Axial length growth is closely associated with the onset and progression of myopia and may help identify excessive ocular growth and an elevated risk of myopia [4]. Furthermore, children who subsequently develop myopia have been shown to exhibit longer axial lengths before myopia onset, suggesting that axial length can serve as an important structural indicator for assessing the risk of myopia onset and progression [5]. Therefore, simultaneously assessing myopia, poor vision, and axial length helps evaluate eye health from different perspectives, including refractive status, visual function, and ocular structure.

Previous studies have reported that daily behaviors are associated with the onset and progression of myopia among children and adolescents. Greater time spent outdoors may be associated with a lower risk of myopia [6, 7]. Increased screen time may be associated with a higher risk of myopia. A dose-response meta-analysis reported that each additional hour per day of digital screen time was associated with a higher risk of myopia [8]. Evidence on sleep duration remains inconsistent: insufficient sleep may be associated with myopia, but studies have not consistently reported associations with axial length growth or myopia progression [9, 10].

Because physical activity, sedentary behavior, and sleep compete for time within a 24-hour day, examining one behavior alone may be insufficient. The Canadian 24-Hour Movement Guidelines integrate moderate-to-vigorous physical activity, recreational screen time, and sleep within a single framework [11]. Although this framework has been examined in relation to obesity and physical and mental health, evidence for eye health remains limited. Most studies assessed myopia or poor vision alone, with limited attention to axial length, individual recommendations, and their combinations [12–14]. Children and adolescents also differ in academic workload, screen use, sleep patterns, and rates of axial length growth. Whether these differences translate into age-specific associations between 24-hour movement behaviors and eye health remains unclear.

Therefore, this study aims to comprehensively assess the eye health of the study population using multiple indicators, including myopia, poor vision, and axial length. It examines individual adherence to the sleep duration, recreational screen time, and moderate-to-vigorous physical activity recommendations, as well as the number and combinations of recommendations met. It also aims to explore age-related differences in these relationships, with the aim of providing evidence-based guidance for interventions to promote eye health and recommendations on daily movement behaviors among children and adolescents.

Methods

Study Design and Participants

Between 2022 and 2023, the Beijing Children and Adolescent Health Cohort recruited participants from 10 representative primary and secondary schools in one specific district of Beijing using random cluster sampling. A total of 5,741 participants were initially recruited. Participants aged outside the 6-17-year range or with missing data on eye health outcomes, 24-hour movement behavior measures, or key covariates were excluded. A total of 3,957 participants were included in the final analysis. Institutional Review Board (IRB)/Ethics Committee approval was obtained from the Ethics Committee of the Capital Institute of Pediatrics (approval No. SHERLL2022043). Written informed consent was obtained from all participants and/or their guardians. The study adhered to the tenets of the Declaration of Helsinki.

Eye Health Outcomes

Eye health outcomes were obtained from baseline vision screening and included myopia, poor vision, and axial length. Distance visual acuity was assessed using an international standard 5-m logarithmic visual acuity chart. Noncycloplegic refraction was measured using a vision screener, which provided spherical power, cylindrical power, and axis readings. Axial length was measured in both eyes using the IOLMaster 500 (ZEISS, Oberkochen, Germany).

Spherical equivalent (SE) was calculated as spherical power plus one-half of cylindrical power. According to the National Health Commission guidelines and the International Myopia Institute epidemiologic definition, myopia was defined as a worse-eye SE of ≤ -0.50 D [15,16]. Poor vision was defined as uncorrected distance visual acuity <5.0 in participants aged ≥ 6 years [15]. Axial length was measured in both eyes, and the mean value was analyzed as a continuous outcome. Myopia and poor vision were binary outcomes.

24-Hour Movement Behaviors

Parents or guardians completed a questionnaire assessing sleep duration, recreational screen time, and moderate-to-vigorous physical activity (MVPA). Adherence was classified according to the Canadian 24-Hour Movement Guidelines for Children and Youth [11].

Sleep duration: Sleep duration was derived from reported bedtimes and wake times on weekdays and weekends during the school year. Average daily sleep duration was calculated as $(\text{weekday sleep duration} \times 5 + \text{weekend sleep duration} \times 2) / 7$ [17]. Participants aged 6-13 years met the recommendation if they slept 9-11 h/day. Those aged 14-17 years met it if they slept 8-10 h/day [11].

Recreational screen time: Recreational screen time was calculated from reported use of televisions, mobile phones, tablets, and computers outside class hours. Participants with an average daily recreational screen time of >120 min/day were classified as not meeting the recommendation [11].

Moderate-to-vigorous physical activity (MVPA): Average daily MVPA duration was obtained from questionnaire responses regarding time spent in physical activity of at least moderate intensity. Physical

activity of at least moderate intensity included brisk walking, running, jumping rope, swimming, various ball sports, and physical education class time. Sessions lasting ≥ 10 min were counted. Participants averaging ≥ 60 min/day met the recommendation [11].

Covariates

Covariates were age, sex, body mass index (BMI), parental myopia, highest parental education, and sugar-sweetened beverage intake frequency. Age was modeled continuously and sex as male or female. Height and weight were measured using standardized procedures, and BMI was calculated as weight (kg) divided by height² (m²). Height was measured using a mechanical stadiometer according to standardized procedures and recorded in centimeters (cm). Information on parental myopia, parents' highest level of education, and frequency of sugar-sweetened beverage consumption was obtained from the questionnaire. Parental myopia was defined as myopia in either parent. Parents' highest level of education was categorized as high school or below and bachelor's degree or above. Frequency of sugar-sweetened beverage consumption was categorized as <1 time/day and ≥ 1 time/day.

Statistical Analysis

Statistical analysis was performed using R 4.5.1. A two-sided P value < 0.05 was considered statistically significant. Categorical variables were presented as frequencies and percentages, and continuous variables were presented as mean $\pm$ standard deviation or median (interquartile range). Comparisons were made between participants with and without myopia and between participants with and without poor vision. For continuous variables, independent-samples t-tests or Wilcoxon rank-sum tests were used depending on the distribution. For categorical variables, chi-square tests or Fisher's exact tests were used.

The primary outcomes were myopia, poor vision, and axial length. Myopia and poor vision were analyzed as binary outcomes using multivariable logistic regression models, whereas axial length was analyzed as a continuous outcome using multivariable linear regression models. The primary exposure variables were adherence to the sleep duration, recreational screen time, and moderate-to-vigorous physical activity recommendations of the 24-hour movement guidelines, each modeled as a binary variable. The number of recommendations met and different combinations of recommendations met were also examined. For analyses of individual recommendations, participants who did not meet the corresponding recommendation served as the reference group. For analyses of combinations of recommendations met, participants who met none of the recommendations served as the reference group. All models were adjusted for age, sex, BMI, parental myopia, highest parental education, and sugar-sweetened beverage intake. Logistic regression results are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs), and linear regression results as β coefficients with 95% CIs. Age-stratified analyses were conducted for participants aged 6-13 and 14-17 years. Additionally, sleep

duration, recreational screen time, and time spent in moderate-to-vigorous physical activity were modeled as continuous variables to examine their associations with the eye health outcomes.

Results

Participant Characteristics and Adherence to the 24-Hour Movement Guidelines

A total of 3,957 children and adolescents aged 6-17 years were included. Their mean age was 10.69 ± 2.92 years, and 50.21% were male. Myopia and poor vision prevalence were 75.26% and 58.15%, respectively, and mean axial length was 23.83 ± 1.21 mm. Compared with participants without myopia, those with myopia were older, had shorter sleep duration, longer recreational screen time, and longer axial length (all $P < .05$). The same pattern was observed for participants with versus without poor vision.

The proportions meeting the sleep duration, recreational screen time, and moderate-to-vigorous physical activity recommendations were 53.37%, 60.73%, and 16.58%, respectively. Among the different combinations, 30.60% of participants met both the sleep duration and recreational screen time recommendations, representing the highest proportion. In addition, 17.06% met none of the recommendations, and 5.00% met all three recommendations. These results are shown in Table 1.

Associations Between Adherence to the 24-Hour Movement Guidelines and Myopia and Poor Vision

Figure 1 shows the adjusted associations between adherence to the 24-hour movement guidelines and myopia and poor vision. The results of the full model are presented in Supplementary Table S1. All models were adjusted for age, sex, BMI, parental myopia, parents' highest level of education, and frequency of sugar-sweetened beverage consumption. In analyses of individual recommendations, meeting the recreational screen time recommendation was associated with lower odds of myopia (aOR = 0.60, 95% CI = 0.50-0.72, $p < 0.001$) and poor vision (aOR = 0.87, 95% CI = 0.75-1.00, $p = 0.044$). Meeting the sleep duration recommendation was associated with lower odds of poor vision (aOR = 0.82, 95% CI = 0.71-0.94, $p = 0.004$), but was not significantly associated with myopia. Meeting the MVPA recommendation was not significantly associated with the odds of either myopia or poor vision (both $p > 0.05$).

Each additional recommendation met was associated with lower odds of myopia (aOR = 0.77, 95% CI = 0.69-0.85, $p < 0.001$) and poor vision (aOR = 0.84, 95% CI = 0.78-0.92, $p < 0.001$). In analyses of combinations of recommendations met, compared with participants who met none of the recommendations, lower odds of myopia were observed among those who met both the sleep duration and recreational screen time recommendations (aOR = 0.64, 95% CI = 0.49-0.86, $p = 0.002$), both the recreational screen time and MVPA recommendations (aOR = 0.57, 95% CI = 0.37-0.89, $p = 0.013$), or all

three recommendations (aOR = 0.53, 95% CI = 0.35-0.79, $p = 0.002$). For poor vision, lower odds were observed among those who met the sleep duration recommendation alone, both the sleep duration and recreational screen time recommendations, both the recreational screen time and MVPA recommendations, or all three recommendations (aORs = 0.77, 0.72, 0.68, and 0.57, respectively). In age-stratified analyses, associations of adherence to the 24-hour movement guidelines with myopia and poor vision were primarily observed among children aged 6-13 years. Detailed results are presented in Supplementary Table S2.

Associations Between Adherence to the 24-Hour Movement Guidelines and Axial Length

Figure 2 presents the associations between adherence to the 24-hour movement guidelines and axial length from multivariable linear regression models. Full model estimates are presented in Supplementary Table S3. Among all participants, axial length was not significantly associated with adherence to any individual recommendation, the number of recommendations met, or combinations of recommendations met. In age-stratified analyses, no significant associations between axial length and any adherence indicator were observed among participants aged 6-13 years. Among participants aged 14-17 years, meeting the sleep duration recommendation was associated with a shorter axial length ($\beta = -0.246$, 95% CI = -0.422 to -0.070). Compared with participants who met none of the recommendations, those who met both the sleep duration and recreational screen time recommendations had a shorter axial length ($\beta = -0.303$, 95% CI = -0.580 to -0.025). Participants who met all three recommendations also tended to have a shorter axial length ($\beta = -0.482$, 95% CI = -0.956 to -0.000).

Associations of Continuous Movement Behavior Durations With Myopia, Poor Vision, and Axial Length

Table 2 presents the associations of sleep duration, recreational screen time, and moderate-to-vigorous physical activity duration, modeled as continuous variables, with myopia, poor vision, and axial length. After adjusting for age, sex, BMI, myopia in either parent, parents' highest level of education, and frequency of sugar-sweetened beverage consumption, each 1 h/day increase in recreational screen time was associated with higher odds of myopia (aOR = 1.159, 95% CI = 1.102-1.221, $p < 0.001$), while each 1 h/day increase in sleep duration was associated with lower odds of poor vision (aOR = 0.875, 95% CI = 0.808-0.947, $p < 0.001$). The associations between the remaining continuous movement behavior durations and myopia, poor vision, and axial length were not statistically significant.

Discussion

Key Findings

This study found that adherence to the 24-hour movement guidelines was associated with lower odds of myopia and poor vision among children and adolescents. Specifically, meeting the recreational screen time recommendation was significantly associated with lower odds of myopia, and meeting the sleep duration recommendation was significantly associated with lower odds of poor vision. Several combinations of recommendations met were also associated with lower odds of myopia or poor vision. In contrast, overall associations between 24-hour movement behaviors and axial length were limited. Only in age-stratified analyses were sleep-related recommendations associated with shorter axial length.

Individual Behaviors, Previous Studies, and Mechanistic Explanations

Among the three individual behaviors, recreational screen time showed the most consistent association with myopia. In this study, meeting the recreational screen time recommendation was associated with lower odds of myopia, whereas each additional hour of recreational screen time was associated with higher odds of myopia. These findings are consistent with a previous dose-response meta-analysis [8]. Screen use is typically accompanied by near work, sustained fixation, reduced time spent outdoors, and increased exposure to artificial light at night. These factors may collectively influence the onset and progression of myopia [18–20]. Thus, recreational screen time may reflect not only screen exposure itself but also near work, nighttime viewing habits, and daily schedules.

The association of adequate sleep duration with poor vision was relatively clear, whereas its associations with myopia and axial length were less consistent than those observed for recreational screen time. These findings are consistent with the mixed evidence from previous sleep studies. Although some studies suggest that insufficient sleep may be associated with an increased risk of myopia, longitudinal studies and systematic reviews indicate inconsistent associations of sleep duration with myopia progression and axial length growth [9, 10, 21]. From a mechanistic perspective, sleep may participate in ocular physiological regulation through mechanisms such as the circadian rhythms, melatonin secretion, and retinal dopamine signaling [22, 23]. Therefore, adequate sleep may reflect a more regular circadian rhythm and may be more closely associated with functional visual status, as reflected by uncorrected visual acuity. In contrast, myopia and axial length primarily reflect refractive development and changes in ocular structure and are more strongly influenced by long-term exposures and genetic factors.

Meeting the MVPA recommendation did not show a consistent independent association with the eye health outcomes. This finding does not necessarily contradict previous evidence on outdoor activity and myopia. Previous systematic reviews and randomized clinical trials have suggested that increasing time spent outdoors can reduce the risk of myopia in children [6, 7]. This study measured the duration of moderate-to-vigorous physical activity but did not distinguish between indoor and outdoor activities or actual light exposure. Outdoor exposure may influence the onset and progression of myopia through mechanisms such as higher light levels and retinal dopamine release [24, 25]. Future studies should

distinguish between indoor and outdoor physical activity and actual light exposure to more accurately assess the associations of activity-related behaviors with eye health in children and adolescents.

Number and Combinations of Recommendations Met

Compared with individual behaviors, the number and combinations of recommendations met better reflect the integrated nature of the 24-hour movement framework. Excessive screen time may displace time available for sleep and outdoor activities, and insufficient sleep is often associated with nighttime screen use and irregular sleep schedules. Therefore, the number of recommendations met and combinations of recommendations met may reflect an overall lifestyle rather than the isolated effect of a single behavior [11]. In this study, each additional recommendation met was associated with lower odds of myopia and poor vision, suggesting that children and adolescents who met more 24-hour movement recommendations had a more favorable eye health status. Previous studies have also found that meeting more 24-hour movement recommendations was associated with lower odds of myopia or poor vision [12–14]. Among specific combinations, meeting both the recreational screen time and sleep duration recommendations was particularly notable, suggesting that limiting recreational screen time and ensuring adequate sleep may be important targets for eye health interventions in children and adolescents. Meeting all three recommendations was associated with lower odds of both myopia and poor vision, further supporting the importance of comprehensive behavioral management.

Outcome Differences and Age-Stratified Findings

In this study, associations of 24-hour movement behavior patterns with myopia and poor vision were more evident than associations with axial length. This difference may be related to the nature of the outcome measures. Myopia reflects refractive status, whereas poor vision reflects uncorrected distance visual function. Both may be more readily influenced by current screen exposure, near work, sleep patterns, and visual fatigue. In contrast, axial length is a structural indicator of ocular growth. Changes in axial length involve ocular growth regulation and scleral remodeling and may therefore reflect long-term cumulative exposures and developmental processes to a greater extent. Previous studies have emphasized that axial length growth and the onset and progression of myopia are jointly influenced by genetic and environmental factors, including long-term visual behaviors [26]. Furthermore, studies have shown that myopia and axial length-related vision impairment increase with age among children and adolescents, suggesting that axial length-related changes exhibit developmental and cumulative characteristics [27]. These features may explain the finding in the present study that no stable overall association was observed between 24-hour movement behavior patterns and axial length.

Age-stratified analyses showed that associations of 24-hour movement behavior patterns with myopia and poor vision were primarily observed among children aged 6–13 years. This age range represents a critical period for refractive development and myopia onset, during which the eye is still undergoing active growth and emmetropization. Associations between behavioral factors and myopia risk may therefore be more readily detectable during this period. In contrast, adolescents aged 14–17 years had a higher prevalence of myopia, and their refractive status may already have been influenced by long-term

visual habits, learning environments, and genetic factors. Cumulative past exposures may therefore attenuate cross-sectional associations of current lifestyle behaviors with myopia or poor vision. Previous real-world studies have shown that myopia progression rates vary substantially by age, with faster progression in younger children and relatively slower progression in late adolescence [28].

In the axial length analysis, meeting sleep-related recommendations was associated with shorter axial length among adolescents aged 14–17 years. Adolescence is a period when delayed sleep onset, insufficient sleep, and nighttime screen use are more common. These behaviors may affect circadian rhythms and melatonin secretion. Mechanistic research suggests that retinal dopamine signaling, choroidal blood flow, and ocular inflammation may be involved in the association between sleep disturbances and myopia [22, 23]. However, axial length is a long-term structural measure, and the cross-sectional design cannot determine the temporal sequence between sleep behaviors and axial length changes. Age stratification reduced the sample size and may have increased uncertainty in the estimates.

Study Limitations

This study has several limitations. First, its cross-sectional design precluded causal inference. Second, sleep duration, recreational screen time, and MVPA were assessed by questionnaire and may be subject to recall bias. Third, outdoor time, light intensity, near-viewing distance, reading posture, and academic workload were not directly measured. Fourth, noncycloplegic refraction may have overestimated myopia prevalence, particularly in younger children [27]. Finally, current behaviors may not fully capture long-term exposures relevant to axial length, and the findings from one district in Beijing may not be generalizable to other populations.

Conclusions

In summary, adherence to 24-hour movement guidelines was associated with lower odds of myopia and poor vision. Indicators involving recreational screen time and sleep showed consistent associations with these outcomes. Compared with other combinations of recommendations met, meeting all three recommendations exhibited the strongest associations with lower odds of myopia and poor vision. The associations with axial length varied across different age groups, with a more pronounced trend observed during adolescence. These findings suggest that eye health promotion among children and adolescents may benefit from emphasizing balanced 24-hour movement behavior patterns, particularly recreational screen time and sleep duration, while tailoring intervention strategies to age-specific characteristics.

Abbreviations

aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; MVPA, moderate-to-vigorous physical activity; SE, spherical equivalent; SD, standard deviation; ST, recreational screen time.

Declarations

Ethics approval and consent to participate

Institutional Review Board/Ethics Committee approval was obtained from the Ethics Committee of the Capital Institute of Pediatrics (approval No. SHERLL2022043). Written informed consent was obtained from all participants and/or their guardians. The study adhered to the tenets of the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available because of privacy and ethical restrictions but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

JZ, JL, and TL conceived and designed the study. JZ, HZ, HG, KL, GH, DH, YC, XZ, FC, SL, LW, JL, and TL contributed to data acquisition and/or data curation. JZ and TL performed the statistical analysis. JZ drafted the manuscript. All authors critically revised the manuscript, approved the final version, and agree to be accountable for all aspects of the work.

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Tables

Table 1 and 2 are available in the Supplementary Files section.

Figures

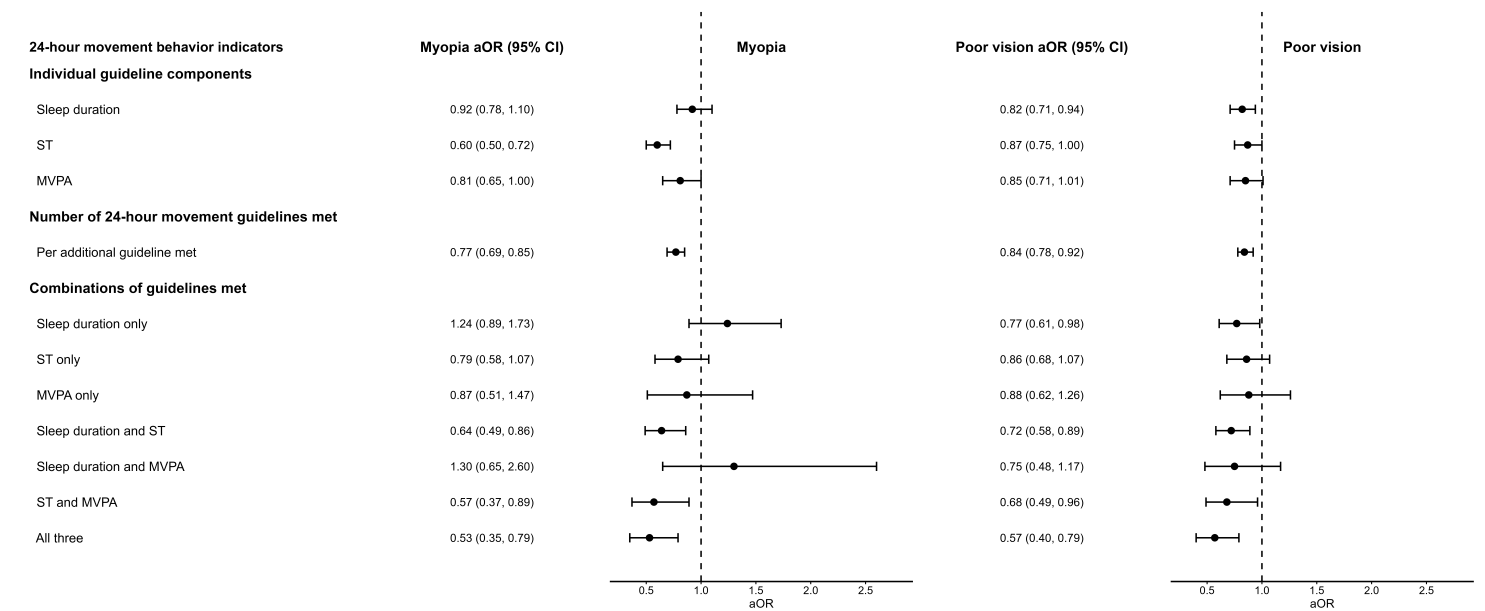


Figure 1

Adjusted associations between 24-hour movement guideline adherence and myopia and poor vision. Models were adjusted for age, sex, body mass index (BMI), parental myopia, parental education, and sugar-sweetened beverage intake. ST, recreational screen time; MVPA, moderate-to-vigorous physical activity; aOR, adjusted odds ratio; CI, confidence interval.

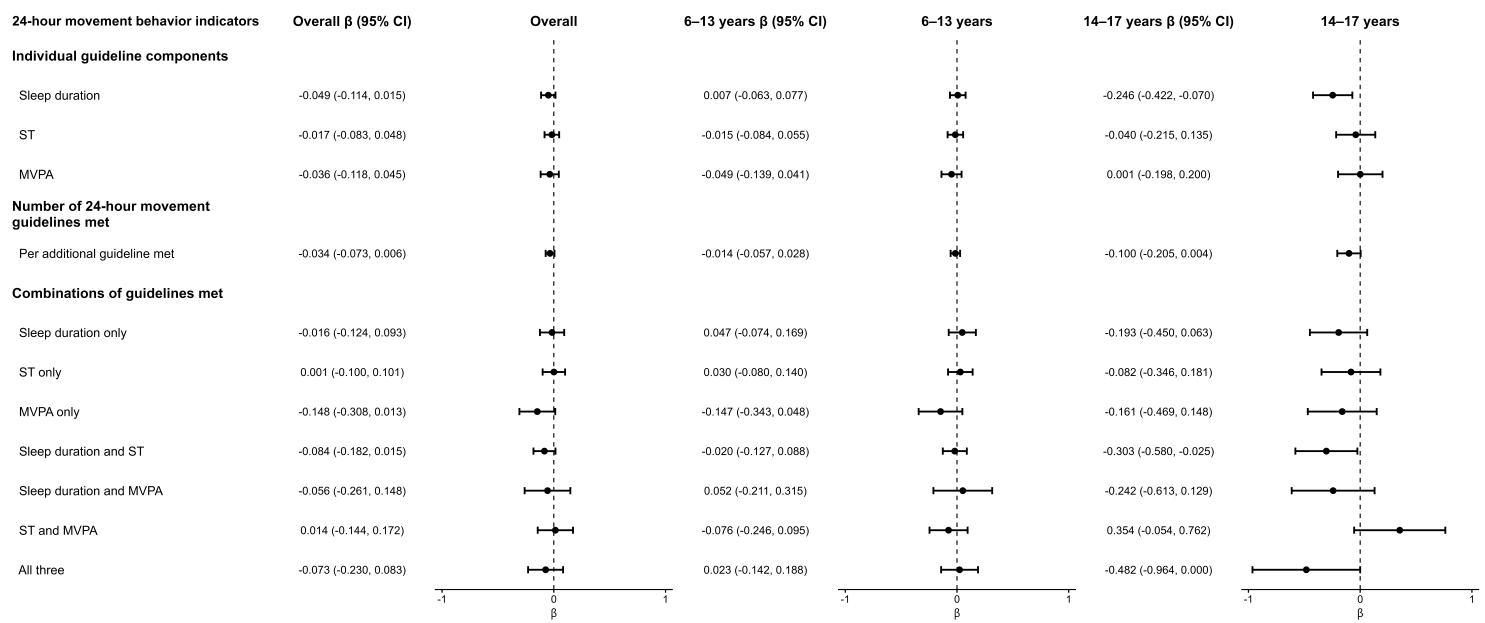


Figure 2

Overall and age-stratified associations between 24-hour movement guideline adherence and axial length. Models were adjusted for age, sex, body mass index (BMI), parental myopia, parental education, and

sugar-sweetened beverage intake. ST, recreational screen time; MVPA, moderate-to-vigorous physical activity; β , regression coefficient; CI, confidence interval.

Supplementary Files

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- [TableS1.pdf](#)
- [TableS2.pdf](#)
- [TableS3.pdf](#)
- [Table1.docx](#)
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