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Generational difference of refractive error in the baseline study of the Beijing Myopia Progression Study

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ABSTRACT

Aims To report the refractive error difference (RED) between parents and their children and the estimated single generational myopic shift in an urban area in China.

Methods 395 children aged 6–17 years and their parents, who had been enrolled in the Beijing Myopia Progression Study were included. Cycloplegic and non-cycloplegic refraction of the children and parents were performed, respectively. RED was defined as the difference between the average parental spherical equivalent (SE) and the average SE of their children. Binomial fitted curves of RED were plotted as a function of the children's age. Generational myopic shift was defined as the estimated RED according to the prediction model at the age of 18 years.

Results 395 families were enrolled. The RED was positively correlated with the children's age ($r_{spearman}$=0.58, $p<0.001$). The RED (median (25th and 75th percentile)) was −1.88 (−3.23 to −1.00) dioptres (D) in children at 6.0–7.9 years of age, and it increased to 1.53 (−0.12 to 3.44) D in children at 16.0–17.9 years of age. The SE of the children approached the average SE of their parents at the age of 11 years. At the age of 18 years, the children's estimated myopic shift would be 1.94 D.

Conclusions In this sample, children's refractive errors at the age of 11 years were already similar to their parents. Moreover, the estimated myopia in children at the age of 18 years would be up to 2.0 D higher than their parents. This remarkable single-generation myopic shift indicates that there are likely effects of environmental factors on myopia development in urban Chinese children.

INTRODUCTION

Myopia in school children is a critical public health problem in rural and urban populations in East Asia.[1–4] Epidemiological studies have identified parental history of myopia as a significant risk factor for both the onset and progression of myopia in children.[5–7] The odds of children born to two parents with myopia becoming myopic are approximately six times greater than in children with only one or no parent with myopia .[5] However, few studies have reported the quantitative relation between refractive errors in parents and their children.

In addition to the genetic risk factors, environment factors also play an important role in the development of myopia.[8–10] Prevalence of myopia in the Chinese adult (40 years or older) population in urban (Beijing) or rural area (Handan) is approximately 20%.[11 12] The similarity in prevalence of myopia among adults suggests that environmental or lifestyle determinants for myopia may be likely similar in the older members of the Chinese population living in urban and rural settings. The overall increasing prevalence of myopia in the younger population in China, and the significantly higher prevalence of myopia in urban children (eg, 78.4% in 15-year-old children in Guangzhou)[1] as compared with rural ones (eg, 43.0% in 15-year-old children in Yangxi, a rural country located in the west of Guangzhou),[3] implied that the lifestyle and exposure to environmental factors are different in the younger generation.[13] Epidemiological studies found a remarkable increasing trend in the prevalence of myopia in the same area decades later in children[14–16] and adults,[16 17] which provides strong evidence for the importance of environmental factors on the development of myopia.

Besides the re-evaluation of prevalence of myopia decades later, the generational myopic shift from parents to their children, who share extremely similar genetic factors, would be of great importance as it would reflect the environmental effects on the development of myopia in a relatively short span of time. In the Beijing Myopia Progression Study (BMPS), details of the refractive error in the majority of the parents had been obtained. Thus, in this present report, we describe the quantitative, age-specific refractive error differences (REDs) from parents to their children.

METHODS

Subjects

The BMPS is a 3-year, hospital-based, cohort study that primarily aims to investigate the possible relationship between near-work-induced transient myopia and permanent myopia. The study followed the tenets of the Declaration of Helsinki and was approved by the ethics committee of the Beijing Tongren Hospital. All participants (children and their parents) signed a written informed consent. Details of the study design, sample size estimation and baseline characteristics of BMPS have been reported elsewhere.[18]

The criteria for recruitment included: (1) children from elite primary or secondary schools in Beijing aged 6–17 years; (2) best-corrected visual acuity 0.1 or better (log minimum angle of resolution, LogMAR); and (3) children who were able to cooperate and return for scheduled visits. The exclusion criteria were: (1) presence of amblyopia and/or strabismus; (2) history of intraocular surgery or penetrating ocular trauma; (3) severe medical or ocular health problems or mental disease. The parents of these children were also invited to join the study. The participants (both children and their parents) received comprehensive vision examinations and a detailed questionnaire related to their health and daily habits.

Refractive error

Cycloplegic refraction of each eye was performed in all children after instilling three drops of cyclopentolate 1% (Cyclogyl, Alcon, Fort Worth, Dallas, USA), whereas a non-cycloplegic refraction was performed for the parents (Accuref-K9001, Shin-Nippon, Japan). Preoperative refractive error was used in 13 parents who had previously undergone refractive surgery. Besides refractive surgery, no intraocular surgery history or other ocular diseases that could have impacted the refractive error were found for the parents who visited the clinical centre. About 186 (23.5%, 186/790) parental refractive error readings (138 fathers and 48 mothers) were obtained by self-report through a telephone call, as they could not visit the clinical centre.

Definitions

Children's refractive error was defined as the average of the cycloplegic spherical equivalent (SE, sphere+1/2 cylinder) of both eyes combined. Parental refractive error was defined as the average of non-cycloplegic SE of the father and the mother (four eyes), as the influence of either parent remains unknown. Myopia and high myopia were defined as, respectively, SE≤−0.50 D and SE≤−6.0 D.[6] The RED was defined as the difference in the refractive error of the parents and their children, that is, parental SE minus children's SE.

Data analysis

Data with either a normal or non-normal distribution were presented as the mean±1 SD and the median (25th and 75th percentile), respectively. Spearman's correlation between RED and the children's age was performed. Statistical significance was determined using the rank-sum test (non-normal distribution). The χ^2 test was used to assess the statistical significance of the categorical data.

As the number of subjects in some age subgroups (ie, children aged 6, 15 or 17 years) was less than 20, adjacent age groups were combined. The RED of each family was calculated, and then averaged in each age group. The median RED and proportion of children with a higher myopic SE than their parents as a function of the children's combined age were calculated. Binomial curves with RED/the proportion of higher myopic SE of children than their parents as dependent variable, and the children's combined age as independent variable, were fitted to investigate the trend of RED/the higher myopic proportion. Binomial curve fitting was performed for RED and children's age, as it showed the highest R^2 value among several comprehensive curve fitting methods (eg, linear, logarithmic curve fitting). Generational myopic shift was defined as the estimated RED according to the fitted curve at the age of 18 years because the age of myopia stabilisation in the majority of children was reported to be less than 18 years.[19]

Statistical analysis was performed with Statistical Analysis System for Windows V.9.1.3 (SAS Inc., Cary, North Carolina, USA). A p value less than 0.05 was considered to be statistically significant.

RESULTS

A total of 395 families (each consisting of one child and two parents) with complete refractive error data were enrolled in this study including 187 boys and 208 girls. The mean (±SD) age of the children was 10.4±3.1 years (range from 6 to 17 years). Figure 1 showed the distribution of refractive error in children of all ages and their parents (figure 1A, skewness was −0.04 and −0.70 for children and parents, respectively), in

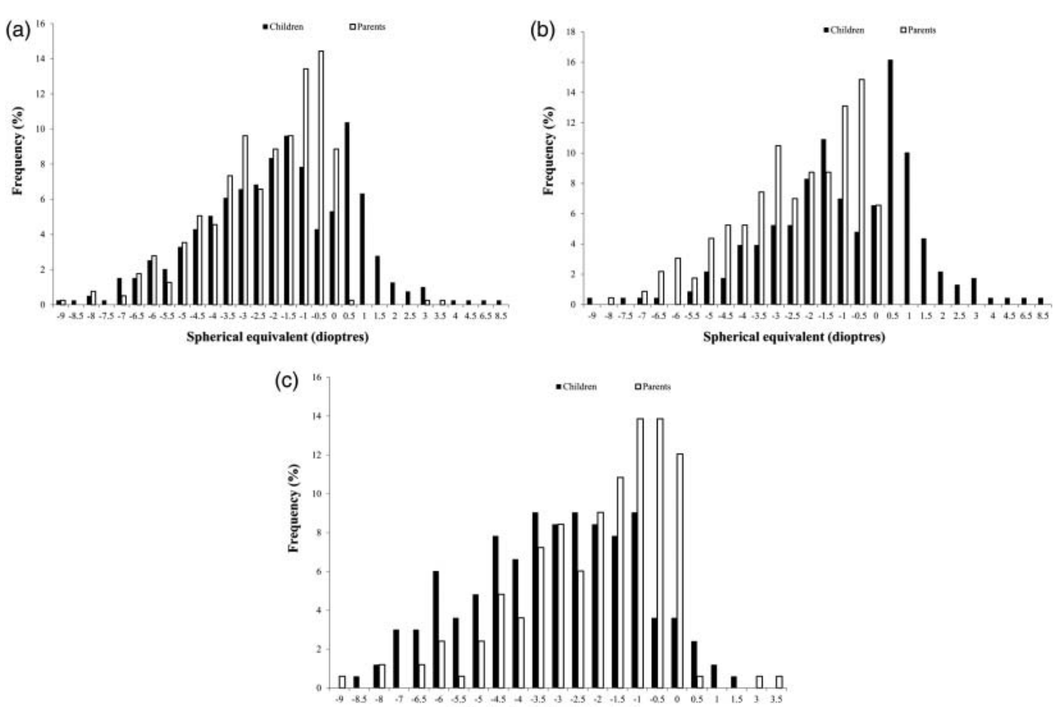

Figure 1 (A) Distribution of refractive error in children at all ages and their parents. (B) Distribution of refractive error in children at 11 years old or less and their parents. (C) Distribution of refractive error in children at 12 years old or more and their parents.

Table 1 Characteristics of children and parents included in this study

	Total
Number of children (M : F)	187 : 208
Age (mean±SD, years)	
Children	10.4±3.1
Fathers	41.4±4.6
Mothers	39.1±4.0
Spherical equivalent (median (25th and 75th percentiles), dioptres)	
Children*	−1.44 (−3.13 to 0.38)
Fathers*	−1.00 (−3.50 to 0.00)
Mothers*	−1.09 (−3.56 to −0.25)
Parents†	−1.69 (−3.22 to −0.50)
Myopia (n, %)‡	
Children	264 (66.8)
Fathers	238 (60.3)
Mothers	271 (68.6)
High myopia (n, %)‡	
Children	17 (4.3)
Fathers	26 (6.6)
Mothers	45 (11.4)§
Parents with myopia (n, %)‡	
None	63 (16.0)
One	155 (39.2)
Both	177 (44.8)

*Refractive error was defined as the average spherical equivalent of both eyes.
†Refractive error defined as the average spherical equivalent of father and mother.
‡Myopia was defined as SE less than/equal to −0.50 D; high myopia as SE less than/equal to −6.0 D.
§Significant difference compared with that in children, using χ^2 test.

children at 11 years old or less and their parents (figure 1B, skewness was −0.07 and −0.69, respectively), in children at 12 years old and more and their parents (figure 1C, skewness was −0.29 and −0.78, respectively). We found that children 11 years old or less showed a more hyperopic distribution than their parents, whereas children 12 years old or more showed a more myopic distribution than their parents. The median (25th and 75th percentile) of SE of the children and their parents was −1.44 (−3.13 to 0.38) D and −1.69 (−3.22 to −0.50) D, respectively (table 1). There were 264 (66.8%) children with myopia. No significant difference was found compared with the 238 (60.3%) fathers with myopia ($p=0.055$), or the 271 (68.6%) mothers with myopia ($p=0.59$). There were 17 (4.3%) children with high myopia. No significant difference was found compared with the 26 (6.6%) fathers with high myopia ($p=0.16$), but it was significantly less than for the 45 (11.4%) mothers with high myopia ($p<0.001$). There were 63 (16.0%), 155 (39.2%) and 177 (44.8%) children with no, one or two parents with myopia, respectively.

RED significantly correlated with the children's age ($r=0.58$, $p<0.001$). Children at 6.0–9.9 years had a more hyperopic SE compared with their parents ($p<0.001$), and no significant difference at 10.0–11.9 years ($p=0.58$), whereas in children aged 12–17.9 years, the reverse was found with a more myopic SE in children compared with their parents ($p<0.01$) (table 2). RED and its binomial fitting curve ($R^2=0.91$) are presented in figure 2. The RED (median (25th and 75th percentile)) was −1.88 (−3.23 to −1.00) D in the 6.0–7.9 year-old children. Only 9.8% (9/92) of the children at 6.0–7.9 years showed a higher myopic SE than their parents. At the age of 10.0–11.9 years, the RED was 0.42 (−1.50 to 1.81) D, hence closest to zero, that is, the children's SE was close to the average SE of their parents. About 56.7% (17/30) of the children aged 10.0–11.9 years showed a higher myopic SE than their parents. In children more than 11 years of age, RED continued to increase with the age of the children. At age 16.0–17.9 years, the RED increased to 1.53 (−0.12 to 3.44) D; 70.0% (28/40) of the children aged 16.0–17.9 years, showed a higher myopic SE than their parents.

Using a binomial fitted function, the children's estimated myopic shift would be 1.94 D at the age of 18 years. Figure 3 shows the binomial fitting curve in the proportion of children with a higher myopic SE than their parents, using the children's combined age ($R^2=0.86$). Slightly more than half (52.2%) of the children would have a higher myopic SE than their parents at the age of 11 years, and the estimated proportion would reach 78.2% by the age of 18 years.

DISCUSSION

To the best of our knowledge, this is the first study to describe the quantitatively refractive error shift from parents to children, over a relatively wide age range of children. Wu *et al*[20] reported that the prevalence of myopia increased from 5.8% in the grandparents' generation to 20.8% in the parents' generation, and then further to 26.2% in the children's generation in China, suggesting a considerable environmental effect on myopia development over this relatively short time span. Although the data spanned through three generations with a very large sample size (n>3000) and wide age range (7–17 years), only the children's non-cycloplegic refractive error, and the parents and grandparents binary refractive error state (myopia or not), were obtained. Hence, the important

Table 2 Number and refractive error of children and parents

Children's age (years)	Number	Refractive error (dioptres)† Children	Parents	p Value*
6.0–7.9	92	0.22 (−1.20 to 1.06)	−1.77 (−2.98 to −0.47)	<0.001
8.0–9.9	107	−0.56 (−1.94 to 0.88)	−2.00 (−3.34 to −0.69)	<0.001
10.0–11.9	30	−2.56 (−3.88 to −1.44)	−2.00 (−3.78 to −0.94)	0.58
12.0–13.9	103	−2.69 (−4.06 to −1.31)	−1.89 (−3.22 to −0.50)	<0.01
14.0–15.9	23	−2.94 (−4.00 to −1.25)	−0.59 (−1.88 to 0.00)	<0.001
16.0–17.9	40	−2.59 (−5.19 to −1.47)	−1.05 (−2.58 to −0.23)	<0.001

*p Value: using rank-sum test.
†Children's refractive error was defined as the average spherical equivalent of both eyes; parental refractive error was defined as the average spherical equivalent of father and mother; presented as median (25th and 75th percentile).

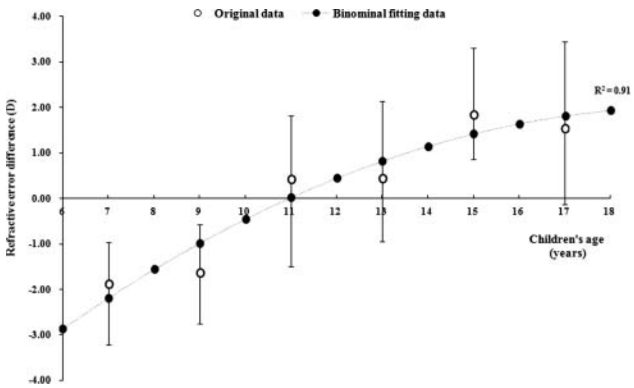

Figure 2 Refractive error difference (RED) from parents to children as a function of children's combined age (open circle) and its binomial fitting values (filled circle). The binomial fitting function was RED= $-0.025a^2+1.01a-8.00$ ('a' stands for the children's age). RED was defined as parental spherical equivalent (SE) minus children's SE, plotted is the median and 25th and 75th percentile. Children's combined age was defined as the average of every two adjacent ages.

quantitative changes over the generations remain unknown. Three epidemiological studies reported the prevalence of myopia in urban children in China.[1 4 21] The population-based prevalence of myopia increased from 5.9% at the age of 6 years, to 78.4% at the age of 15 years, in urban children of South China.[1] The school-based prevalence of myopia increased from 28.9% at the age of 7 years, to 48.2% at the age of 10 years, and further to 53.1% at the age of 11 years or more in Hong Kong students.[21] A recent survey on self-reported prevalence of myopia in children aged 12–19 years in Taiwan was 70.3%.[4] The prevalence of myopia in the current study also increased from 39.3% at the age of 7 years, to 68.8% at the age of 10 years, and further to 89.4% at the age of 11–17 years. However, our study provides the crucial quantitative shift of refractive error in children when compared with their parents. Thus, due to the increased environmental demands (such as more near-work or less time outdoors) at age 11 years, the children would have already attained the level of myopia of their parents and furthermore, have gone even beyond that as discussed below as per the estimated model findings. We believe

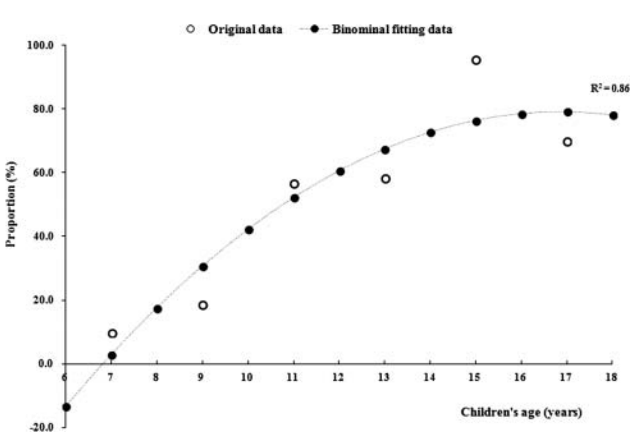

Figure 3 Proportion of children with higher myopic spherical equivalent than their parents as a function of children's combined age (open circle) and its binomial fitting values (filled circle). The binomial fitting function was percentage=$-0.78a^2+26.39a-143.42$, respectively ('a' stands for the children's age). Children's combined age was defined as the average of every two adjacent ages.

that it is very significant to predict the development of myopia in children at different ages, as well as the myopic shift between generations, for example, for public health management and for development of preventive measures.

There were several important findings in our study. First, with regard to the overall age range (6–17 years), the RED and the proportion of children who had a higher myopic refractive error compared with their parents, increased with the age of children. Second, by using the estimated model at the age of 11 years, the children's SE would be close to the average SE of their parents; and furthermore, half of the children would have a higher myopic refractive error than their parents. Third, by using the estimated model, the children's myopic shift and their chances of having higher myopia compared with their parents at the age of 18 years would be nearly 2.0 D and 80%, respectively. To some extent, this noticeable myopic shift found in only a span of two generations reflects an additional effect of an environmental change (such as exposure to more intensive near-work, educational attainment and less time outdoors).[22–24]

The generational myopic shift described and quantified in our study supports a predominant, although not necessarily exclusive, environmental effect on the increasing prevalence of myopia over the two generations.[14 15] Indeed, previous longitudinal studies showed a predominant hyperopic shift,[25 26] that is, a physiological decrease in the prevalence of myopia with age, among adults aged 40–60 years.[27] This was principally explained by a change in the crystalline lens with age.[28] However, a longitudinal clinical observation of simple myopia (SE ranged from −1.0 to −6.0 D) for more than 20 years showed an average *myopic* shift of −0.60 D, −0.39 D and −0.29 D during the third (20–29 years, and so on), fourth and fifth decades, respectively; and a *hyperopic* shift of +0.28 D and +0.41 D during the sixth and seventh decades, respectively.[29] The myopic shift among adults younger than 45 years suggested that a decrease in the prevalence of myopia is unlikely due to physiological decrease in the ocular biometric parameters; although further direct evidence of the ocular parameters is warranted. Furthermore, the final stable myopic level was supposed to be consistent over two generations if and only if a physiological effect exists. As the time spent on reading and time outdoors were associated with longer ocular length and refractive change towards myopia,[22–24] we conclude that environmental factors, such as near-work and time outdoors, play an important role in this generational myopic progression.

Although our study provides interesting findings, the representativeness of RED in this study may be limited because the participants in the BMPS were not selected randomly. The median (mean) refractive error was 0.00 (−1.01) D in an urban Beijing population aged 40–44 years,[11] which was clearly more hyperopic than that of the parents (median −1.69 D; mean −2.03 D) in a similar age group in the current study. We enrolled children through flyers provided to the schools and our hospital. As most of the children were driven to participate in this study by their parents, it was possible that parents with higher myopia, higher socioeconomic status and/or higher educational attainment were more likely to join the study, and thus the generational myopic shift may have been underestimated. Furthermore, the mean non-cycloplegic SE would be approximately 0.4 D more myopic than the cycloplegic SE in the 16–45-year-old participants.[30] In addition, the myopia would continue to progress after the age of 18 years in some subjects.[29 31] As a result, the non-cycloplegic parental SE in the present study may also underestimate the generational myopic shift. Hence, these various methodological biases may contribute to the *underestimation* of the generational myopic shift in the present study and thus may represent a conservative estimate of the generational myopic shift.

For the current study, the students mainly in the low grades in the elite primary or secondary schools were arbitrarily selected for participation in the BMPS. This may have led to undersampling in some age groups, as well as a bias towards higher socioeconomic status and/or educational attainment. Hence, further investigations with larger sample sizes on RED are warranted. Parallel investigations in rural children and different ethnic groups would be equally interesting. It is also noteworthy that our study had some information bias, because 23.5% of the parental refractive error was obtained through self-reporting. However, analysis for RED with both parents' refractive error tested in the clinical centre (n=224) demonstrated a good consistency. The RED was −2.53 D, −1.97 D, 0.42 D, 0.38 D, 1.84 D and 1.50 D compared with −1.88 D, −1.63 D, 0.42 D, 0.44 D, 1.84 D and 1.53 D for all the 395 families of children in each combined age group. It will be optimal to include those aged 18–25 years as well, which would help to predict the generational myopic shift in this part of China.

In summary, this report provides information on the RED between parents and their children in urban China. At the age of 11 years, the SE of children would reach the average SE of their parents, and the estimated myopic shift at 18 years of age would be nearly 2.0 D. This generational myopic shift provides an evidence of a cohort effect on the increasing prevalence of myopia over generations of young adults, presumably due to environmental factors such as near-work.

Contributors YBL contributed to study design; ZL and YBL conducted the study; ZL, TYG and SSR collected the data; VJ, AY and YBL were involved in management; ZL, VJ and TYG contributed to the analysis of data; ZL, VJ and YBL were in charge of the interpretation of the data and preparation of the manuscript; AY, YBL and NW were responsible for the provision of materials and resources, review and approval of the manuscript.

Competing interests None.

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REFERENCES

1 He M, Zeng J, Liu Y, *et al*. Refractive error and visual impairment in urban children in southern china. *Invest Ophthalmol Vis Sci* 2004;45:793–9.
2 Saw SM, Tong L, Chua WH, *et al*. Incidence and progression of myopia in Singaporean school children. *Invest Ophthalmol Vis Sci* 2005;46:51–7.
3 He M, Huang W, Zheng Y, *et al*. Refractive error and visual impairment in school children in rural southern China. *Ophthalmology* 2007;114:374–82.
4 Guo YH, Lin HY, Lin LL, *et al*. Self-reported myopia in Taiwan: 2005 Taiwan National Health Interview Survey. *Eye (Lond)* 2012;26:684–9.
5 Mutti DO, Mitchell GL, Moeschberger ML, *et al*. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci* 2002;43:3633–40.
6 Ip JM, Huynh SC, Robaei D, *et al*. Ethnic differences in the impact of parental myopia: findings from a population-based study of 12-year-old Australian children. *Invest Ophthalmol Vis Sci* 2007;48:2520–8.
7 Lam DS, Fan DS, Lam RF, *et al*. The effect of parental history of myopia on children's eye size and growth: results of a longitudinal study. *Invest Ophthalmol Vis Sci* 2008;49:873–6.
8 Morgan I, Rose K. How genetic is school myopia? *Prog Retin Eye Res* 2005;24:1–38.
9 Morgan IG, Ohno-Matsui K, Saw SM. Myopia. *Lancet* 2012;379:1739–48.
10 Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt* 2012;32:3–16.
11 Xu L, Li J, Cui T, *et al*. Refractive error in urban and rural adult Chinese in Beijing. *Ophthalmology* 2005;112:1676–83.
12 Liang YB, Wong TY, Sun LP, *et al*. Refractive errors in a rural Chinese adult population the Handan eye study. *Ophthalmology* 2009;116:2119–27.
13 He M, Zheng Y, Xiang F. Prevalence of myopia in urban and rural children in mainland China. *Optom Vis Sci* 2009;86:40–4.
14 Matsumura H, Hirai H. Prevalence of myopia and refractive changes in students from 3 to 17 years of age. *Surv Ophthalmol* 1999;44(Suppl 1):S109–15.
15 Lin LL, Shih YF, Hsiao CK, *et al*. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. *Ann Acad Med Singapore* 2004;33:27–33.
16 Vitale S, Sperduto RD, Ferris FL. Increased prevalence of myopia in the United States between 1971–1972 and 1999–2004. *Arch Ophthalmol* 2009;127:1632–9.
17 Seet B, Wong TY, Tan DT, *et al*. Myopia in Singapore: taking a public health approach. *Br J Ophthalmol* 2001;85:521–6.
18 Lin Z, Vasudevan B, Liang YB, *et al*. Baseline characteristics of nearwork-induced transient myopia. *Optom Vis Sci* 2012;89:1725–33.
19 Thorn F, Gwiazda J, Held R. Myopia progression is specified by a double exponential growth function. *Optom Vis Sci* 2005;82:286–97.
20 Wu MM, Edwards MH. The effect of having myopic parents: an analysis of myopia in three generations. *Optom Vis Sci* 1999;76:387–92.
21 Fan DS, Lam DS, Lam RF, *et al*. Prevalence, incidence, and progression of myopia of school children in Hong Kong. *Invest Ophthalmol Vis Sci* 2004;45:1071–5.
22 Zylbermann R, Landau D, Berson D. The influence of study habits on myopia in Jewish teenagers. *J Pediatr Ophthalmol Strabismus* 1993;30:319–22.
23 Saw SM, Carkeet A, Chia KS, *et al*. Component dependent risk factors for ocular parameters in Singapore Chinese children. *Ophthalmology* 2002;109:2065–71.
24 Jacobsen N, Jensen H, Goldschmidt E. Does the level of physical activity in university students influence development and progression of myopia?—a 2-year prospective cohort study. *Invest Ophthalmol Vis Sci* 2008;49:1322–7.
25 Lee KE, Klein BE, Klein R, *et al*. Changes in refraction over 10 years in an adult population: the Beaver Dam Eye study. *Invest Ophthalmol Vis Sci* 2002;43:2566–71.
26 Guzowski M, Wang JJ, Rochtchina E, *et al*. Five-year refractive changes in an older population: the Blue Mountains Eye Study. *Ophthalmology* 2003;110:1364–70.
27 Mutti DO, Zadnik K. Age-related decreases in the prevalence of myopia: longitudinal change or cohort effect? *Invest Ophthalmol Vis Sci* 2000;41:2103–7.
28 Dubbelman M, Van der Heijde GL. The shape of the aging human lens: curvature, equivalent refractive index and the lens paradox. *Vision Res* 2001;41:1867–77.
29 Ellingsen KL, Nizam A, Ellingsen BA, *et al*. Age-related refractive shifts in simple myopia. *J Refract Surg* 1997;13:223–8.
30 Fotouhi A, Morgan IG, Iribarren R, *et al*. Validity of noncycloplegic refraction in the assessment of refractive errors: the Tehran Eye Study. *Acta Ophthalmol* 2012;90:380–6.
31 Hashemi H, Fotouhi A, Mohammad K. The age- and gender-specific prevalences of refractive errors in Tehran: the Tehran Eye Study. *Ophthalmic Epidemiol* 2004;11:213–25.