Influence of Lifestyle Patterns On Myopia In Students Aged 9 To 18 In Tianjin, China: A Latent Class Analysis

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Abstract

Purpose: This study aims to determine influence of lifestyle patterns on myopia and spherical equivalent refraction (SE) in school-aged children in Tianjin.

Methods: Students aged 9 to 18 in grade 4 to 12 were recruited. Non-cycloplegic SE was obtained. A self-administration questionnaire was used to collect demographic and lifestyle information.

Results: The overall prevalence of myopia of 8651 students was 81.5% and that of high myopia was 8.88%. Myopia and high myopia rate increased dramatically with grade ($p<0.001$). Students were classified into 3 groups based on latent class analysis (LCA). Students in class 2 had the lowest myopia rate of 74.1% and those in class 1 had the highest rate of 82.8%. Binary logistic regression analysis showed that class 1 and 3 had a higher risk for myopia compared to class 2 (OR= 1.68, $p<0.001$; OR= 1.46, $p=0.004$). The risk for high myopia of Class 1 and 3 were also higher compared to that of class2 (OR= 2.41, $p<0.001$; OR= 2.13, $p=0.006$). General linear model showed that SE of students in class 1 and 3 was lower than that of students in class 2 ($\beta=-0.82$, $p<0.001$; $\beta=-0.68$, $p<0.001$).

Conclusion: Lifestyle is associated with myopia and SE value.

Introduction

Myopia is the most common refractive error among children and young adults. In recent decades, it has gradually become a serious public health problem particularly in urban areas of East Asia, in which myopia accounts for the largest proportion of ametropia[1]. A recent meta-analysis shows that the prevalence of myopia among children and adolescents aged 3-19 years in China is 37.7%, and it is expected to reach 84% by 2050[2]. Besides the rapidly increasing prevalence, early onset of myopia is another issue as longitudinal study showed that annual incidence of myopia can be as high as 20%-30% among school-aged children[3]. These problems have attracted universal attention to risk factors research for myopia control.

Previous studies have shown that behavioral and environmental factors play a major role in myopia. Evidence showed that too short working distances and long-time near-work activity are risk factors for myopia onset and progression[4]. Electronic screen use such as smart device screen time and computer use were also significantly associated with myopia[5]. Randomized controlled trials showed that outdoor time can reduce the risk of myopia by slowing down the change of axial length, which means it maybe a protective factor against myopia[6]. Evidence also showed that unhealthy diet increased probability of myopia development[7]. However, how these factors act together, or how the patterns of risk factors influence myopia is still unknown.

Tianjin locates in northeastern China and is one of the four municipalities. With the developed economy, prevalence of myopia among school aged children in Tianjin is estimated to be 78.2%, which was higher compared with other regions with the rate of 47.7% in Xinjiang Province (in western China)[8], 50.3-58.6% in Wenzhou (in southern China)[9]. To the best of our knowledge few studies detailing the relationship between patterns of lifestyle and myopia in an area with such high myopia prevalence. Therefore, this association needs further investigation.

Latent class analysis (LCA) is a statistical tool to classify the study population with heterogeneity into subgroups with homogeneous factors based on specific characteristics[10]. Lifestyle or behavioral factors are often used as indicators for classification. LCA has been used in several studies to explorer lifestyle factors associated with oral health[11], obesity[12], mental health[13], and other health related outcomes but few with myopia.

This study aims to determine how patterns of risk factors influence myopic status and spherical equivalent refraction in school-aged children in Tianjin, which is a high rate of myopia area. We hoped that our findings will help explain the impacts of patterns of risk on myopia progression and provide evidence for myopia prevention in high myopia prevalence areas.

Results

Participant characteristics

Among 8651 students, 4347(50.3%) were boys. Mean age of all participants was13.6±2.8y while the mean height and weight was 159.0±12.9 cm and54.8±17.0 kg. The number of students in grade 4-6, 7-9 and 10-12 was 3626(41.9%), 2471(28.6%) and 2554(29.5%) respectively. The overall prevalence of myopia was 81.5% and that of high myopia was 8.88%. Myopia and high myopia rate increased dramatically with grade (p<0.001). Students in urban areas had higher myopia rate (78.9% vs. 52.9%, p<0.001) compare with those in rural areas but high myopia rate was not statistically significant between two areas (9.0% vs. 8.7%, p=0.163). Table 1 shows other characteristics of the study population by myopia status. The overall SE was -2.13±2.27D., and SE of grade 4-6, 7-9 and 10-12 was -1.16±1.78D, -2.47±2.21D and -3.18±2.36D respectively, which showed a decrease trend. One-way Anova analysis showed that the mean difference of SE between each two grade group was statistically significant after Bonferroni adjusting for alpha at level of 0.0167.

Univariate analysis of myopia status.

Table 1 showed univariate analysis results of myopia status. Higher myopia prevalence was significantly associated with less outdoor activity (p=0.001), more near work (p<0.001), not having enough sleep (p=0.013), not consuming egg everyday (p=0.041), and taking sugary drink (p<0.001). On the other side, larger high myopia prevalence was significantly associated with less outdoor activity (p<0.001), more near work (p<0.001), more screen use (p=0.008), not having enough sleep (p=0.026), and taking sugary drink (p<0.001).

Table 1 Characteristics of the study population stratified by myopia status (n=8651)

	Non-myopia	Myopia			p_1†	p_2‡
		total	low	high		
Age, y	11.9±2.4	14.0±2.7	13.8±2.7	15.5±2.2	<0.001	<0.001
Sex					<0.001	0.342
Male	925(21.3)	3422(78.7)	3037(69.9)	385(8.9)		
Female	672(15.6)	3632(84.4)	3249(75.5)	383(8.9)		
Height, cm	152.1±13.4	160.5±12.3	159.8±12.4	166.3±9.8	<0.001	<0.001
Weight, kg	48.5±16.2	56.2±16.9	55.4±16.7	63.0±16.3	<0.001	<0.001
BMI, kg/m^2	20.5±4.9	21.5±4.8	21.4±4.8	22.6±4.8	<0.001	<0.001
Grade					<0.001	<0.001
4-6	1155(31.9)	2471(68.2)	2386(65.8)	85(2.3)		
7-9	264(10.7)	2207(89.3)	1963(79.4)	244(9.9)		
10-12	178(7.0)	2376(93.0)	1937(75.8)	439(17.2)		
School location					<0.001	0.163
Urban	888(21.1)	3323(78.9)	2943(69.9)	380(9.0)		
Rural	709(16.0)	3731(52.9)	3343(75.3)	388(8.7)		
Outdoor					0.001	<0.001
>1h/d	777(19.9)	3122(80.1)	2842(72.9)	280(7.2)		
≤1h/d	820(17.3)	3932(82.7)	3444(72.5)	488(10.3)		
Near work					<0.001	<0.001
≤2h/d	928(21.9)	3309(78.1)	3012(71.1)	297(7.0)		
>2h/d	669(15.2)	3745(84.8)	3274(74.2)	471(10.7)		
Screen use					0.179	0.008
≤0.5h/d	584(19.2)	2454(80.8)	2220(73.1)	234(7.7)		
>0.5h/d	1013(18.1)	4600(82.0)	4066(72.4)	534(9.5)		
Sleep					0.013	0.026
Enough	932(19.4)	3876(80.6)	3483(72.4)	393(8.2)		
Not enough	665(17.3)	3178(82.7)	2803(72.9)	375(9.8)		
Breakfast					0.851	0.527
Everyday	452(18.6)	1980(81.4)	1757(72.3)	223(9.2)		
Not everyday	1145(18.4)	5074(81.6)	4529(72.8)	545(8.8)		
Egg					0.041	0.742

Everyday	1192(18.0)	5434(82.0)	4846(73.1)	588(8.9)		
Not everyday	405(20.0)	1620(80.0)	1440(71.1)	180(8.9)		
Milk					0.421	0.148
Everyday	1077(18.7)	4683(81.3)	4191(72.8)	492(8.5)		
Not everyday	520(18.0)	2371(82.0)	2095(72.5)	276(9.6)		
Sugary drink					<0.001	<0.001
No	506(22.8)	1711(77.2)	1564(70.6)	147(6.6)		
Yes	1091(17.0)	5343(83.0)	4722(73.4)	621(9.7)		
Latent class					<0.001	<0.001
Class 1	929(17.3)	4456(82.8)	3942(73.2)	514(9.6)		
Class 2	148(25.9)	423(74.1)	299(69.9)	24(4.20)		
Class 3	520(19.3)	2175(80.7)	1945(72.2)	230(8.5)		

†p_1: p value for non-myopia and myopia;

‡ p_1: p value for non-high myopia and high myopia.

BMI= body mass index.

Univariate analysis of SE

General linear model analysis showed that less outdoor activity ($p<0.001$), more near work ($p<0.001$), more screen use ($p<0.001$), and taking sugary drink ($p<0.001$) had inverse effect on SE. After adjust for cofactors, only the relationship between more near work and SE was statistically significant ($p<0.001$)(Table 2).

Table 2 Univariate analysis of factors associated with SE

	Unadjusted			Adjusted†		
	β	95%CI	*p*	β	95%CI	*p*
Outdoor						
>1h/d	Ref.	-	-	Ref.	-	-
≤1h/d	-0.26	(-0.36, -0.17)	<0.001	-0.02	(-0.11, 0.07)	0.711
Near work						
≤2h/d	Ref.	-	-	Ref.	-	-
>2h/d	-0.58	(-0.68, -0.49)	<0.001	-0.20	(-0.29, -0.11)	<0.001
Screen use						
≤0.5h/d	Ref.	-	-	Ref.	-	-
>0.5h/d	-0.19	(-0.29, -0.09)	<0.001	-0.01	(-0.11, 0.08)	0.794
Sleep						
Enough	Ref.	-	-	Ref.	-	-
Not enough	-0.10	(-0.19, 0.00)	0.05	0.01	(-0.08, 0.10)	0.809
Breakfast						
Everyday	Ref.	-	-	Ref.	-	-
Not everyday	-0.07	(-0.17, 0.04)	0.228	0.07	(-0.03, 0.17)	0.153
Egg						
Everyday	Ref.	-	-	Ref.	-	-
Not everyday	0.00	(-0.12, 0.11)	0.968	0.08	(-0.02, 0.19)	0.130
Milk						
Everyday	Ref.	-	-	Ref.	-	-
Not everyday	0.00	(-0.10, 0.10)	0.965	0.08	(-0.02, 0.17)	0.110
Sugary drink						
No	Ref.	-	-	Ref.	-	-
Yes	-0.39	(-0.50, -0.28)	<0.001	-0.05	(-0.16, 0.04)	0.264

†Adjusted for age, gender, school location and BMI.

Latent Class Analysis

In order to obtain optimal number of student clusters, we tested different numbers of latent class from 1 to 10 in model analysis. The BIC and aBIC was minimum when number of clusters was 5 and 6 respectively. However, the entropy decreased dramatically when number of latent class increased to 4. Meanwhile, Vuong-Lo-Mendell-Rubin (LMR) likelihood ratio test showed that difference between 3 and 4 classes was not significantly different (Table 3), which indicating that classifying participants into 3 clusters could have better performance. Consequently, three-latent-class model was selected as the final model for further analysis (Figure 1).

Table 3 Latent class analysis of lifestyle in students aged 9 to 18 (n=8651)

Class	K	AIC	BIC	aAIC	entropy	LMR	probablity
1	8	87575.99	87632.52	87607.09	-	-	1.00
2	17	84474.61	84594.72	84540.69	0.980	<0.001	0.06/0.94
3	26	82881.62	83065.32	82982.69	0.712	<0.001	0.07/0.31/0.62
4	35	82776.06	83023.35	82912.13	0.577	0.060	0.06/0.22/0.33/0.39
5	44	82687.61	82998.49	82858.66	0.574	0.013	0.06/0.07/0.18/0.21/0.48
6	53	82625.27	82999.74	82831.31	0.544	0.013	0.06/0.10/0.10/0.14/0.17/0.42
7	62	82613.83	83051.88	82854.86	0.489	0.781	0.04/0.06/0.11/0.13/0.15/0.17/0.34

Latent class 1 was characterized by low egg and milk consumption. Class 2 was characterized by low time outdoor, near work and screen use, not enough sleep, unregular breakfast, low egg and milk and sugary drink consumption. Children in class 3 had regular breakfast and high egg and milk consumption. Class 2 had the lowest myopia rate of 74.1%, and class 1 had the highest rate of 82.8% (Table 1). Difference among three latent classes was statistically significant (p<0.001). High myopia prevalence showed the same trend as myopia prevalence and the deference across three latent classes was statistically significant (p<0.001).

Class 2 was recognized as reference group for following analysis due to its lowest myopia prevalence. Binary logistic regression analysis showed that class 1 and 3 had a higher risk for myopia compared to class 2 (OR= 1.68, p<0.001; OR= 1.46, p=0.004) (Table 1). However, this increased risk was not detected after adjusted for co-factors (p>0.05). The risk for high myopia of Class 1 and 3 was also higher compared to that of class2 (OR= 2.41, p<0.001; OR= 2.13, p=0.006), but this trend was not found after adjusted for co-factors (p>0.05)(Table 4). General linear model showed that SE of students in class 1 and 3 was lower than that of students in class 2 (β=-0.82, p<0.001; β=-0.68, p<0.001), and this statistical difference were also observed after adjusted for co-factors (β=-0.23, p=0.013; β=-0.26, p=0.007) (Table 5).

Table 4 Binary logistic regression of latent classes and myopia (n=8651)

Latent class	For myopia				For high myopia			
	OR (95%CI)	p	aOR† (95%CI)	p	OR (95%CI)	p	aOR† (95%CI)	p
Class 2	Ref.	-	Ref.	-	Ref.	-	Ref.	-
Class 1	1.68 (1.37, 2.05)	<0.001	0.98 (0.79, 1.21)	0.865	2.41 (1.58, 3.66)	<0.001	1.51 (0.98, 2.32)	0.060
Class3	1.46 (1.19, 1.81)	0.004	1.03 (0.82, 1.28)	0.821	2.13 (1.38, 3.27)	0.006	1.52 (0.97, 2.36)	0.065

†Adjusted for age, gender, school location and BMI.

Table 5 General linear model of latent class and SE (n=8651)

Latent Class	Unadjusted			Adjusted†		
	β	95%CI	*p*	β	95%CI	*p*
Class 2	Ref.	-	-	Ref.	-	-
Class 1	-0.82	(-1.02, -0.63)	<0.001	-0.23	(-0.41, -0.05)	0.013
Class 3	-0.68	(-0.89, -0.48)	<0.001	-0.26	(-0.45, -0.07)	0.007

†Adjusted for age, gender, school location and BMI.

Discussion

In this study, the overall prevalence of myopia in children aged 9 to 18 was 81.5%, which was similar to another cross-sectional survey conducted in school-based children in Tianjin.[14] However the prevalence was higher than that of 63.1% in East China[15], 34.3% in Northwest China[16], 55.8% in South China[9], and other countries[17-19]. These results elucidated that there is an urgent need to control the high prevalence of myopia in school-aged students in Tianjin. On the other side, prevalence of high myopia in our study was not notably higher than those reported in other studies[15,20].

In our study population, myopia prevalence increased rapidly from 57.2% in grade 4 to 85.4% in grade 7, slowly increased to 93.6% in grade 10 and then remained in the high level. The prevalence of high myopia increased dramatically from 0.7% in grade 4 to 18.5% in grade 7. Longitudinal study in China showed that the incidence of myopia was approximately 20% to 30% each year, and progression of myopia was found to be as early as grade 1 to 2[3]. The increasing prevalence with age or grade may mainly be due to risk factors change such as education onward and increased academic burden for students instead of age only. Study showed that new high myopia was strongly associated with education-related parameters[21].

Besides, environmental factors were also strong influencing factors for myopia development. Increasing evidence suggests that light intensity is associated with myopia and refractive error change. Li[22] recorded light exposure patterns and self-reported time outdoors and found that more time spent outdoors was associated with lower risk of myopia (OR=0.82, 95% CI=0.70, 0.95, p=0.009). A recent prospective study by Sánchez[23] revealed that children with shorter daylight hours had higher increase in SER over 18 months (p<0.001). Dopamine (DA) pathway is one of the links between light and myopia. After Stone et al first described that reduced DA and its metabolite 3,4-dihydroxyphenylacetic (DOPAC) acid were detected in myopic eyes compared with control eyes[24], extensive studies focused on relationship between dopamine level and eye growth or myopia. In eyes, neurotransmitter DA is released by amacrine cell and plays an important role in the signaling cascade which controls eye growth[25]. The synthesis and excretion of DA in retina is control by both light exposure and retinal circadian clock[26]. Light can rapidly activate amacrine cells and then accelerate the rate of DA formation[27]. Animal experiment results showed that Intravitreal and topical application of DA inhibit the progression of myopia induced by form-deprivation[28,29]. Meanwhile this inhibit effect was also detected by increased light intensity in mice models[30]. These results suggests that exposure to light by spent more time on outdoor activity could protest myopia progress by alter DA levels in retina during eye development. In our study population, students spent more than 1h/d outdoor had lower rate of myopia and high myopia and larger SE value, which was consistent with the hypothesis described above.

Near work over 2h/d was associated with higher prevalence of myopia and lower SE in our study. However, whether near work interacts with myopia and eye development remains in dispute. Results similar to ours were found in some studies[4,31-33] but not in others[34,35]. To date, near work is not strictly defined and thus measures of near viewing behavior were not homogeneous between studies[36]. Near work habit such as continuous reading time, close screen distance, head tilt while writing and reading, desk lighting type, and discontinuing near work period is associated with myopia[33,37]. Near work related parameters act as independent factors or not should be examined.

In the past decades, electronic device is becoming increasingly common in students and the influence of screen watching on visual acuity is investigated. Liu[38] revealed that under the condition of coronavirus (COVID-19) and digital devices became common learning tools, time of television, computer, and mobile phone was positively associated with myopia progression. Yang[39] found same trend among preschool-aged children. Mechanisms beyond screen use and myopia or SE change may be the interaction between focusing errors and lags of accommodation[40-42].

Our results showed that not enough sleep increased risk of myopia, which is consistent with previous studies[43-45]. Axial length (AL) and choroidal thickness had significant diurnal variation[46] which was regulated by melatonin and melanopsin[47]. Melatonin and melanopsin play an important role in circadian rhythm regulation. Chakraborty[48] evaluated sleep time and urinary melatonin level of human participants and found that myopia was associated with delayed sleep onset, shorter sleep duration, and lower urinary melatonin level, suggesting that abnormal circadian rhythms may be a risk factor of myopia.

Currently, results of influence of diet on myopia are inconsistent in database. We only detected association between myopia and sugary drink but not breakfast and milk. Berticcat[7] reported increased probability of myopia for girls with elevated consumption of refined carbohydrates in France children. However, no evidence of carbohydrate intakes and SE was discovered in Singapore children by Chua[49]. Meanwhile the lack of associations between dietary habits and myopia also occurs in several other studies[49,50]. Relationship between dietary intakes and myopia development needs further discussion.

In areas with high prevalence of myopia such as Asian countries, prevention is an urgent task. A variety of studies investigated lifestyle (mainly including outdoor, near work, and screen use)[51-54], but how these factors work together and lead to myopia or promote myopia progression is intricated. Though many efforts have been tried to reduce the incidence of myopia and the effect of myopia prevention was checked[55], most of them implemented only a few intervention measures which may not be suitable for every single person in practice. In addition, how to identify target population with high risk of early-onset myopia is another significant important issue[56] because delivery of accurate early intervention could be twice as effective. One of the aims of this study is to attempt to identify if the risk of myopia or SE value is different among children with different lifestyles. Our results revealed that children having longer near work and screen use and consumed sugary drink had higher risk for myopia and lower SE value compared with others. Thus, students exposed to these risk factors should be paid more attention for myopia prevention. Whether individual combined with universal intervention strategy is better than universal strategy needs more evidence.

The main advantage of our study is that this survey is part of 8th CNSSCH and standard protocol ensured data quality. Meanwhile we try to classify children into subgroups using LCA model according to lifestyle and found that myopia risk was different among groups. A few disadvantages existed. Non-cycloplegic SE was used to evaluate myopia status and may lead to overestimate of myopia[57]. However, in such a large-scale myopia epidemiological survey, non-cycloplegic SE was most frequently used[58-61] concerning of the resistance to cycloplegia and time efficacy[62]. Our study design is cross-sectional research so that causal relationship between lifestyle and myopia cannot be testified.

In conclusion, our findings suggest that prevalence of myopia in children aged 9 to 18 in Tianjin is high. Lifestyle is associated with myopia and SE value. More efforts should be implemented precisely to students with different lifestyle.

Methods

Participants

This study was part of Eighth Chinese National Survey on Students' Constitution and Health (CNSSCH) in 2019. In this research, stratified multi-stage cluster randomization sampling was used. Schools were randomly selected based on economic status of the municipal district. Students from certain classes were treated as clusters and were randomly selected from each grade in the selected schools. Written informed consent was received from all participants either by their parent (in elementary or secondary school, mainly under 15 years old) or by the students their own (in high school, mainly over 15 years old) after fully explain study design. Finally, a sample of 8651 students aged 9 to 18 in grade 4 to 12 in Tianjin were included in data analysis. Study protocol was approved by the Institutional Review Board of Tianjin Medical University (Grant No. TMUhMEC2017020) and adhered to the declare of the Declaration of Helsinki.

Ocular examinations

All students underwent non-cycloplegic autorefraction using an auto-kerato-refractor (Canon Autorefractor RK-F1, Tokyo, Japan). Three consecutive measurements were taken in both eyes by qualified Ophthalmologists with the assistants. Spherical refraction and cylindrical refraction were recorded. Means of the three validated measurements were used in data analysis. All statistical tests were two-sided and significant level α was 0.05.

Anthropometric evaluation

Height (cm) and weight (kg) were obtained following standard protocols in each CNSSCH. Subjects were asked to take off shoes and heavy clothes and stand barefoot on electronic weighing scale and height meter. Weighing scale and height meter were calibrated before everyday measurement with standard calibration tools.

Questionnaire

A questionnaire was developed to analyze myopia-related risk factors according to our previous study and literature reviews. All participants completed the self-administrated questionnaire with the help from their teachers and parents. Main variables included: gender, age, ethic, district, grade, outdoor activity time per day, near work time per day, screen use time per day, sleep time, breakfast practices, and egg, milk, and sugary drink intake.

Statistical analysis

Database were created using EpiData version 3.1. Data analysis was performed using SAS 9.4 for Windows software (SAS INSTITUTE INC,112 USA). Spherical equivalent refraction (SE) was calculated as spherical refraction value plus half of cylindrical value. AS the SE values of both eyes were highly correlated, only the SE of right eye was used for further analysis. Myopia was defined as -6.00 diopters (D)≤SE≤-0.5 D, and high myopia was defined as SE≤-6.00D.

Average hours spent per day of outdoor activity, near work and screen use were calculated with the following formula: [(hours spent on every weekday)×5+(hours spent on every weekend day)×2]/7. Enough sleep was defined as ≥9h/d for students less than or equal to grade 6 or ≥8h/d for students over grade 6. Normal distributed variables were presented as mean ± standard deviation and binary variables were presented as frequency (percentage). T tests and Chi-square tests were used to explore the associations between those risk factors and myopia status for quantitative and qualitive variables, respectively. General linear model was used to determine relationships between risk factors and SE. LCA was used to classify participants into different latent class groups. After that, binary logistic regression and general linear model was used to check the relationship between subgroups and myopia or SE respectively.

Declarations

Data availability statement

The datasets generated and analyzed during this study are not publicly available to protect the privacy of the participants. The data are available from the Department of Maternal, Child and Adolescent Health at the School of Public Health of Tianjin Medical University and can be obtained from the corresponding author (email: zhangxinty06@163.com) upon reasonable request.

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Author contributions

X.Z. conceived the study, participated in its design and wrote the protocol; L.L., S.Y. and W.X. performed the investigations and collected the samples; W.X. and L.G. participated in the design of the study; T.C. and Y.C. performed the investigations, collected the samples, undertook the statistical analysis and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Additional Information

Competing Interests: The authors declare no competing interests.

References

1. Baird, P. N. *et al.* Myopia. Nature reviews. Disease primers **6**, 99, doi:10.1038/s41572-020-00231-4 (2020).
2. Dong, L., Kang, Y. K., Li, Y., Wei, W. B. & Jonas, J. B. PREVALENCE AND TIME TRENDS OF MYOPIA IN CHILDREN AND ADOLESCENTS IN CHINA: A Systemic Review and Meta-Analysis. Retina (Philadelphia, Pa.) **40**, 399–411 (2020).
3. Wang, S. K. *et al.* Incidence of and Factors Associated With Myopia and High Myopia in Chinese Children, Based on Refraction Without Cycloplegia. *JAMA ophthalmology* **136**, 1017-1024,2018.2658 (2018).
4. Atowa, U. C., Wajuihian, S. O. & Munsamy, A. J. Associations between near work, outdoor activity, parental myopia and myopia among school children in Aba, Nigeria. Int J Ophthalmol **13**, 309–316 (2020).
5. Foreman, J. *et al.* Association between digital smart device use and myopia: a systematic review and meta-analysis. The Lancet. Digital health, doi:10.1016/s2589-7500(21)00135-7 (2021).

6. 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 **63**, 97–105 (2020).
7. Berticat, C. *et al.* Probability of myopia in children with high refined carbohydrates consumption in France. BMC Ophthalmol **20**, 337, doi:10.1186/s12886-020-01602-x (2020).
8. Jing, S. *et al.* Prevalence and risk factors for myopia and high myopia: A cross-sectional study among Han and Uyghur students in Xinjiang, China. Ophthalmic & physiological optics **42**, 28–35 (2021).
9. Xu, L. *et al.* Design, methodology, and baseline of whole city-million scale children and adolescents myopia survey (CAMS) in Wenzhou, China. Eye and vision **8**, 31, doi: 10.1186/s40662-021-00255-1 (2021).
10. Liberali, R., Del Castanhel, F., Kupek, E. & Assis, M. A. A. Latent Class Analysis of Lifestyle Risk Factors and Association with Overweight and/or Obesity in Children and Adolescents: Systematic Review. Child Obes **17**, 2–15 (2021).
11. Simancas-Pallares, M. A. *et al.* Children's oral health-related behaviours and early childhood caries: A latent class analysis. Community Dent Oral Epidemiol, doi:10.1111/cdoe.12645 (2021).
12. Anderson, L. N. *et al.* Latent class analysis of obesity-related characteristics and associations with body mass index among young children. Obes Sci Pract **6**, 390–400 (2020).
13. Wadsworth, M. E., Hudziak, J. J., Heath, A. C. & Achenbach, T. M. Latent class analysis of child behavior checklist anxiety/depression in children and adolescents. J Am Acad Child Adolesc Psychiatry **40**, 106–114, doi:10.1097/00004583-200101000-00023 (2001).
14. Wang, J. *et al.* School-based epidemiology study of myopia in Tianjin, China. International ophthalmology **40**, 2213–2222 (2020).
15. Wang, J. *et al.* Prevalence of myopia and vision impairment in school students in Eastern China. BMC Ophthalmol **20**, 2, doi:10.1186/s12886-019-1281-0 (2020).
16. Wang, X. *et al.* Prevalence and risk factors of myopia in Han and Yugur older adults in Gansu, China: a cross-sectional study. Scientific reports **10**, 8249, doi:10.1038/s41598-020-65078-x (2020).
17. Alvarez-Peregrina, C. C., Sanchez-Tena, M., Martinez-Perez, C. C. & Villa-Collar, C. C. Prevalence and Risk Factors of Myopia in Spain. *Journal of ophthalmology* 2019, 3419576, doi:10.1155/2019/3419576 (2019).
18. Nakao, S. Y. *et al.* Myopia Prevalence and Ocular Biometry Features in a General Japanese Population: The Nagahama Study. Ophthalmology **128**, 522–531 (2021).
19. Pärssinen, O. The increased prevalence of myopia in Finland. Acta ophthalmologica **90**, 497–502 (2012).
20. Jing, S. *et al.* Prevalence and risk factors for myopia and high myopia: A cross-sectional study among Han and Uyghur students in Xinjiang, China. Ophthalmic & physiological optics: the journal of the British College of Ophthalmic Opticians (Optometrists) **42**, 28–35 (2022).
21. Jonas, J. B. *et al.* Education-Related Parameters in High Myopia: Adults versus School Children. PLoS One **11**, e0154554, doi:10.1371/journal.pone.0154554 (2016).
22. Li, M. *et al.* Association of time outdoors and patterns of light exposure with myopia in children. Br J Ophthalmol, doi:10.1136/bjophthalmol-2021-318918 (2021).
23. Sánchez-Tocino, H. *et al.* The effect of light and outdoor activity in natural lighting on the progression of myopia in children. J Fr Ophtalmol **42**, 2–10, doi:10.1016/j.jfo.2018.05.008 (2019).
24. Stone, R. A., Lin, T., Laties, A. M. & Iuvone, P. M. Retinal dopamine and form-deprivation myopia. Proc Natl Acad Sci U S A **86**, 704–706 (1989).

25. Feldkaemper, M. & Schaeffel, F. An updated view on the role of dopamine in myopia. Exp Eye Res **114**, 106–119 (2013).
26. Goel, M. & Mangel, S. C. Dopamine-Mediated Circadian and Light/Dark-Adaptive Modulation of Chemical and Electrical Synapses in the Outer Retina. Front Cell Neurosci **15**, 647541, doi:10.3389/fncel.2021.647541 (2021).
27. Iuvone, P. M., Galli, C. L., Garrison-Gund, C. K. & Neff, N. H. Light stimulates tyrosine hydroxylase activity and dopamine synthesis in retinal amacrine neurons. Science **202**, 901–902 (1978).
28. Thomson, K., Karouta, C. & Ashby, R. Topical application of dopaminergic compounds can inhibit deprivation myopia in chicks. Exp Eye Res **200**, 108233, doi:10.1016/j.exer.2020.108233 (2020).
29. Thomson, K., Karouta, C. & Ashby, R. Form-Deprivation and Lens-Induced Myopia Are Similarly Affected by Pharmacological Manipulation of the Dopaminergic System in Chicks. Investigative ophthalmology & visual science **61**, 4, doi:10.1167/iovs.61.12.4 (2020).
30. Karouta, C. & Ashby, R. S. Correlation between light levels and the development of deprivation myopia. Investigative ophthalmology & visual science **56**, 299–309 (2014).
31. Lanca, C. *et al.* Near work, screen time, outdoor time and myopia in schoolchildren in the Sunflower Myopia AEEC Consortium. Acta ophthalmologica, doi:10.1111/aos.14942 (2021).
32. Lin, Z. *et al.* Near work, outdoor activity, and myopia in children in rural China: the Handan offspring myopia study. BMC Ophthalmol **17**, 203, doi:10.1186/s12886-017-0598-9 (2017).
33. Li, S. M. *et al.* Near Work Related Parameters and Myopia in Chinese Children: the Anyang Childhood Eye Study. PLoS One **10**, e0134514, doi:10.1371/journal.pone.0134514 (2015).
34. Choi, K. Y., Mok, A. Y., Do, C. W., Lee, P. H. & Chan, H. H. The diversified defocus profile of the near-work environment and myopia development. Ophthalmic & physiological optics: the journal of the British College of Ophthalmic Opticians (Optometrists) **40**, 463–471, doi:10.1111/opo.12698 (2020).
35. Low, W. *et al.* Family history, near work, outdoor activity, and myopia in Singapore Chinese preschool children. Br J Ophthalmol **94**, 1012–1016 (2010).
36. Gajjar, S. & Ostrin, L. A. A systematic review of near work and myopia: measurement, relationships, mechanisms and clinical corollaries. Acta ophthalmologica, doi:10.1111/aos.15043 (2021).
37. Huang, P. C. *et al.* Protective behaviours of near work and time outdoors in myopia prevalence and progression in myopic children: a 2-year prospective population study. Br J Ophthalmol **104**, 956–961 (2020).
38. Liu, J., Li, B., Sun, Y., Chen, Q. & Dang, J. Adolescent Vision Health During the Outbreak of COVID-19: Association Between Digital Screen Use and Myopia Progression. Front Pediatr **9**, 662984, doi:10.3389/fped.2021.662984 (2021).
39. Yang, G. Y. *et al.* Associations Between Screen Exposure in Early Life and Myopia amongst Chinese Preschoolers. Int J Environ Res Public Health **17**, 1056, doi:10.3390/ijerph17031056 (2020).
40. Bach, A., Villegas, V. M., Gold, A. S., Shi, W. & Murray, T. G. Axial length development in children. Int J Ophthalmol **12**, 815–819 (2019).
41. Berntsen, D. A., Sinnott, L. T., Mutti, D. O. & Zadnik, K. Accommodative lag and juvenile-onset myopia progression in children wearing refractive correction. Vision Res **51**, 1039–1046 (2011).
42. López-Gil, N. *et al.* Retinal image quality during accommodation. Ophthalmic & physiological optics **33**, 497–507 (2013).
43. Qu, Y., Yu, J., Xia, W. & Cai, H. Correlation of Myopia with Physical Exercise and Sleep Habits among Suburban Adolescents. *Journal of ophthalmology* 2020, 2670153, doi:10.1155/2020/2670153 (2020).

44. Zhou, S. *et al.* Association between parents' attitudes and behaviors toward children's visual care and myopia risk in school-aged children. Medicine **96**, e9270, doi:10.1097/md.0000000000009270 (2017).
45. Jee, D., Morgan, I. G. & Kim, E. C. Inverse relationship between sleep duration and myopia. Acta ophthalmologica **94**, e204-210, doi:10.1111/aos.12776 (2016).
46. Chakraborty, R., Read, S. A. & Collins, M. J. Diurnal variations in axial length, choroidal thickness, intraocular pressure, and ocular biometrics. Investigative ophthalmology & visual science **52**, 5121–5129 (2011).
47. Martínez-Águila, A., Martín-Gil, A., Carpena-Torres, C., Pastrana, C. & Carracedo, G. Influence of Circadian Rhythm in the Eye: Significance of Melatonin in Glaucoma. Biomolecules **11**, doi:10.3390/biom11030340 (2021).
48. Chakraborty, R. *et al.* Myopia, or near-sightedness, is associated with delayed melatonin circadian timing and lower melatonin output in young adult humans. Sleep **44**, doi:10.1093/sleep/zsaa208 (2021).
49. Chua, S. Y. *et al.* Diet and risk of myopia in three-year-old Singapore children: the GUSTO cohort. Clin Exp Optom **101**, 692–699 (2018).
50. Li, M. *et al.* Dietary intake and associations with myopia in Singapore children. Ophthalmic & physiological optics, doi:10.1111/opo.12929 (2021).
51. Enthoven, C. A. *et al.* Physical Activity Spaces Not Effective against Socioeconomic Inequalities in Myopia Incidence: The Generation R Study. Optometry and vision science **98**, 1371–1378 (2021).
52. Zhang, X. *et al.* Myopia incidence and lifestyle changes among school children during the COVID-19 pandemic: a population-based prospective study. Br J Ophthalmol, doi:10.1136/bjophthalmol-2021-319307 (2021).
53. Saxena, R., Gupta, V., Prasad, P., Bhardwaj, A. & Vashist, P. Prevalence of myopia and its risk factors in rural school children in North India: the North India myopia rural study (NIM-R Study). Eye (Lond), doi:10.1038/s41433-021-01797-3 (2021).
54. Armarnik, S. *et al.* The relationship between education levels, lifestyle, and religion regarding the prevalence of myopia in Israel. BMC Ophthalmol **21**, 136, doi:10.1186/s12886-021-01891-w (2021).
55. Zhu, Z. *et al.* Interventions recommended for myopia prevention and control among children and adolescents in China: a systematic review. Br J Ophthalmol, doi:10.1136/bjophthalmol-2021-319306 (2021).
56. Chen, Y. X., Liao, C. M., Tan, Z. & He, M. G. Who needs myopia control? Int J Ophthalmol **14**, 1297–1301 (2021).
57. Gu, F. *et al.* Effect of Cycloplegia on Refractive Error Measure in Chinese School Students. Ophthalmic Epidemiol, 1–11, doi:10.1080/09286586.2021.1999986 (2021).
58. Wong, Y. L. *et al.* Prediction of myopia onset with refractive error measured using non-cycloplegic subjective refraction: the WEPrOM Study. BMJ Open Ophthalmol **6**, e000628, doi:10.1136/bmjophth-2020-000628 (2021).
59. Leng, L. *et al.* Effect of Sunshine Duration on Myopia in Primary School Students from Northern and Southern China. Int J Gen Med **14**, 4913–4922 (2021).
60. Fu, A., Watt, K., B, M. J., Delaveris, A. & Stapleton, F. Prevalence of myopia among disadvantaged Australian schoolchildren: A 5-year cross-sectional study. PLoS One **15**, e0238122, doi:10.1371/journal.pone.0238122 (2020).
61. Megreli, J., Barak, A., Bez, M., Bez, D. & Levine, H. Association of Myopia with cognitive function among one million adolescents. BMC Public Health **20**, 647, doi:10.1186/s12889-020-08765-8 (2020).
62. He, X. *et al.* Design and methodology of the Shanghai child and adolescent large-scale eye study (SCALE). Clin Exp Ophthalmol **46**, 329–338 (2018).

Figures

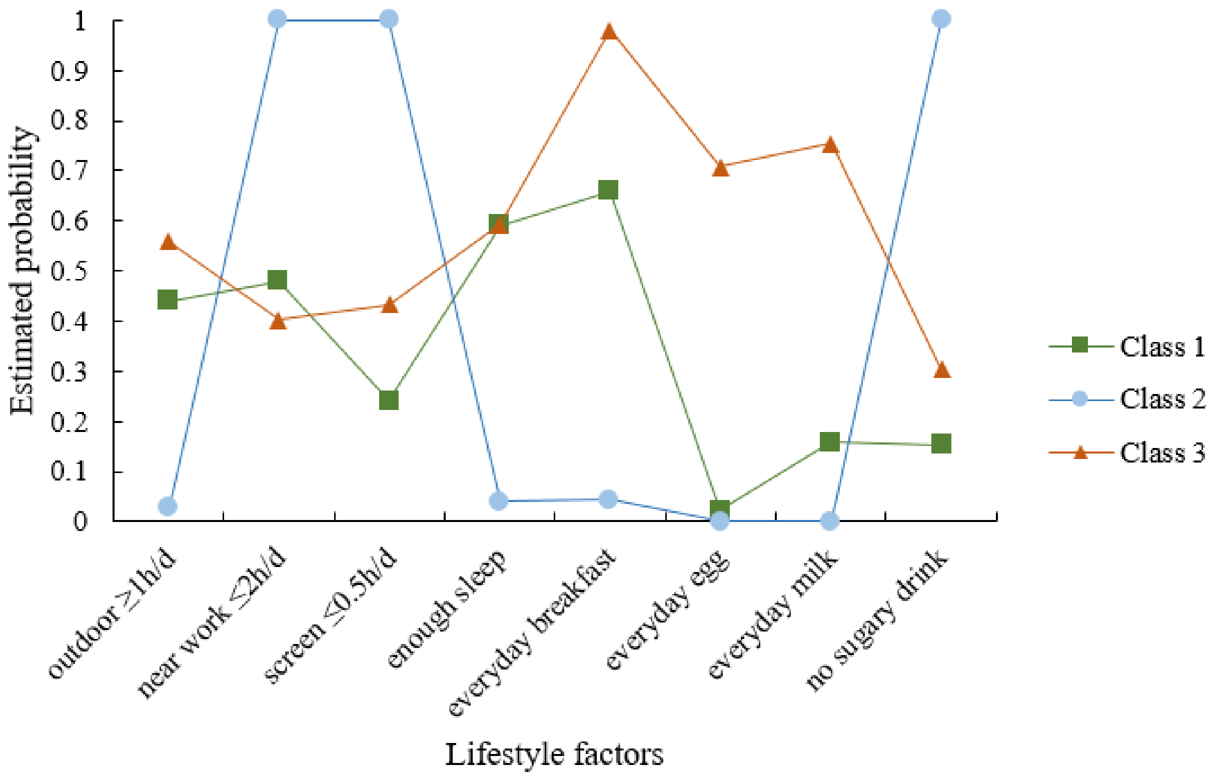

Figure 1

Latent class for the three lifestyle classes attributions. Latent class 1 was characterized by low egg and milk consumption. Class 2 was characterized by low time outdoor, near work and screen use, not enough sleep, unregular breakfast, low egg and milk and sugary drink consumption. Children in class 3 had regular breakfast and high egg and milk consumption.