Associations between Meeting 24-hour Movement Guidelines and Myopia Among School-aged Children: A cross-sectional study

Mengxian Zhao
Shenzhen University
Yanjie Zhang
Chinese University of Hong Kong
Haowen Wu
Shenzhen University
Fabian Herold
University of Potsdam
Alyx Taylor
AECC University College
Jianyu Chen
Shenzhen University
Meijun Hou
Shenzhen University
Zhihao Zhang
Shenzhen University
Yanping Gao
Shenzhen University
Jing Sun
Griffith University
M. Mahbub Hossain
University of Houston
Arthur F Kramer
Northeastern University
Notger G. Müller
University of Potsdam
Liye Zou (liyezou123@gmail.com)
Shenzhen University

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Abstract

Background

The Canadian 24-hour movement behavior (24-HMB) guidelines recommend an adequate level of physical activity (PA), a limited amount of screen time (ST), and sufficient sleep duration (SLP) to promote the healthy development of children. Although the positive effects of adhering to the 24-HMB guidelines have been established for several health parameters, less is known about how adherence to the 24-HMB guidelines relates myopia risk (i.e., inability to see distant objects properly). This study investigated associations between meeting 24-HMB guidelines and myopia risk in school-aged children.

Method

Using a questionnaire survey, this cross-sectional study was conducted among parents of school-aged children (5–13 years) in China from September 15 to October 15, 2022, with a total of 1,423 respondents with complete data for analysis. Parents reported their child's time spent in moderate-to-vigorous physical activity (MVPA), SLP and ST. Multiple logistic regression analyses were performed to examine the associations between measures of PA, ST, and SLP alone and in combination, and myopia.

Results

A relatively low percentage of the children (4.92%) met all 24-HMB guidelines, while 32.46% had myopia. Girls had a significantly higher risk of myopia compared to boys (OR = 1.3, 1.002 to 1.68, p = 0.049). Children of parents without myopia had a lower risk of myopia (OR = 0.45, 0.34–0.59, p < 0.001). Children who lived in cities (OR = 1.83, 95% CI 1.33 to 2.52, p < 0.001) or towns (OR = 1.60, 1.03 to 2.47, p = 0.04) had a significantly higher risk of myopia compared to those living in villiages. Meeting SLP guidelines (OR = 0.50, 95% CI 0.31 to 0.82, p < 0.01), meeting ST + SLP guidelines (OR = 0.47, 95% CI 0.32–0.69, < 0.001), and meeting all three guidelines were associated with significantly decreased risk of myopia (OR = 0. 40, 95% CI 0.20–0.82, p = 0.01). Meeting more 24-HMB guidelines was associated with reduced risk of myopia.

Conclusions

Adhering to SLP guideline, ST + SLP guideines, and ST + SLP + PA may be a preventive approach to the onset and progression of myopia. Future research investigating dose-response associations, and potential mechanisms, is necessary to achieve a more nuanced understanding of the observed associations.

1. Introduction

Myopia is one of the most common vision disorders [1, 2] with a global prevalence of approximately 23% in 2000. It is forecasted that myopia prevalence will reach about 50% of the world population in 2050 [1], and children are more likely to suffer from myopia [3]. Recent studies have reported a myopia prevalence

of 60% in Asia and 40% in Europe [4]. Statistical data shows that China has the highest myopia rates worldwide among children, with an estimated prevalence of 52.7% in 2020 [5]. Of note, an increasing number of studies have shown that children with myopia had poorer academic performance and poorer quality of life [6, 7]. Moreover, myopia in children is associated with a greater likelihood of myopia in adulthood, and can lead to permanent vision damage [1, 8–10]. Thus, myopia has become a considerable global public health problem [11] requiring special attention from the scientific community to better understand the causes and consequences of this condition.

The etiology of myopia remains debated, but previous studies have shown that genetic factors play an important role in the development of myopia [12–15]. Specifically, parents with myopia reported a greater chance of having a child with myopia than non-myopic parents [16, 17] [18–20]. In addition, an unhealthy lifestyle (e.g., characterized by the excessive use of electronic devices (refering to screening time: ST), insufficient amount of sleep (SLP), and lack of physical activity (PA) may contribute to the onset and progression of myopia [21–27]. First, ST has been assumed to play a central role in the development of myopia [28, 29], with many studies showing a positive association between ST and the occurrence of myopia in adolescents [26, 29–33]. Second, inadequate SLP was associated with a greater odds of reporting visual impairments and myopia progression [34–37]. In particular, going to bed late in school-aged children was observed as a risk factor for myopia development [38]. Third, studies have also shown that beng physically active is beneficial in reducing the incidence of myopia [22, 39]. Furthermore, different kinds of PA (e.g., basketball, volleyball, and badminton) can effectively reduce the risk of developing myopia [40–44]. In this context, the findings of several studies suggest that engagement in outdoor PA can significantly reduce myopic progressions by slowing down the growth of the optic axis [45–50]. Previous studies, as cited above, have investigated the association(s) between isolated or independent lifestyle factors and myopia. To the best of our knowledge, there have been no studies that evaluated the synergistic effects of different movement behaviors and the risk of developing myopia in children. An integrative and holistic approach to deepen understanding of associations between movement behaviors combinations (PA, ST, and SLP) and myopia is necessary so that early interventions can be implemented to effectively reduce myopia development or progression.

Recently, the 24-hour movement behavior guidelines (24-HMB) have drawn increased attention in public health research and practice. 24-HMBs include PA, sedentary behavior [51], and SLP [52, 53]. There is evidence that meeting the recommendations of 24-HMB guidelines has a positive influence on health-related outcomes, including psychosocial health, motor development, cognitive development, and cardiometabolic health of children [54–61]. In general, a higher level of PA, a lower amount of ST, and a sufficient SLP have been shown to be beneficial alone and in combination to promote the healthy development of children [61–63]. However, to the best of our knowledge, the relationship between 24-HMB guideline adherence and myopia in school-aged children has not been examined yet. A better understanding of whether meeting the 24-HMB guidelines is associated with lower myopia rates is crucial to promoting evidence-informed interventions aiming to prevent and control the onset and progression of myopia. Accordingly, we aimed to investigate the associations between meeting 24-HMB guidelines and myopia in school-aged children. Based on the evidence showing that adherence to the 24-HMB is

associated with better overall health, we hypothesized that meeting 24-HMB guidelines would be associated with lower risk of myopia after controlling for demographic, socioeconomic, and other factors.

2. Methods

2.1. Study design and participants

A cross-sectional survey was conducted from September 15 to October 15, 2022 in China. To obtain a representative sample, simple random sampling was employed in which parent(s) of children were randomly selected from a sample pool while 31 provinces were pre-determined. A total of 1,790 parents of school-aged children (5–13 years) agreed to participate in this study and then complete the e-survey. After removing the data of those participants who did not provide complete data, 1,423 participants were included in the final data analysis. This study was approved by the ethical committee of Shenzhen University (PN-2021-014). All legal guardians of the participating children provided written informed consent.

2.2. Measures

All participating parents completed a questionnaire survey that was used to assess age, sex, living location, ST, SLP, PA level, myopia, and family myopia history. Myopia was defined as a spherical equivalent (SE) of − 0.5 diopter (D) or less, and emmetropia was an SE between − 0.50 and 0.50 D. Further classifications included mild, moderate, and high myopia as an SE of − 0.5 to − 3.0 D, − 3.0 to − 6.0 D, and <-6.0 D, respectively [64]. Parent(s) were asked to report their child's latest vision test results conducted by an optometrist. Myopia was assessed with the following question:"is your child myopic?" The response categories were "yes" and "no". If they answered "Yes", follow-up questions on refractive range were asked to allow caterogization into pre-myopia and low-myopia according to the China CDC.

The 24-HMBs include three components - PA, ST, and SLP- that were assessed using specific questions as described below. Parent(s) of participating children was asked to answer three different questions. The first question was "Over the past 7 days, how many days did your child engage in at least 60-min moderate-to-vigorous PA (MVPA referring to sweating slightly and breathing faster with difficulty in talking to others - including physical education lessons, sports training, brisk walking, hiking)", with response options from 1 day to 7 days. Second, ST was measured with the question, "On most weekdays, how much time did your child spend in front of a TV, computer, cell phone, or other electronic device watching programs, playing games, accessing the internet, or using social media? (do not include time spent doing schoolwork.)", with response options 1 = less than 1 h, 2 = 1 h, 3 = 2 h, 4 = 3 h, and 5 = 4 h or more. SLP was quantified with the question, "During the past week, how many hours of sleep did your child get on most weeknights?", with response options 1 = less than 6 hours, 2 = 6 hours, 3 = 7 hours, 4 = 8 hours, 5 = 9 hours, 6 = 10 hours, and 7 = 11 hours or more. For children aged 5 to 13 years, responses 5 to 7 (9 h or above) were considered to meet the guideline. The participants who met or did not meet the 24-HMB guidelines were coded as 1 or 0, respectively [65]. Adherence to 24-HMB guidelines (≥ 60 min/day MVPA, ≤ 120 min/day ST and 9–11 h SLP per day) were handled in terms of continuous (0 vs. 1 vs. 2 vs.

3) and categorical variables (the combinations of guidelines met). More specifically, the results of 24-HMB guidelines as categorical variables were reported as (a) meeting 1 of 3 (PA or ST, or SLP), (b) meeting 2 of 3 (PA + ST or PA + Sleep or ST + Sleep), (c) meeting all guidelines, and (d) not meeting any guidelines.

2.3. Statistical analysis

Descriptive statistics were conducted for all assessed variables. The mean (M) and standard deviation (SD) of all variables were calculated. Differences emerging from age and other demographic variables (e.g., sex, place of residence, family income, only-child, education background, and parents have myopia or not) on outcomes of interest were determined through t-tests and analysis of variance. Partial correlation analyses were used to examine the associations among MVPA and other questions after controlling for the above-presented demographic variables. Multivariable logistic regressions were used to estimate adherence to 24-HMB guidelines and risk of myopia by using odds ratios (OR) with a 95% confidence interval (CI). Multiple logistic regression analyses were performed to examine the association between independent factors (demographic data, PA, ST, and/or SLP) and myopia. All statistical analyses were conducted using the SPSS version 24.0. The significance level was set at 0.05.

3. Results

3.1. Sample Characteristics

A total of 1,423 parents of children aged 5 to 13 years participated. Table 1 presents the descriptive characteristics of our sample. The mean (± SD) age of the children was 8.69 ± 1.86 years, and 62.9% were females. The proportion living in villages, towns, and cities was 39.99%, 10.75%, 49.26%, respectively. Prevalence of myopia was 32.46% (Pre-myopia n = 18 and low-myopia n = 444). The number of children, house income level, highest education level of parents, and parent myopia are presented in Table 1.

The prevalence of meeting the 24-HMB guideline(s) is presented in Table 1. The prevalence of meeting PA, ST, and SLP guidelines was 0.84%, 26.7%, and 11.17%, respectively. In addition, 42.66% met ST + SLP guideline, 1.69% met ST + PA guideline, and 0.49% met SLP + PA guideline. Additionally, 11.52% met none of the 24-HMB guidelines, and only 4.92% met all three 24HMB guidelines.

Table 1
Participants characteristics

(*n* = 1423)	
Characteristics	Value[1]
Age (years)	8.69(1.86)
Sex	
Male	528(37.10)
Female	895(62.90)
House income level	
≤3000	89(6.25)
3001–6000	338(23.75)
6001–10000	477(33.52)
10001–20000	419(29.44)
> 20000	100(7.03)
Highest education level of the parents	
Less than high school	103(7.24)
High school	168(11.81)
College or associated degree	1035 (72.73)
Master degree or higher	117(8.22)
Living	
Village	569(39.99)
Town	153(10.75)
City	701(49.26)
Number of Children in respective households	
1	805(56.57)
2	564(39.63)
≥ 3	54(3.79)
History of myopia in parents	

Note: Values[#] are mean (SD) or n (%).

(*n* = 1423)	
Yes	960 (67.46)
No	463(32.54)
Adherence to the 24-hour movement guidelines	
None	164(11.52)
Screen time	380(26.70)
Sleep	159(11.17)
Physical activity	12(0.84)
Screen time + Sleep	607(42.66)
Screen time + Physical activity	24(1.69)
Sleep + Physical activity	7(0.49)
All	70(4.92)
Myopia	
No	961(67.53)
Yes	462(32.46)
Pre-myopia	18(1.26)
Low-myopia	444(31.20)
Note: Values[#] are mean (SD) or n (%).	

3.2 Associations between meeting 24-HMB guidelines and myopia.

Table 2 shows associations between all covariates, meeting 24-HMB guidelines, and myopia. Participating girls were associated with a significantly higher risk of myopia compared to boys (OR = 1.3, 1.002 to 1.68, $p = 0.049$). children of parents who was not myopic had a lower risk of myopia (OR = 0.45, 0.34–0.59, $p < 0.001$). Concerning living location, children who lived in city (OR = 1.83, 95% CI 1.33 to 2.52, $p < 0.001$) and town (OR = 1.60, 1.03 to 2.47, $p = 0.04$) had a significantly higher risk of myopia compared to those living in villiage.

Results showed that meeting SLP guidelines was associated with a lower risk of myopia (OR = 0.50, 95% CI 0.31 to 0.82, $p < 0.01$), meeting ST + SLP guidelines was associated with a lower risk of myopia (OR = 0.47, 95% CI 0.32–0.69, < 0.001), and meeting all three guidelines is significantly linked to decreased risk of myopia (OR = 0. 40, 95% CI 0.20–0.82, $p = 0.01$. In addition, the number of meeting 24-HMB guideline was negatively associated with reduced risk of myopia as follow (see Table 2).

Table 2
Associations between all covariates, meeting 24-HMB and myopia.

Myopia		
	Odds ratio (95% CI)	*p*
Intercept	0.02(0.01–0.06)	< 0.001
Age		
Sex		
Male (reference)	1 (reference)	
Female	1.30 (1.002–1.68)	0.049
Income		
<3000 (reference)	1 (reference)	
3000–6000	1.28 (0.70–2.35)	0.43
6000–10000	1.54 (0.83–2.87)	0.17
10000–20000	1.59 (0.83–3.02)	0.16
> 20000	1.92 (0.91–4.06)	0.09
Highest education level among reported adults		
Less than high school (reference)	1 (reference)	
High school	1.04 (0.56–1.92)	0.91
College or associated degree	0.91 (0.51–1.59	0.73
Master degree or higher	0.50 (0.24–1.04)	0.07
Living		
Village (reference)	1 (reference)	
Town	1.60 (1.03–2.47)	0.04
City	1.83 (1.33–2.52)	< 0.001
Number of Children		
1 (reference)	1 (reference)	
2	1.00 (0.76–1.31)	0.99
3	1.22 (0.63–2.37)	0.56
Parents' myopia		
Yes (reference)	1 (reference)	

Myopia		
No	0.45(0.34–0.59)	< 0.001
24-HMB guidelines met (categorical)		
None (reference)	1 (reference)	
Screen time only	0.72 (0.48–1.08)	0.11
Sleep only	0.50 (0.31–0.82)	< 0.01
Physical activity only	1.51 (0.44–5.20)	0.51
Screen time + Sleep	0.47 (0.32–0.69)	< 0.001
Screen time + Physical activity	0.41 (0.14–1.16)	0.09
Sleep + Physical activity	0.28 (0.03–2.82)	0.28
All three	0.40 (0.20–0.82)	0.01
General combinations		
None (reference)	1 (reference)	
One	0.66 (0.45–0.97)	0.03
Two	0.46 (0.31–0.68)	< 0.001
Three	0.40 (0.20–0.81)	0.01

4. Discussion

To the best of our knowledge, the current study is the first study investigating the associations between 24-HMB guideline adherence and myopia among 5–13 year-old children. Results suggest that only 4.92% of the children in our sample met all three 24-HMB recommendations, which is comparable to the observations of previous studies [66, 67]. This low prevalence of meeting 24-HMB in Chinese children is a call for further actions for different stakeholders (e.g., policymakers) to design measures to promote adherence to the 24-HMB in order to foster the healthy development of children.

With respect to living location, children who lived in urban areas (city and town) demonstrated higher risk of myopia compared to those living in rural areas. Such findings are in line with previous studies, suggesting that children living in urban areas were more likely to suffer from myopia [68–71]. This finding might be a consequence of urbanization (e.g., increasing burden of education) and modernity (e.g., availability of more digital screens) that limit the opportunities for outdoor activities, especially outdoor PA with distance viewing, and increase the chances for ST-based sedentary behaviors among children in China. Another potential reason for more myopia in urban environments might be the lack of the same opportunity (as in rural areas) to change your focus from near to distant objects. Conversely,

engaging in outdoor PA is likely to be preserved in rural areas where the children have less access to screens, less pollution and more healthy opportunities to play in outdoor spaces. Such behaviors may promote higher amounts of MVPA and lower amount time spent on ST-based sedentary behaviors. Participating girls were associated with a higher risk of myopia compared to boys, which may be attributed to habitual reading in girls. Finally,

children of parents who was not myopic had a lower risk of myopia, which is supported by previous studies indicating the role of genetical factor in the development of myopia (Guggenheim & Williams, 2015; Li et al., 2022; Morgan & Rose, 2005; Wojciechowski, 2011).

Results indicated associations of myopia with meeting 24-HMB guidelines, specifically SLP guideline and ST + SLP guidelines. Such findings are in line with previous studies. For instance, Liu et al. [72] observed that meeting only the SLP was linked myopia in children. Other studies also reported that inadequate SLP was linked to a greater possibility of reporting visual impairments and myopia progression [21, 73–75]. Likewise, children who adhered to SLP + ST guideline were linked to reduced risk of myopia. Taken together, such results on SLP guideline adherence may be explained by circadian rhythm as it plays an essential role in the development of visual health (Stone et al., 2013). The disruption of circadian rhythms due to inadequate SLP and poor sleep quality may interfere with regulatory mechanisms controlling optic axis growth that underlie the emmetropization process, leading to refractive errors (Chakraborty et al., 2018; Morgan et al., 2013; Nickla, 2013). Interestingly, myopia was not associated with ST, but ST + SLP in the present study. Such findings are particially supported by a recent meta-analysis reporting no significant association between myopia and ST among children aged 3–19 years old[26]. Such findings may be due to social expectation bias or recall bias. Thus, more high-quality studies should be further conducted on this topic. Finally, the number of meeting 24-HMB guidelines were negatively associated with reduced risk of myopia. Taken together, action should be taken to encourage school-aged children to meet a maximum of guideline, to promote healthy growth and development generally, but also to mitigate the risk of myopia.

Of note, the number of children adhering to PA guideline was only 12, which may not have enough power to generate significant findings in terms of PA alone and its combination (ST + PA and SLP + PA). Another possible explanation on PA guideline alone and its combination may be attributed to PA (indoors vs. outdoors). Previous studies on association between indoor PA and myopia are inconsistent. For example, some studies reported an association between increased level of PA and myopia [76–79], and others did not observe such a link [80, 81]. Conversely, studies investigating outdoor PA and myopia provide more consistent evidence [82, 83]. For instance, results from clinical trials indicated that outdoor PA effectively alleviated myopic progressions by slowing down the growth of the optic axis amd keeping ocular distance muscle strong [45–47]. Additional possible explanation may be attributed to that outdoor PA on myopia effectively elevated blood flow and thickness of the choroid [84]. In particular, when children participated in outdoor PA, they were exposed to strong environmental light, which leads to a constricted pupil size and consequently to an increase in depth of field, a decrease in a blur, or an increased dopamine level to antagonize myopic shift [85].

Strength and limitations of study

The major strength of this study is that we are among the first that utilized the holistic approach to investigate the associations between 24-HMB movement behaviors and myopia risk in school-aged children. From a clinical perspective, strategies are needed to promote and support adherence to the 24-HMB guidelines, particularly the ST + SLP guideline and all three guidelines, given their potential importance to reducing the myopia risk in Chinese children being shown by the data of our study. However, as our cross-sectional study does not allow assumptions to be made concerning the causality of the observations, longitudinal studies and intervention trials are needed to investigate whether positively influencing the 24-HMB reduces myopia prevalence among Chinese children. In this context, it seems important, based on the available evidence, to investigate whether the setting of the PA intervention (e.g., indoor vs. outdoor) influences the possible effects. Of note, several limitations should be considered when interpreting the findings of the current study. First, due to the cross-sectional design of this study, we are not able to track the consistency of the different movement behavior and whether they change over time (e.g., due to seasonal rhythms), precluding any causal inferences. Second, we used parental-report questionnaires and thus our data might be influenced by awareness of the child's behaviors, recall and social desirability biases. Third, the small sample size of some groups in the current study may limit the power to detect associations, which is also an important reason why we have conducted a limited number of subgroup analyses. Therefore, future studies may consider using a larger sample size to confirm or rebut our findings.

5. Conclusion

In conclusion, the present study provides some evidence that the risk of myopia in school-aged Chinese children is lower when they met the SLP guideline, SLP + ST, and ST + SLP + PA compared to those children that did not meet any of the 24-HMB guideline. Thus, our study extends the literature related to the 24-HMB framework as it broadens the current knowledge regarding the important role of movement behaviors to promote vision health – namely to lower the risk of myopia among Chinese school-aged children.

Declarations

Ethic approval and consent participants

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Shenzhen University (PN-2021-014). All legal guardians of the participating children provided written informed consent.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

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Interests of conflict

The authors declare that they have no competing interests.

Authors' contributions

Author Contributions: Conceptualization, M. Z and L.Y. Z.; methodology, M. Z and L.Y.Z.; soft-ware, Y.JZ., H.W.W.; validation, L.Y. Z.; formal analysis, Y.J.Z and L.Y.Z; investigation, M.Z., Y.J.Y., L.Y.Z.; resources, M.Z., L.Y.Z; data curation, M.Z., L.Y.Z.; writing—original draft preparation, M.Z., Y.J.Z., L.Y.Z; writing—review and editing, all authors; visualization, all authors.; supervision, L.Y.Z.; project administration, M.Z., L.Y.Z; Funding acquisition. All authors have read and agreed to the published version of the manuscript

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References

1. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, Wong TY, Naduvilath TJ, Resnikoff S: **Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050**. *Ophthalmology* 2016, **123**(5):1036-1042.
2. Leo S-W, Young TL: **An evidence-based update on myopia and interventions to retard its progression**. *Journal of American Association for Pediatric Ophthalmology and Strabismus* 2011, **15**(2):181-189.
3. Liu L, Jiang D, Li C, Lin Y, Zhou W, Xiao H, Chen Y: **Relationship between myopia progression and school entrance age: a 2.5-year longitudinal study**. *Journal of ophthalmology* 2021, **2021**.
4. Grzybowski A, Kanclerz P, Tsubota K, Lanca C, Saw S-M: **A review on the epidemiology of myopia in school children worldwide**. *BMC Ophthalmology* 2020, **20**(1):27.
5. NHC: 2021.
6. Wang S, Hao X, Ma X, Yu Y, Wu L, Wang Y, Li Y: **Associations between poor vision, vision-related behaviors and mathematics achievement in chinese students from the cnaeq-peh 2015**. *International*

Journal of Environmental Research and Public Health 2020, **17**(22):8561.

7. Rose K, Harper R, Tromans C, Waterman C, Goldberg D, Haggerty C, Tullo A: **Quality of life in myopia**. *British journal of ophthalmology* 2000, **84**(9):1031-1034.
8. Wong Y-L, Saw S-M: **Epidemiology of Pathologic Myopia in Asia and Worldwide**. *The Asia-Pacific Journal of Ophthalmology* 2016, **5**(6).
9. Morgan IG, He M, Rose KA: **EPIDEMIC OF PATHOLOGIC MYOPIA: What Can Laboratory Studies and Epidemiology Tell Us?** *RETINA* 2017, **37**(5).
10. Chen M, Wu A, Zhang L, Wang W, Chen X, Yu X, Wang K: **The increasing prevalence of myopia and high myopia among high school students in Fenghua city, eastern China: a 15-year population-based survey**. *BMC Ophthalmology* 2018, **18**(1):159.
11. WHO: 2015.
12. Guggenheim JA, Williams C: **Role of educational exposure in the association between myopia and birth order**. *JAMA ophthalmology* 2015, **133**(12):1408-1414.
13. Wojciechowski R: **Nature and nurture: the complex genetics of myopia and refractive error**. *Clinical genetics* 2011, **79**(4):301-320.
14. Morgan I, Rose K: **How genetic is school myopia?** *Progress in retinal and eye research* 2005, **24**(1):1-38.
15. Li S-M, Ren M-Y, Gan J, Zhang S-G, Kang M-T, Li H, Atchison DA, Rozema J, Grzybowski A, Wang N: **Machine learning to determine risk factors for myopia progression in primary school children: the anyang childhood eye study**. *Ophthalmology and Therapy* 2022, **11**(2):573-585.
16. Zhang X, Qu X, Zhou X: **Association between parental myopia and the risk of myopia in a child**. *Experimental and therapeutic medicine* 2015, **9**(6):2420-2428.
17. Mutti DO, Mitchell GL, Moeschberger ML, Jones LA, Zadnik K: **Parental myopia, near work, school achievement, and children's refractive error**. *Investigative ophthalmology & visual science* 2002, **43**(12):3633-3640.
18. Atowa UC, Wajuihian SO, Munsamy AJ: **Associations between near work, outdoor activity, parental myopia and myopia among school children in Aba, Nigeria**. *International journal of ophthalmology* 2020, **13**(2):309.
19. Kim H, Seo JS, Yoo W-S, Kim G-N, Kim RB, Chae JE, Chung I, Seo S-W, Kim SJ: **Factors associated with myopia in Korean children: Korea National Health and nutrition examination survey 2016–2017 (KNHANES VII)**. *BMC ophthalmology* 2020, **20**:1-7.
20. McCrann S, Flitcroft I, Lalor K, Butler J, Bush A, Loughman J: **Parental attitudes to myopia: a key agent of change for myopia control?** *Ophthalmic and Physiological Optics* 2018, **38**(3):298-308.
21. Wei S-F, Li S-M, Liu L, Li H, Kang M-T, Sun Y-Y, Wang Y-P, Yang X-Y, Wang N: **Sleep duration, bedtime, and myopia progression in a 4-year follow-up of Chinese children: the Anyang Childhood Eye Study**. *Investigative Ophthalmology & Visual Science* 2020, **61**(3):37-37.

22. Suhr Thykjaer A, Lundberg K, Grauslund J: **Physical activity in relation to development and progression of myopia–a systematic review**. *Acta Ophthalmologica* 2017, **95**(7):651-659.
23. Rose KA, Morgan IG, Ip J, Kifley A, Huynh S, Smith W, Mitchell P: **Outdoor activity reduces the prevalence of myopia in children**. *Ophthalmology* 2008, **115**(8):1279-1285.
24. Recko M, Stahl ED: **Childhood myopia: epidemiology, risk factors, and prevention**. *Missouri medicine* 2015, **112**(2):116.
25. Liu S-a, Chen S-T, Stubbs B, Yu Q, Griffiths M, Jiao C, Chen A-g, Hossain MM, Demetrovics Z, Yeung AS: **Association between active school travel and depressive symptoms among 51,702 adolescents in 26 low-and middle-income countries**. 2020.
26. Lanca C, Saw SM: **The association between digital screen time and myopia: A systematic review**. *Ophthalmic and Physiological Optics* 2020, **40**(2):216-229.
27. Flitcroft D: **The complex interactions of retinal, optical and environmental factors in myopia aetiology**. *Progress in retinal and eye research* 2012, **31**(6):622-660.
28. Dirani M, Salim A, Keel S, Crowston JG, Wong TY: **A Multi-Country Study of Myopia in Children: Digital Data Capture Using an Innovative Application-plano**. *Investigative Ophthalmology & Visual Science* 2019, **60**(9):6451-6451.
29. Foreman J, Salim AT, Praveen A, Fonseka D, Ting DSW, He MG, Bourne RR, Crowston J, Wong TY, Dirani M: **Association between digital smart device use and myopia: a systematic review and meta-analysis**. *The Lancet Digital Health* 2021, **3**(12):e806-e818.
30. Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Gupta V, Menon V: **Incidence and progression of myopia and associated factors in urban school children in Delhi: The North India Myopia Study (NIM Study)**. *PloS one* 2017, **12**(12):e0189774.
31. Guan H, Yu NN, Wang H, Boswell M, Shi Y, Rozelle S, Congdon N: **Impact of various types of near work and time spent outdoors at different times of day on visual acuity and refractive error among Chinese school-going children**. *PloS one* 2019, **14**(4):e0215827.
32. Enthoven CA, Tideman JWL, Polling JR, Yang-Huang J, Raat H, Klaver CC: **The impact of computer use on myopia development in childhood: The Generation R study**. *Preventive medicine* 2020, **132**:105988.
33. Wong K, Dahlmann-Noor A: **Myopia and its progression in children in London, UK: a retrospective evaluation**. *JournAL of optometry* 2020, **13**(3):146-154.
34. Wei S, Li S-M, An W, Du J, Liang X, Sun Y, Zhang D, Tian J, Wang N: **Safety and efficacy of low-dose atropine eyedrops for the treatment of myopia progression in Chinese children: a randomized clinical trial**. *JAMA ophthalmology* 2020, **138**(11):1178-1184.
35. Huang L, Chen X, Lin J, Fan X, Chen T, Yu Y, Chen J, Hu J: **Association between sleep duration and myopia among Chinese children during the COVID-19 pandemic: A cross-sectional study**. *Frontiers in public health* 2022, **10**.
36. Lin S, Gong Q, Wang J, Gao H, Hong J, Guo Y, Zhang Y, Jiang D: **The association between sleep duration and risk of myopia in Chinese school-aged children: a cross-sectional study**. *Sleep and*

Breathing 2023:1-7.

37. Chakraborty R, Micic G, Thorley L, Nissen TR, Lovato N, Collins MJ, Lack LC: **Myopia, or near-sightedness, is associated with delayed melatonin circadian timing and lower melatonin output in young adult humans**. *Sleep* 2021, **44**(3):zsaa208.
38. Liu XN, Naduvilath TJ, Wang J, Xiong S, He X, Xu X, Sankaridurg PR: **Sleeping late is a risk factor for myopia development amongst school-aged children in China**. *Scientific reports* 2020, **10**(1):1-11.
39. O'Donoghue L, Kapetanankis VV, McClelland JF, Logan NS, Owen CG, Saunders KJ, Rudnicka AR: **Risk factors for childhood myopia: findings from the NICER study**. *Investigative ophthalmology & visual science* 2015, **56**(3):1524-1530.
40. Dhakal R, Vupparaboina KK, Verkicharla PK: **Anterior sclera undergoes thinning with increasing degree of myopia**. *Investigative Ophthalmology & Visual Science* 2020, **61**(4):6-6.
41. Dhakal R, Shah R, Huntjens B, Verkicharla PK, Lawrenson JG: **Time spent outdoors as an intervention for myopia prevention and control in children: an overview of systematic reviews**. *Ophthalmic and Physiological Optics* 2022, **42**(3):545-558.
42. Eppenberger LS, Sturm V: **The role of time exposed to outdoor light for myopia prevalence and progression: a literature review**. *Clinical Ophthalmology* 2020:1875-1890.
43. Yin Y, Qiu C, Qi Y: **Myopia in Chinese Adolescents: Its Influencing Factors and Correlation with Physical Activities**. *Computational and Mathematical Methods in Medicine* 2022, **2022**.
44. Qu Y, Yu J, Xia W, Cai H: **Correlation of myopia with physical exercise and sleep habits among suburban adolescents**. *Journal of ophthalmology* 2020, **2020**.
45. Cao K, Wan Y, Yusufu M, Wang N: **Significance of outdoor time for myopia prevention: a systematic review and meta-analysis based on randomized controlled trials**. *Ophthalmic research* 2020, **63**(2):97-105.
46. Xiong S, Sankaridurg P, Naduvilath T, Zang J, Zou H, Zhu J, Lv M, He X, Xu X: **Time spent in outdoor activities in relation to myopia prevention and control: a meta-analysis and systematic review**. *Acta ophthalmologica* 2017, **95**(6):551-566.
47. Sherwin JC, Reacher MH, Keogh RH, Khawaja AP, Mackey DA, Foster PJ: **The association between time spent outdoors and myopia in children and adolescents: a systematic review and meta-analysis**. *Ophthalmology* 2012, **119**(10):2141-2151.
48. Wu P-C, Tsai C-L, Wu H-L, Yang Y-H, Kuo H-K: **Outdoor activity during class recess reduces myopia onset and progression in school children**. *Ophthalmology* 2013, **120**(5):1080-1085.
49. Dirani M, Tong L, Gazzard G, Zhang X, Chia A, Young TL, Rose KA, Mitchell P, Saw S-M: **Outdoor activity and myopia in Singapore teenage children**. *British Journal of Ophthalmology* 2009, **93**(8):997-1000.
50. Ngo CS, Pan CW, Finkelstein EA, Lee CF, Wong IB, Ong J, Ang M, Wong TY, Saw SM: **A cluster randomised controlled trial evaluating an incentive-based outdoor physical activity programme to increase outdoor time and prevent myopia in children**. *Ophthalmic and Physiological Optics* 2014, **34**(3):362-368.

51. Tremblay MS, Rollo S, Saunders TJ: **Sedentary Behavior Research Network members support new Canadian 24-Hour Movement Guideline recommendations**. *J Sport Health Sci* 2020, **9**(6):479-481.
52. Sampasa-Kanyinga H, Colman I, Goldfield GS, Janssen I, Wang J, Podinic I, Tremblay MS, Saunders TJ, Sampson M, Chaput J-P: **Combinations of physical activity, sedentary time, and sleep duration and their associations with depressive symptoms and other mental health problems in children and adolescents: a systematic review**. *International Journal of Behavioral Nutrition and Physical Activity* 2020, **17**(1):72.
53. Chen: **Common Psychological Problems and Counseling Countermeasures of Children in Single-parent Families**. *Science Education Journal* 2021(10):165-167+174.
54. Zeng X, Li H, Jiang W, Li Q, Xi Y, Wang X, Li J: **Phytochemical compositions, health-promoting properties and food applications of crabapples: A review**. *Food Chemistry* 2022:132789.
55. Chaput J-P, Gray CE, Poitras VJ, Carson V, Gruber R, Birken CS, MacLean JE, Aubert S, Sampson M, Tremblay MS: **Systematic review of the relationships between sleep duration and health indicators in the early years (0–4 years)**. *BMC public health* 2017, **17**:91-107.
56. Hugues N, Pin-Barre C, Pellegrino C, Rivera C, Berton E, Laurin J: **Time-dependent cortical plasticity during moderate-intensity continuous training versus high-intensity interval training in rats**. *Cerebral Cortex* 2022, **32**(17):3829-3847.
57. Timmons BW, LeBlanc AG, Carson V, Connor Gorber S, Dillman C, Janssen I, Kho ME, Spence JC, Stearns JA, Tremblay MS: **Systematic review of physical activity and health in the early years (aged 0–4 years)**. *Applied Physiology, Nutrition, and Metabolism* 2012, **37**(4):773-792.
58. Sampasa-Kanyinga H, Lien A, Hamilton HA, Chaput J-P: **The Canadian 24-hour movement guidelines and self-rated physical and mental health among adolescents**. *Canadian Journal of Public Health* 2022:1-10.
59. Kong C, Chen A, Ludyga S, Herold F, Healy S, Zhao M, Taylor A, Müller NG, Kramer AF, Chen S: **Associations between meeting 24-hour movement guidelines and quality of life among children and adolescents with autism spectrum disorder**. *Journal of sport and Health Science* 2023, **12**(1):73-86.
60. Feng J, Zheng C, Sit CH-P, Reilly JJ, Huang WY: **Associations between meeting 24-hour movement guidelines and health in the early years: a systematic review and meta-analysis**. *Journal of Sports Sciences* 2021, **39**(22):2545-2557.
61. Rollo S, Antsygina O, Tremblay MS: **The whole day matters: understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan**. *Journal of Sport and Health Science* 2020, **9**(6):493-510.
62. Kuzik N, Poitras VJ, Tremblay MS, Lee E-Y, Hunter S, Carson V: **Systematic review of the relationships between combinations of movement behaviours and health indicators in the early years (0-4 years)**. *BMC public health* 2017, **17**(5):109-122.
63. Bang F, Roberts KC, Chaput J-P, Goldfield GS, Prince SA: **Physical activity, screen time and sleep duration: Combined associations with psychosocial health among Canadian children and youth**. *Health Rep* 2020, **31**(5):9-16.

64. Foo LL, Lim GYS, Lanca C, Wong CW, Hoang QV, Zhang XJ, Yam JC, Schmetterer L, Chia A, Wong TY: **Deep learning system to predict the 5-year risk of high myopia using fundus imaging in children**. *NPJ Digital Medicine* 2023, **6**(1):10.
65. Kong C, Chen A, Ludyga S, Herold F, Healy S, Zhao M, Taylor A, Müller NG, Kramer AF, Chen S: **Associations between meeting 24-hour movement guidelines and quality of life among children and adolescents with autism spectrum disorder**. *Journal of sport and health science* 2022.
66. Lu S, Cheval B, Yu Q, Hossain MM, Chen S-T, Taylor A, Bao R, Doig S, Li J, Wang T *et al*: **Associations of 24-Hour Movement Behavior with Depressive Symptoms and Anxiety in Children: Cross-Sectional Findings from a Chinese Sample**. *Healthcare* 2021, **9**(11):1532.
67. Chen ST, Guo T, Yu Q, Stubbs B, Clark C, Zhang Z, Zhu M, Hossain MM, Yeung A, Griffiths MD *et al*: **Active school travel is associated with fewer suicide attempts among adolescents from low-and middle-income countries**. *Int J Clin Health Psychol* 2021, **21**(1):100202.
68. French AN, Ashby RS, Morgan IG, Rose KA: **Time outdoors and the prevention of myopia**. *Exp Eye Res* 2013, **114**:58-68.
69. Zhou H, Bai X: **A Review of the Role of the School Spatial Environment in Promoting the Visual Health of Minors**. *Int J Environ Res Public Health* 2023, **20**(2).
70. He M, Zheng Y, Xiang F: **Prevalence of myopia in urban and rural children in mainland China**. *Optom Vis Sci* 2009, **86**(1):40-44.
71. Wang Y, Liu L, Lu Z, Qu Y, Ren X, Wang J, Lu Y, Liang W, Xin Y, Zhang N *et al*: **Rural-urban differences in prevalence of and risk factors for refractive errors among school children and adolescents aged 6-18 years in Dalian, China**. *Front Public Health* 2022, **10**:917781.
72. Liu XN, Naduvilath TJ, Wang J, Xiong S, He X, Xu X, Sankaridurg PR: **Sleeping late is a risk factor for myopia development amongst school-aged children in China**. *Scientific Reports* 2020, **10**(1):17194.
73. Zhou M, Li D-L, Kai J-Y, Zhang X-F, Pan C-W: **Sleep duration and the risk of major eye disorders: a systematic review and meta-analysis**. *Eye* 2023.
74. Chakraborty R, Micic G, Thorley L, Nissen TR, Lovato N, Collins MJ, Lack LC: **Myopia, or near-sightedness, is associated with delayed melatonin circadian timing and lower melatonin output in young adult humans**. *Sleep* 2020, **44**(3).
75. Liu S, Chen S, Zhu X, Stubbs B, Yu Q, Griffiths M-D, Jiao C, Chen A, Hossain M-M, Demetrovics Z *et al*: **Association between Active School Travel and Depressive Symptoms among 51,702 Adolescents in 26 Low- and Middle-Income Countries**. *International Journal of Mental Health Promotion* 2021, **23**(2):141–153.
76. Rusnak S, Salcman V, Hecova L, Kasl Z: **Myopia progression risk: seasonal and lifestyle variations in axial length growth in Czech children**. *Journal of ophthalmology* 2018, **2018**.
77. Guo Y, Liu L, Lv Y, Tang P, Feng Y, Wu M, Xu L, Jonas JB: **Outdoor jogging and myopia progression in school children from rural Beijing: the Beijing Children Eye Study**. *Translational vision science & technology* 2019, **8**(3):2-2.

78. Hinterlong JE, Holton VL, Chiang C-C, Tsai C-Y, Liou Y-M: **Association of multimedia teaching with myopia: A national study of school children**. *Journal of Advanced Nursing* 2019, **75**(12):3643-3653.
79. Hansen MH, Laigaard PP, Olsen EM, Skovgaard AM, Larsen M, Kessel L, Munch IC: **Low physical activity and higher use of screen devices are associated with myopia at the age of 16-17 years in the CCC2000 Eye Study**. *Acta Ophthalmologica* 2020, **98**(3):315-321.
80. Lundberg K, Suhr Thykjær A, Søgaard Hansen R, Vestergaard AH, Jacobsen N, Goldschmidt E, Lima RA, Peto T, Wedderkopp N, Grauslund J: **Physical activity and myopia in Danish children—The CHAMPS Eye Study**. *Acta Ophthalmologica* 2018, **96**(2):134-141.
81. Battersby K, Koy L, Phillips N, Sim J, Wilk J, Schmid KL: **Analysis of physical activity in emmetropic and myopic university students during semester and holiday periods: a pilot study**. *Clinical and Experimental Optometry* 2015, **98**(6):547-554.
82. Jin J-X, Hua W-J, Jiang X, Wu X-Y, Yang J-W, Gao G-P, Fang Y, Pei C-L, Wang S, Zhang J-Z: **Effect of outdoor activity on myopia onset and progression in school-aged children in northeast China: the Sujiatun Eye Care Study**. *BMC ophthalmology* 2015, **15**:1-11.
83. Gupta S, Joshi A, Saxena H, Chatterjee A: **Outdoor activity and myopia progression in children: A follow-up study using mixed-effects model**. *Indian Journal of Ophthalmology* 2021, **69**(12):3446.
84. Fitzgerald MEC, Wildsoet CF, Reiner A: **Temporal Relationship of Choroidal Blood Flow and Thickness Changes during Recovery from Form Deprivation Myopia in Chicks**. *Experimental Eye Research* 2002, **74**(5):561-570.
85. Norton TT, Siegwart JT: **Light levels, refractive development, and myopia – A speculative review**. *Experimental Eye Research* 2013, **114**:48-57.