Preplanned Studies

Combined Effect of Outdoor Time and Other Modifiable Factors on Myopia Incidence Among Children and Adolescents — 9 PLADs, China, 2020

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Summary

What is already known about this topic?

Myopia has been identified as a significant emerging challenge and policy priority among children and adolescents in China by the Ministry of Education and seven other departments. Limited research has been conducted to investigate the collective impact of outdoor time and other modifiable factors on the incidence of myopia.

What is added by this report?

This study provides support for the protective effect of combining increased outdoor time with other prevention strategies in reducing the incidence of myopia. The results indicate the presence of a dose-response relationship.

What are the implications for public health practice?

To effectively prevent myopia, it is important to implement comprehensive interventions that encompass various aspects such as outdoor time, eye-use habits, eye-use environments, and lifestyle modifications.

Myopia is a global public health concern, affecting approximately 30% of the world's population and is expected to reach 50% by 2050 (*1*). In China, myopia was recognized as a significant health issue by the Lancet Commission in 2021 and identified as a major emerging challenge and policy priority for children and adolescents by the Ministry of Education and seven other departments of the People's Republic of China (*2*–*3*). Increasing outdoor time has been identified as a preventive measure against myopia in children (*4*). However, other modifiable factors, with equivocal to modest evidence of a relationship with myopia, which have not been studied in depth, are worth investigation, given a looming myopia epidemic (*5*). In this study, researchers analyzed follow-up data to examine the combined impact of outdoor time and other modifiable factors on myopia incidence. Its findings revealed a dose-response relationship between these factors and myopia risk. To effectively combat myopia, comprehensive interventions addressing multiple factors are necessary.

Data were collected from a follow-up investigation conducted in China across nine provincial-level administrative divisions (PLADs): namely Guangxi, Chongqing, Gansu, Hunan, Henan, Shanxi, Fujian, Shanghai, and Jiangsu. The investigation took place between September and November of 2020, with baseline information gathered in June of the same year. Supplementary Figure S1 (available at https://weekly.chinacdc.cn/) provides an overview of the sampling and investigation procedures, which have been previously published (*6*). A total of 3,993 children and adolescents in grades 1–6, 7–8, and 10–11 who did not have myopia at baseline were included in the analysis. Students with missing information regarding their parents' myopia status, outdoor time, and more than three other modifiable factors were excluded (Supplementary Figure S2, available at https://weekly.chinacdc.cn/). In this population-based study, myopia was defined as low unaided distance visual acuity (<5.0) and non-cycloplegic spherical equivalent refractive error (spherical equivalent <−0.50 Diopter). Questionnaires were used to measure outdoor time and ten other modifiable factors, including eye-use habits (eye exercises, screen time, lying down while watching/reading, watching a screen in darkness, posture reminding), eye-use environment (desktop brightness on sunny days, light brightness in the evening, seat/desk fitted for height), and lifestyle (sleep duration, sedentary time). Outdoor time and the other modifiable factors were categorized as binary variables (assigned 0 or 1 point according to Table 1). The ten other modifiable factors were then summed up to

TABLE 1. Assignment of modifiable factors.

Variables	Question	Assignment	
		0	1
Outdoor time	What was your daily exposure to sunlight? (Time spent in direct sunlight)	<2 h	≥2 h
Eye-use habits			
Eye exercises	On average, how many times a day do you do eye exercises during school days this semester?	<2 times/day	≥2 times/day
Screen time	In the past 7 days, how much time did you spend watching TV, using computer, mobile phone and tablet every day (including surfing the Internet, watching movies, browsing the web, and playing games)?	≥2 h	<2 h
Lying down while watching/reading	In the past 7 days, have you read a book or watched a video (tablet or phone) lying down?	Often	Occasionally/never
Watching a screen in darkness	In the past 7 days, have you continued to look at your phone or tablet after turning off the lights?	Often	Occasionally/never
Posture reminding	In the past 7 days, have your parents or teachers reminded of your reading and writing posture?	Occasionally/never	Often
Eye-use environment			
Desktop brightness on sunny days	Is your desktop bright enough on a sunny day?	Not very bright	Very bright
Light brightness in the evening	Do you think the lights are bright enough when you study at night?	Not bright enough	Bright enough
Seat/desk fitted for height	Do you think your desk and seat are fitted for your height?	No	Yes
Lifestyle			
Sleeping duration	In the past 7 days, how long did you sleep on average per day?	< 9 h or >11 h for the grade 1–6 children <8 h or >10 h for the grade 7–11 children	≥9 h and ≤11 h for the grade 1–6 children ≥8 h and ≤10 h for the grade 7–11 children
Sedentary time	In the past 7 days, how long have you been sitting on average per school day?	≥5 h	<5 h

create a cumulative effect score (CES) ranging from 0 to 10, using multiple imputations to account for missing information. We performed several regressions according to different cutoff points of CES, assigning the combined effect of outdoor time and modifiable factors based on cutoff points of CES and outdoor time. For example, if the cutoff point was defined as 4, the CES was transformed into a binary variable called "binary cumulative effect score (BCES)," with 1 point for CES≥4 and 0 points for CES<4. Regression analysis was performed six times with cutoff points from 3 to 8. A cutoff point of 3 tested those with CES<3 to those with CES≥3. The more extreme cutoff points (1, 2, 9, and 10) did not provide meaningful information due to the creation of very small comparison groups. A binomial generalized linear mixed model with a log link function was employed to explore the combined effect of outdoor time and modifiable factors on the incidence of myopia. The combined effect was defined as a binary variable, that was "positive" when outdoor time was ≥2 hours daily and BCES was 1 point, and was "negative" when outdoor time was <2 hours daily or BCES was 0 points (Supplementary Figure S3, available at https://weekly.chinacdc.cn/). The regression model adjusted for sex, residence (urban or rural), grade, parents' myopia status (0 or 1 or 2 parents with myopia), and the cluster effect of the PLAD. The same analyses were conducted for the three categories of modifiable factors. All statistical analyses were performed using R (version 4.2.2; R Core Team, 2022, R Foundation for Statistical Computing, Vienna, Austria), with the mice package (version 3.16.0) used for multiple imputation and the lme4 package (version 1.1.34) used for the regression analyses.

No individual modifiable factor, including outdoor time, showed a significant association with incident myopia (Table 2, all $P>0.05$). However, there was a dose-response relationship between the combined effect and outdoor time with respect to myopia risk. As the number of modifiable factors increased, the prevalence ratio (PR) decreased. Furthermore, in the total sample, a statistically significant association between the combined effect and myopia was observed when the combined effect score (CES) reached 7 [PR=0.81, 95% confidence interval (*CI*), 0.67, 0.98].

TABLE 2. Effect of single modifiable factors on myopia incidence.

Variables	Total		1–6 grades		7–11 grades	
	PR (95% *CI*)	*P*	PR (95% *CI*)	*P*	PR (95% *CI*)	*P*
Outdoor time						
0	Ref		Ref		Ref	
1	0.92 (0.78, 1.08)	0.315	0.93 (0.77, 1.12)	0.434	0.90 (0.64, 1.26)	0.530
Eye exercises						
0	Ref		Ref		Ref	
1	0.96 (0.80, 1.14)	0.611	1.00 (0.81, 1.22)	0.974	0.82 (0.57, 1.17)	0.272
Screen time						
0	Ref		Ref		Ref	
1	1.04 (0.84, 1.30)	0.697	0.92 (0.69, 1.23)	0.586	1.19 (0.86, 1.66)	0.297
Lying down watching/reading						
0	Ref		Ref		Ref	
1	0.96 (0.71, 1.30)	0.785	0.76 (0.50, 1.16)	0.205	1.17 (0.76, 1.80)	0.474
Watching screen in darkness						
0	Ref		Ref		Ref	
1	0.98 (0.66, 1.45)	0.911	0.69 (0.37, 1.29)	0.244	1.14 (0.69, 1.87)	0.607
Posture reminding						
0	Ref		Ref		Ref	
1	0.98 (0.83, 1.16)	0.845	0.95 (0.79, 1.14)	0.578	1.11 (0.78, 1.59)	0.558
Desktop brightness in sunny day						
0	Ref		Ref		Ref	
1	0.86 (0.73, 1.01)	0.070	0.91 (0.75, 1.11)	0.359	0.74 (0.55, 1.00)	0.050
Light brightness in the evening						
0	Ref		Ref		Ref	
1	1.15 (0.78, 1.70)	0.484	1.49 (0.85, 2.63)	0.164	0.79 (0.46, 1.34)	0.380
Seat/desk fitted for height						
0	Ref		Ref		Ref	
1	0.82 (0.65, 1.03)	0.092	0.89 (0.65, 1.22)	0.477	0.70 (0.49, 0.99)	0.044
Sleeping duration						
0	Ref		Ref		Ref	
1	0.90 (0.76, 1.07)	0.229	0.89 (0.74, 1.08)	0.227	0.94 (0.64, 1.38)	0.475
Sedentary time						
0	Ref		Ref		Ref	
1	0.93 (0.79, 1.10)	0.403	0.95 (0.79, 1.14)	0.579	0.87 (0.60, 1.26)	0.748

Note: The model adjusted sex, residence (urban or rural), grade, parents' myopia status (0 or 1 or 2 parents with myopia), and the cluster effect of the PLAD.
Abbreviation: PR=prevalence ratio; *CI*=confidence interval; PLAD=provincial-level administrative division.

Similar results were found in children in grades 1–6; the statistically significant association appeared when the CES reached 8 (PR=0.76, 95% *CI*: 0.60, 0.97), and a dose-response relationship existed. However, no statistically significant associations or dose-response relationships were observed in children in grades 7–11 (Figure 1A).

In terms of eye-use habits, a statistically significant association between the combined effect of outdoor time and eye-use habits on myopia was observed when the CES subset (ranging from 0 to 5) reached a score of 5 points. This association was found in both the total sample (PR=0.60, 95% *CI*: 0.40, 0.89) and grade 1–6 children (PR=0.63, 95% *CI*: 0.42, 0.94), but not

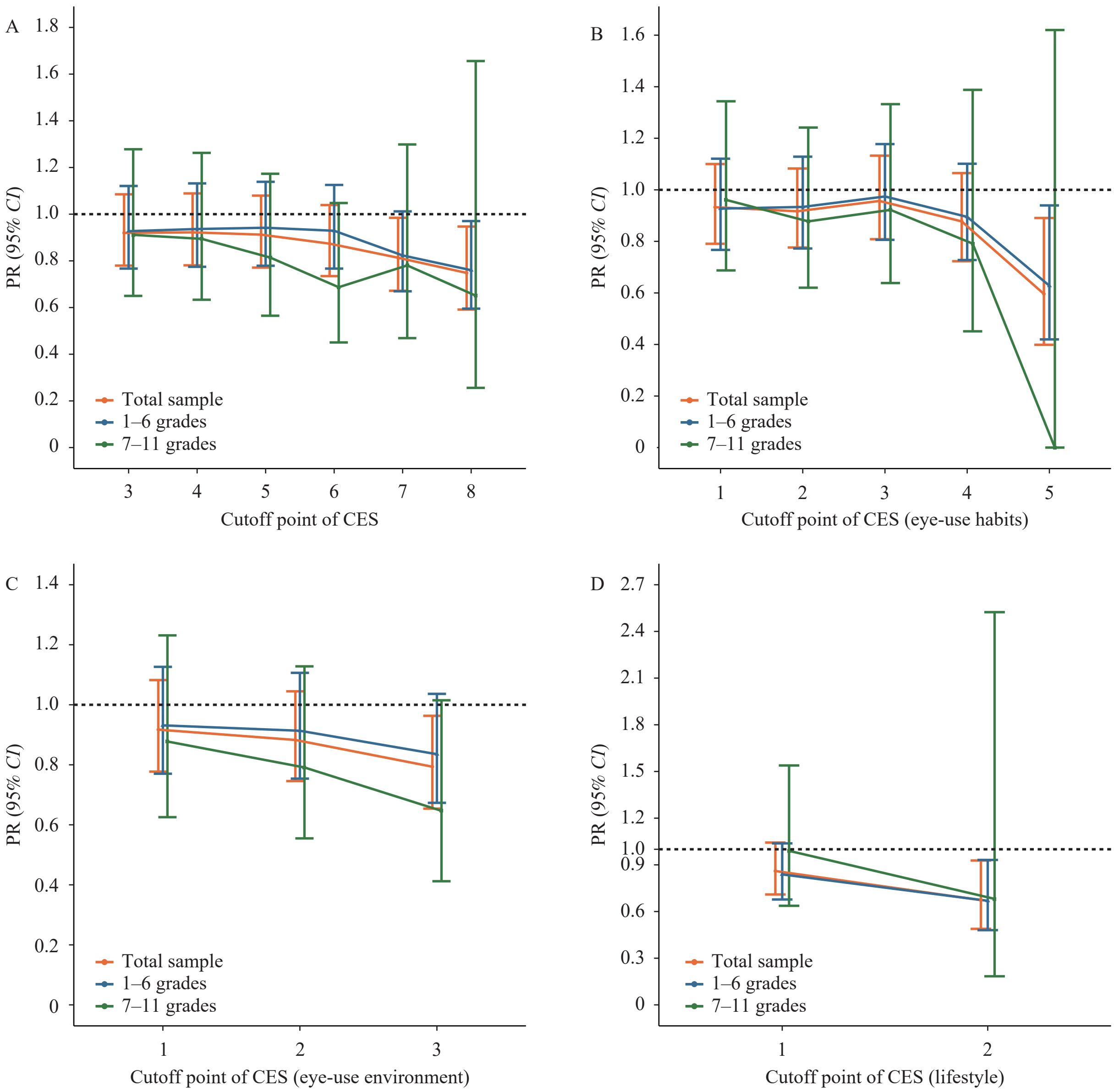

FIGURE 1. The combined effect of outdoor time and other modifiable factors on myopia incidence. (A) The combined effect of outdoor time and ten modifiable factors on myopia incidence; (B) the combined effect of outdoor time and five modifiable factors of eye-use habits on myopia incidence; (C) the combined effect of outdoor time and three modifiable factors of eye-use environment on myopia incidence; (D) the combined effect of outdoor time and two modifiable factors of lifestyle on myopia incidence.

Note: We conducted a binomial generalized linear mixed model with the log link function in every cutoff point of CES, respectively, and every model had a PR of the combined effect of outdoor time and modifiable factors on myopia incidence. The model adjusted sex, residence (urban or rural), grade, parents' myopia status (0 or 1 or 2 parents with myopia), and the cluster effect of the PLAD.

Abbreviation: CES=cumulative effect score; PR=prevalence ratio; *CI*=confidence interval; PLAD=provincial-level administrative division.

in grades 7–11. Regarding the eye-use environment, a statistically significant association was found when the CES subset (ranging from 0 to 4) reached a score of 3 points. However, this association was only observed in the total sample (PR=0.79, 95% *CI*: 0.65, 0.96). For lifestyle factors, a statistically significant association was present when the CES subset (ranging from 0 to 2) reached a score of 1 point. This association was found in both the total sample (PR=0.67, 95% *CI*: 0.49, 0.93) and grade 1–6 children (PR=0.67, 95% *CI*: 0.48, 0.93) (Figure 1B–D).

DISCUSSION

Although no significant individual modifiable factors were found to be associated with myopia, there was a statistically significant combined effect of outdoor time and modifiable factors on the incidence of myopia when the CES reached seven points. This finding supports conclusions about the protective effects of the combination of outdoor time and modifiable factors in preventing myopia. It also confirms that modifiable factors, which have insufficient evidence of a direct association with myopia, do have a protective effect against myopia. These effects may be obscured by their weak individual influences, but when they are cumulated and combined with outdoor time, their protective effects become apparent and can contribute to reversing the myopia epidemic (*6*). These findings align with the 2018 national plan launched by the Ministry of Education and seven other departments of the People's Republic of China, which emphasized the need for comprehensive interventions to protect children from myopia (*3*). Rather than focusing solely on factors with the highest level of evidence, the government should address modifiable factors that have the potential to harm the public. Ignoring these factors could delay the implementation of beneficial policies and perpetuate preventable burdens (*7*).

A similar pattern was observed in children from grades 1–6 but not in children from grades 7–11, potentially due to the weakening effect of educational pressure (*8*–*9*). In China, children from grades 7–9 face the pressure of the national high school entrance exam, while children from grades 10–12 face the pressure of the national college entrance exam. This highlights the need for differentiated recommendations for myopia prevention, taking into account the specific challenges faced by middle school students compared to primary school students.

In this study, researchers aimed to examine the combined effects of outdoor time and various modifiable factors on myopia. The study's findings demonstrate that the combination of modifiable factors and outdoor time significantly influences myopia when an adequate CES is achieved. These modifiable factors encompass three categories: eye-use habits, lifestyle, and eye-use environments. Effective interventions for all these categories should be implemented at multiple levels, including individuals, families, and schools. While the proactive engagement of children is crucial in shaping eye-use habits and lifestyles, the support and guidance from families and schools should not be underestimated. Moreover, creating a vision-friendly environment in schools and at home, such as ensuring bright lighting and appropriately fitted seats and desks, is essential. Children themselves should also be aware of these influential factors and express their needs accordingly. In line with "The appropriate technical guidelines for prevention and control of myopia in children and adolescents (update version)"(*10*), which provides detailed, comprehensive interventions for individuals, families, schools, medical and health institutions, government departments, media, and social groups, this study provides supporting evidence for these guidelines. Furthermore, its findings emphasize the benefits of implementing multiple-level comprehensive interventions, especially among younger children (*10*).

This study had several limitations that need to be acknowledged. First, the definition and measurement of myopia used in this study, although acceptable for population assessment, may not be considered the gold standard for clinical diagnosis. Unfortunately, conducting cycloplegic refraction was not feasible due to the large sample size. Second, the measurement of outdoor time and other modifiable factors relied on questionnaires, which may introduce recall bias and self-reporting bias. Third, the relatively short six-month interval between the two waves of follow-up may have limited the ability to demonstrate the significant protective effect of some modifiable factors, such as outdoor time, which has been confirmed in other studies. Fourth, the small sample size of grade 7–11 children might have influenced the statistical power of the analysis. Lastly, this study's statistical strategy required the dichotomization of each modifiable factor, which reduced the statistical efficiency of the analysis.

Myopia prevention among children and adolescents is a complex undertaking that necessitates comprehensive interventions and collaborative efforts from schools, families, children themselves, governments, and society as a whole.

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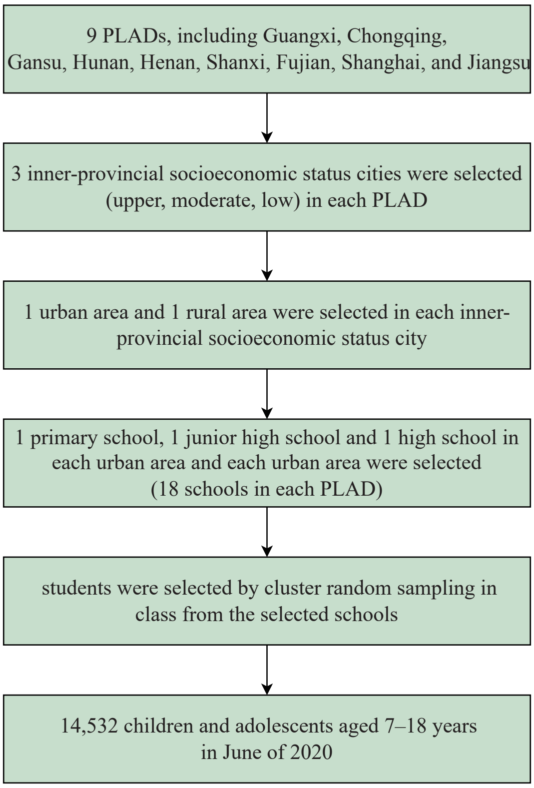
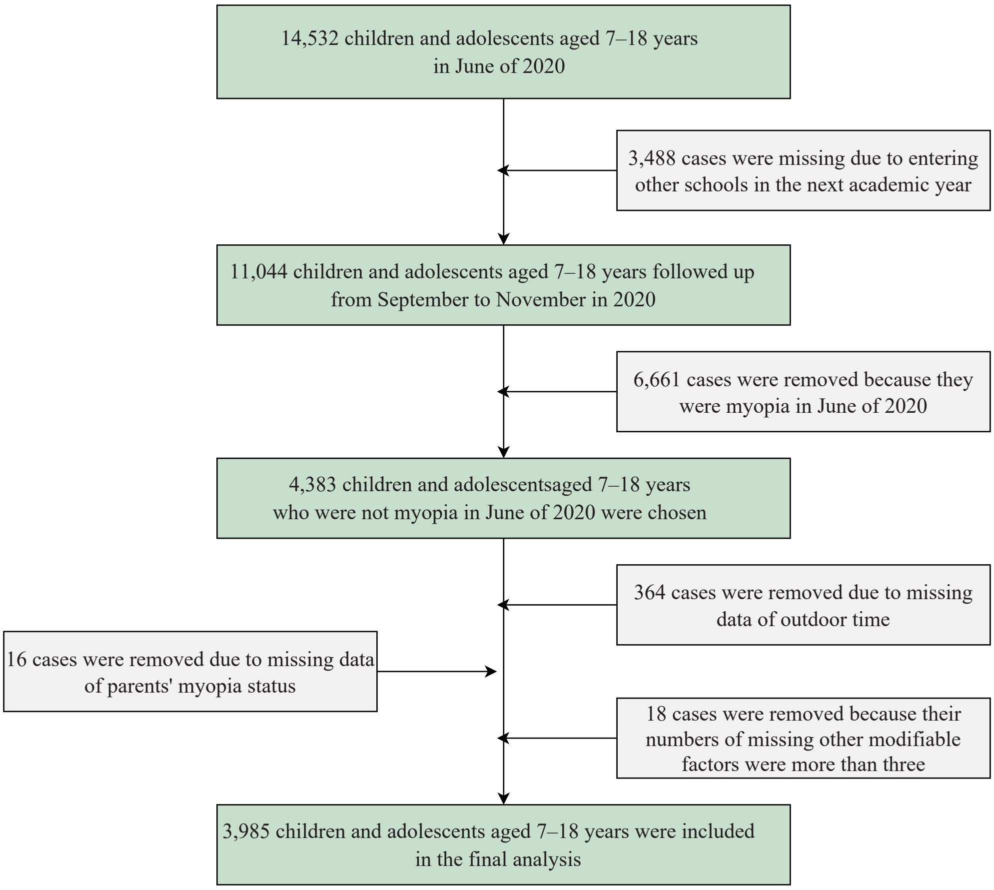
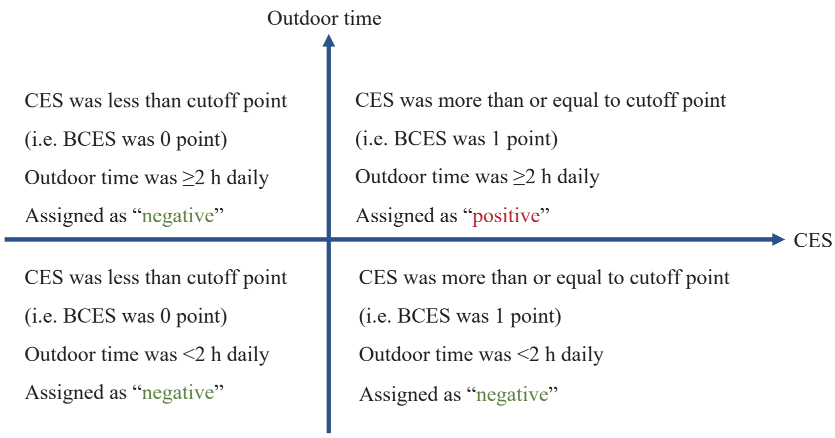


SUPPLEMENTARY FIGURE S1. Sampling frame of the data.
Abbreviation: PLAD=Provincial-level administrative division.



SUPPLEMENTARY FIGURE S2. Data screening flow chart.



SUPPLEMENTARY FIGURE S3. Definition of the combined effect of outdoor time and modifiable factors.
Note: Cutoff points ranged from 3 to 8.
Abbreviation: CES=cumulative effect score; BCES=binary cumulative effect score.