Research Paper

Risk Factors of Myopic Shift among Primary School Children in Beijing, China: A Prospective Study

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Abstract

Objective: To evaluate factors associated with myopic shift among primary school children.

Methods: In a one-year prospective school-based study, 5052 children from ten schools were enrolled using a multi-stage random cluster approach. The baseline examination included non-cycloplegic auto-refractometry and questionnaire interview. Measurements were repeated at the follow-up.

Results: Among 5052 students at baseline investigated, 4292 students (85.0%) returned for the follow-up examination. The mean refractive error (-1.13±1.57 diopters) had changed -0.52±0.73 diopters from the baseline to the follow-up examination. 2170 (51.0%) had a rate of significant myopic shift (significant myopic shift is defined as the change of spherical equivalent of the refraction ≤ -0.50D between the follow-up and baseline measures). We confirmed that common associated factors (older age, parental myopia, lower refractive status at baseline, shorter reading distance and lower frequency of outdoor activities during class recesses) were associated with greater shift towards myopia. After controlling for age, sex, region of habitation, parental myopia and refractive status at baseline, greater shift towards myopia was independently associated with distance from near-work (OR=1.48 , 95% CI=1.26-1.74, *P*<0.001) and longer time outdoors for leisure (OR=0.87, 95% CI=0.78-0.97, *P*<0.013).

Conclusion: Greater shift towards myopia was independently associated with modifiable factors (distance from near-work and longer time outdoors for leisure) might suggest that encouraging children to go outside for outdoor activities during class recess and after school may be a promising and feasible intervention against myopia development.

Key words: Myopic shifts, Risk factors, Primary school children, Myopia, Beijing China.

Introduction

Myopia has emerged as a major global public health issue, particularly in East Asia [1]. Around 80% or more of young adults have myopia in East Asian countries including Mainland China, Taiwan and Korea [2-4]. The economic cost and medical burden of myopia are also high. In Singapore, the direct cost of myopia for each school child was estimated to be US $148 [5]. Myopia, in particular high myopia may increase the risk of uncorrectable visual impairment (open angle glaucoma, retinal detachment and cata-

ract) and even blindness in later life [6-9].

From a series of clinical perspective studies, the efficiency of intervention to slow down the progression of myopia is limited. A meta-analysis of 11 randomized clinical trials showed that the optical treatment is not effective for myopia control [10]. Anti-muscarinic drugs such as atropine eye drops has been found to be effective in reducing the progression of myopia, while the risk of side effects such as photophobia, decreased near vision, dry eye, flushed skin etc is high [10]. Therefore, it is important to identify modifiable risk factors of myopia that can help us to slow or stop myopia progression.

Several longitudinal studies have investigated the relationship between near-work activities and myopia development or progression. However, these studies have produced inconsistent results [11-14]. Two studies found an association between excessive near-work and refractive error change toward myopia [11-12], whereas the other two studies did not support that there exists any effects of near-work on myopia progression [13-14]. Recent epidemiology surveys have shown that increased amounts of time outdoors protect against the development of myopia. Four longitudinal studies have shown associations between more time spent in outdoor activity and reduction of risk in development of myopia [15-18]. A refractive change toward myopia was also found in the group with less outdoor activities [11,12]. However, three other longitudinal studies did not observed the relationship between outdoor activities and the progression of myopia [13,19,20].

The conflict results of the previous studies, therefore, show limited supports that more time in near-work and less time outdoor activity increase the incidence of myopia. The purpose of the present study is to explore the risk factors for myopia shift, particularly the modifiable risk factors such as near-work and outdoor activity, and myopia progression.

Methods

Participants

The study was approved by the respective ethics committees of Capital Medical University, the Beijing Municipal Commission of Education and the Beijing Center for Disease Control and Prevention. It followed the Declaration of Helsinki. Written consent was obtained from the parents of all participants.

This school-based study was initially carried out in November 2010. Sampling was performed using multi-stage random cluster approach. In the first step, five districts were randomly selected from all 16 districts in the rural and urban regions of Beijing. In the second step, two schools were randomly selected from each of the five selected districts. In the third step, all students of grade 1 to 5 of the selected schools with age of 6-12 years were sampled. The exclusion criteria were the followings: 1) Children who reported eye conditions within the last month (e.g., eye injuries, mild conjunctivitis or "red eye", hordeolum, keratitis or corneal irritation, dry eye syndrome, glaucoma; 2) Parents refused to sign the informed consents. The follow-up examinations were performed one year later in November 2011 after the baseline survey.

Interview and follow-up

At baseline and follow-up examinations, all students and their parents completed a detailed questionnaire firstly. The quality of the interview was controlled by school physicians and head teacher in each class.

The questionnaire included two parts. The first part of the questionnaire was filled in by the children and assisted by their parents. For very young children who could not read or understand the questionnaire very well (e.g., the youngest children of 6 years old), help was sought from their parents. Basic socio-demographic data, such as age, sex, ethnic background, region of habitation (urban/rural), was included in the first part of the questionnaire. In the second part, information of parents' myopia was obtained by asking the parents' question "Does children's father/mother have myopia".

The first part of the questionnaire additionally included questions on near-work activities such as the amount of time spent on studying or watching television and on computer activities per day; questions on the average reading distance (closer than 33 cm (equivalent to one "chi" as a Chinese length unit), or ≥33 cm), the average distance in working with a computer (closer than 66 cm (equivalent to two "chi") or ≥66 cm), and the average distance to the television set (closer than 2.5m, or ≥ 2.5m). The total time of near-work per day (defined as the time spent for studying plus time spent for watching television and computer activities) and the distance at which near-work was carried out were assessed. If the average reading distance and the average distance in computer activities was ≥33 cm and if the distance to the television set was ≥2.5m, the distance was overall classified as adequate. Otherwise, the distance was classified as "close". We also inquired whether the students had an active rest during their studying periods. The active rest during studying was defined as the students purposely looking far into the distance for ten minutes every 40-50 minutes during their studying periods. It was graded as "occasional" (≤ 5 times every day), "common" (6-10 times every day), and "often" (≥11 times every day).

The first part of the questionnaire also include questions about outdoor activities such as how long the children spent in outdoor activities for leisure (such as playing outdoors and walking.) during class recess; how long the children spent on outdoor activities for leisure after school; how long the children spent on outdoor activities for leisure during weekends; how long the children spent on sports during week and weekend. The average time of daily outdoor activity for leisure was calculated using the formula: [(hours spent during class recess + hours spent after school) × 5 + (hours spent in weekend days) × 2]/7. The average time of daily sport was calculated using the formula: [(hours spent on weekdays) × 5 + (hours spent in weekend days) × 2]/7.

After the interview, ophthalmological examinations were performed on the school premises by two trained optometrists. Non-cycloplegic auto-refractometry (Topcon RM-A7000; Topcon Co., Tokyo, Japan) was carried out by a senior experienced optometrist. The mean of three readings were taken.

The data were analyzed using a commercially available statistical program (SPSS for Windows, version 21.0; IBM-SPSS, Chicago, Illinois, USA). The spherical equivalent of the refraction (SER) was calculated as the spherical refractive error plus half of the minus cylindrical refractive error. As the SER of the right and left eyes were well correlated (Spearman's correlation coefficient=0.809), only the data for the right eye is presented. The shift in refraction was determined by the difference of mean SER between the follow-up and baseline measures. As auto refractors rounded up refractive measures to the nearest 0.12D in either direction, there may be a measurement error of 0.25D at each point of examination. So, the significant myopic shift was defined as change of SER ≤ -0.50D. To examine the possible impacts of nonparticipation at follow-up examination and relationship between the significant myopic shift with other parameters at baseline (univariate analysis), χ^2 test was used to evaluate the differences in proportions for nominal variables; and Wilcoxon rank test was used to evaluate difference for ordinal variables (such as parental myopia) or continuous variables with abnormal distribution. Multiple logistic regression analysis was then used to determine independent factors associated with significant myopic shift. Odds ratios (OR) and 95% Confidence Interval (95% CI) were calculated. All *P*-values were 2-sided and considered statistically significant when less than 0.05.

Results

In 2011, 4292 (85.0% of the 5052 students examined at baseline) participants returned for the follow-up examination. Socio-demographic characteristics were compared between those children who participated in both examinations and those lost to follow-up (Table 1). The children who participated in the follow-up examination were more likely to be male (*P*<0.001) and have lower refractive status at baseline (*P*=0.026) than those lost to follow-up. There was no difference in socio-demographic factors, including age (*P*=0.396), and region of habitation (*P*=0.357) between children who retained in the study and those lost to follow-up. There was also no differences in parental myopia between the two groups (*P*=0.066). In 2010, the mean age of the 4292 eligible children was 8.47±1.54 years (range: 6-12 years) with 49.2% of them were females; 40.7% of them living in urban.

In 2011 survey, the mean refractive error (-1.13±1.57 diopters) had changed by -0.52±0.73 diopters. 2170 (51.0%) had a rate of significant myopic shift (SER≤-0.5D between the follow-up and the baseline) (Figure 1).
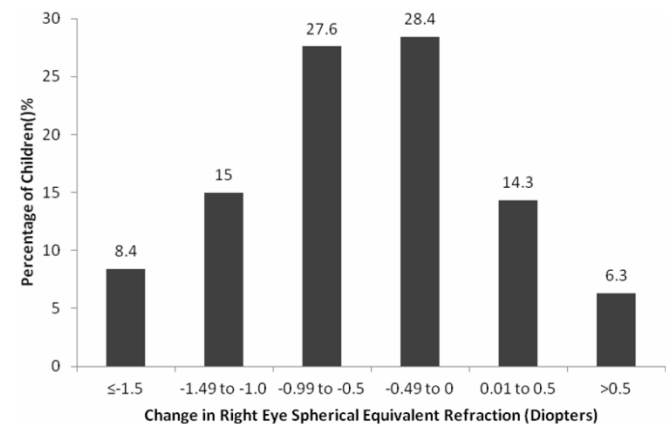
Figure 1. Change in right eye spherical equivalent refraction in one-year follow-up for children in primary schools.

Table 1. Comparisons of demographics, refractive status, near-work and outdoor activities at baseline between those children who participated in both examinations and those lost in follow-up.

Characteristic	In follow-up	Lost in follow-up	*P*
Age (years)	8.47±1.54	8.44±1.53	0.396
Sex n (%)			
Male	2089(50.8)	370(48.7)	<0.001
Female	2021(49.2)	337(44.3)	
Region of Habitation n (%)			
Rural	2538(59.3)	464(61.1)	0.357
Urban	1744(40.7)	296(38.9)	
Parental Myopia n (%)			
Both Not Myopic	2315(55.5)	375(51.2)	0.066
Father or Mother Myopic	1325(31.8)	249(34.0)	
Both Myopic	528(12.7)	109(14.9)	
Refractive Error of Right Eye (Diopters)	-0.61±1.30	-0.55±1.40	0.026

In univariate analysis, greater shift towards myopia was associated with older age (*P*<0.001), female (*P*=0.049), urban region (*P*<0.001), parental myopia (*P*<0.001), lower refractive status at baseline (*P*<0.001), shorter time outdoors for leisure (*P*<0.001), shorter distance from near-work (*P*<0.001), whereas not with time outdoors for sports (*P*=0.154), time spent for near-work (*P*=0.400), and active rest during study (*P*=0.061) (Table 2).

Table 2. Associations（univariate analysis）between the significant myopic shift (defined as of right eye spherical equivalent refraction (SER)≤-0. 50D change between follow-up and baseline within one year) and associated factors in primary school children

	SER≤-0.50D Change	SER>-0.50D Change	*P* value
Age (Years)	8.65±1.51	8.29±1.56	<0.001
Sex n (%)			
Male	1025(49.7)	1038(50.3)	0.049
Female	1057(52.8)	946(47.2)	
Region of Habitation n(%)			
Rural	1193(47.6)	1312(52.4)	<0.001
Urban	977(56.4)	754(43.6)	
Parental Myopia n(%)			
Both Not Myopic	1041(45.5)	1249(54.5)	<0.001
Father Myopic or Mother Myopic	707(53.9)	604(46.1)	
Both Myopic	352(67.3)	171(32.7)	
Refractive Error of Right Eye at Baseline (Diopters)	-0.88±1.48	-0.33±1.00	<0.001
Time Outdoors for Leisure (Hours/Day)	1.03±0.65	1.40±0.70	<0.001
Time Outdoors for Sports (Hours/Day)	0.89±0.61	0.86±0.66	0.154
Time Spent for Near-Work (Hours/Day)	7.74±2.93	7.68±3.02	0.400
Distance from Near-Work n (%)			
Adequate	379(43.3)	497(56.7)	<0.001
Close	1616(53.4)	1412(46.6)	
Active Rest During Study			
Often	900(49.2)	931(50.8)	0.061
Common	622(53.0)	552(47.0)	
Occasionally	648(52.6)	583(47.4)	

In model 1 (Table 3), after controlling for sex and age, greater shift towards myopia was significantly associated with distance from near-work (OR=1.58, 95% CI= 1.35-1.85, *P*<0.001), higher refractive status at baseline (OR=0.72, 95% CI=0.68-0.76, *P*<0.001), longer time outdoors for leisure (OR=0.85, 95% CI=0.77-0.94, *P*=0.002), higher frequency of active rest during study (OR=0.86, 95% CI=0.74-0.99, *P*=0.042), but not with time outdoors for sports (OR=1.09, 95% CI=0.97-1.22, *P*=0.135), and time spent for near-work (OR=1.00, 95% CI=0.98-1.02, *P*=0.935).

In Model 2 (adjusting for age, sex, and region of habitation), greater shift towards myopia remained significantly associated with distance from near-work (OR=1.56, 95% CI= 1.34-1.83, *P*<0.001), higher refractive status at baseline (OR=0.72, 95% CI=0.68-0.76,

P<0.001), longer time outdoors for leisure (OR=0.85, 95% CI=0.77-0.95, *P*=0.003). Higher frequency of active rest during study lose statistical significance (OR=0.87, 95% CI=0.75-1.01, *P*=0.065). Significant myopic shift was not associated with time outdoors for sports, and time spent for near-work (Table 3).

In model 3 adjusting for age, sex, region of habitation and parental myopia, greater shift towards myopia was still associated with distance from near-work (OR=1.51, 95% CI=1.29-1.78, *P*<0.001), higher refractive status at baseline (OR=0.75, 95% CI=0.70-0.79, *P*<0.001), and longer time outdoors for leisure (OR=0.86, 95% CI=0.77-0.96, *P*=0.005). Greater shift towards myopia was not significantly associated with active rest during study, time outdoors for sports, and time spent for near-work (Table 3). In the last model controlling for age, sex, region of habitation, parental myopia and refractive status at baseline, significant myopia was associated with distance from near-work (OR=1.48 , 95% CI=1.26-1.74, *P*<0.001) and longer time outdoors for leisure (OR=0.87, 95% CI=0.78-0. 97, *P*<0.013) (Table 3).

Analysis of collinearity showed a variance inflation factor of less than 1.15, suggesting that inter-dependency of the variables did not markedly affect the results of the analysis.

Discussion

In the longitudinal follow-up analysis, older age, parental myopia, lower refractive status at baseline, shorter reading distance and lower frequency of outdoor activities during class recess was shown to be associated with greater shift towards myopia. The present study showed that greater shift towards myopia is associated with older age, female, parental myopia, lower refractive status at baseline, shorter distance from near-work and shorter time outdoors for leisure, but not with time outdoors for sports, time spent for near-work, active rest during study in univariate analysis. In logistic regression after controlling for age, sex, region of habitation, parental myopia and refractive status at baseline, greater shift towards myopia was associated with distance from near-work (OR=1.48 , 95% CI=1.26-1.74, *P*<0.001) and longer time outdoors for leisure (OR=0.87, 95% CI=0.78-0. 97, *P*<0.013).

The finding of greater shift towards myopia is associated with distance from near-work in this study is consistent with the findings in Australia that children who performed near-work at a distance of less than 30 cm are 2.5 times more likely to have myopia than those who worked at a longer distance [21]. Similar findings were reported from the military conscripts in Taiwan [22].

Table 3. Modifiable associated factors of significant myopic shift (defined as of right eye spherical equivalent refraction (SER)≤-0. 50D change between follow-up and baseline within one year) in primary school children in Beijing, China

Parameters	Model 1		Model 2		Model 3		Model 4	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Refractive Error of Right Eye at Baseline (Diopters)	0.72 (0.68-0.76)	<0.001	0.72 (0.68-0.76)	<0.001	0.75 (0.70-0.79)	<0.001	-	-
Time Outdoors for Leisure (Hours/Day)	0.85 (0.77-0.94)	0.002	0.85 (0.77-0.95)	0.003	0.86 (0.77-0.96)	0.005	0.87 (0.78-0.97)	0.013
Time Outdoors for Sports (Hours/ Day)	1.09 (0.97-1.22)	0.135	1.07 (0.96-1.20)	0.218	1.07 (0.95-1.19)	0.268	1.06 (0.94-1.18)	0.353
Time Spent for Near Work (Hours/Day)	1.00 (0.98-1.02)	0.935	1.00 (0.98-1.02)	0.814	1.00 (0.97-1.02)	0.749	0.99 (0.97-1.02)	0.993
Distance from Near Work n(%)								
Adequate	ref		ref		ref		Ref	
Close	1.58 (1.35-1.85)	<0.001	1.56 (1.34-1.83)	<0.001	1.51 (1.29-1.78)	<0.001	1.48 (1.26-1.74)	<0.001
Active Rest During Study								
Occasionally	ref		Ref		ref		ref	
Common	0.86 (0.74-0.99)	0.042	0.87 (0.75-1.01)	0.065	0.88 (0.76-1.03)	0.884	0.95 (0.81-1.11)	0.520
Often	1.00 (0.85-1.18)	0.984	1.00 (0.85-1.18)	0.999	0.98 (0.83-1.16)	0.977	1.01 (0.85-1.20)	0.892

Model 1, controlling for sex, age; Model 2, controlling for sex, age, and regions; Model 3, controlling for sex, age, regions and parental myopia;
Model 4, controlling for sex, age, regions, parental myopia and refractive error of right eye at baseline (diopters).

In the multivariate analysis, there is no association between myopic shift and longer time spent in near work, which resembled to the other three longitudinal studies showing that reading hours per week was not related to myopia progression [13-15]. Interestingly, longer outdoor time for leisure was associated with greater shift towards myopia negatively. This is also consistent with the findings from the previous cross-sectional studies [23-28], and a longitudinal study which showed that an increase in myopia refractive error is significantly associated with less time spent in outdoors after adjustment for age [12].

However, we have not found any association between time spent in sports and significant myopic shift. This is consistent with a longitudinal study which showed that sport is not associated with less myopia progression from onset [13]. This also confirms our previous cross-sectional study which found that the sport is not associated with myopia [29].

In another study conducted by Jacobsen, physical activity was inversely associated with refractive error change toward myopia [11]. Our results agree with another four longitudinal studies which revealed that time spent in outdoors was predictive of incident myopia [15-18]. Our result further confirms the outcome of an interventional study, in which the interventions consisted of performing a recess outside the classroom (ROC) program that encouraged the children to go outside for outdoor activities during class recess. Outdoor activities during class recess in school have been proved to have significant effects on preventing myopic shift in non-myopic subjects [30].

A less hyperopic refraction at baseline is a strong predictor of greater shift towards myopia in our study. The odds for significant myopic shift increase with decreasing refractive status at baseline. This is in agree with findings from the Sydney Adolescent Vascular and Eye Study which showed that children with myopia at baseline are more likely to have a significant shift in refraction compared with children with no refractive error [17,31]. Our study is also consistent with the findings from the Orinda Longitudinal Study of Myopia which found refraction at baseline to be a strong predictor of the onset of juvenile myopia [32].

Our findings may have public health significances. A call named "one-hour sunshine sports movement" was issued by the China's Ministry of Education in 2006. The aim of the call is to promote students' physique health by encouraging students to have outdoor activities for at least one hour. The total daily recess time in school has been reached to 60 minutes (10, 30, 10 minutes in the morning and 10 minutes in afternoon). So, encouraging children to go outside for outdoor activities during class recess and after school may be a promising and feasible intervention against myopia development.

Our study has at least three limitations. Firstly, cycloplegia was not used in the present study. In our pilot investigation, we found some parents worried about the possible or potential side-effects. If cycloplegia is used, majority of parents will refuse to attend the study. Indeed non-cycloplegic refractometry may overestimate the prevalence of myopia in teenagers with active accommodation [33]. While we do not aim to explore the prevalence or incidence or progression of myopia, but focus to investigate the factors associated with myopic shift; therefore the weakness in this

study is limited and may not markedly influence the results of our study. Secondly, the parameters of reading distance were self-reported and were not measured, and thus were inaccurate to a certain degree [34]. Thirdly, we used the Chinese length measure unit of "Chi" (1 Chi=33cm) which has been used for more than 3000 years in China and is only known to Chinese.

Conclusion

We confirmed that common associated factors (older age, parental myopia, lower refractive status at baseline, shorter reading distance and lower frequency of outdoor activities during class recesses) were associated with greater shift towards myopia. After controlling for age, sex, region of habitation, parental myopia and refractive status at baseline, greater shift towards myopia was independently associated with distance from near-work and longer time outdoors for leisure. Those findings suggest that encouraging children to go outside for outdoor activities during class recess and after school may be a promising and feasible intervention against myopia development.

Acknowledgements

Competing interests

The authors declare there are not conflicts of interest.

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