Optic Disc Ovality in Primary School Children in Beijing

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An oval-shaped optic disc represents the oblique insertion of the optic nerve into the ocular globe. The prevalence of oval-shaped optic discs and their associations with myopia, in particular with high myopia, have been reported in previous studies. In a longitudinal study of 1227 children, Samarawickrama et al.11 found an oval disc prevalence in 37% of their study participants. The prevalence of oval-shaped optic discs was associated with more marked myopic refractive error, higher cylindrical refractive error, and longer axial length. Although previous studies were focused on oval optic discs, only few investigations, besides the study by Samarawickrama et al.11 addressed the prevalence and associations of oval optic discs in children. In addition, the definition of an oval disc varied among studies. Samarawickrama et al.11 defined an oval or tilted optic disc to be present when one margin of the optic disc was raised above the opposite margin as seen from stereoscopic photographs, using a stereoscopic viewer. Other studies usually applied optic disc measurements and used minimal-to-maximal disc diameter ratio or vertical and horizontal disc diameters to define an oval disc shape. Because of the marked increase in the prevalence and severity of axial myopia in the young generation in East Asia and Southeast Asia and, because oval optic discs were associated with axial myopia, assessment of the prevalence and associated factors of oval discs may be of special interest in children, especially in China. One would be particularly interested in identifying features in children which may predispose to an eventual myopic shift. Knowledge of such features also would be of potential help in elucidating factors influencing the axial elongation of the eyes of children. We therefore conducted this study to examine the prevalence of oval optic discs in school children from Beijing and to explore their associations with other parameters.

METHODS

The study included children who attended primary schools (grades 1 and 4) in a rural region and an urban area of greater Beijing. The Human Research Ethics Committee of the Tongren Hospital, Capital Medical University, Beijing, approved the study protocol, and informed written consent according to the Declaration of Helsinki was obtained from at least one parent per child after explaining the study to parents and children.

Ophthalmologic examinations of the children included noncycloplegic autorefraction (autorefractor KR-8900, Topcon, Tokyo, Japan) and measurement of best corrected visual
acuity by subjective refractometry. Spherical equivalent refractive error was calculated as spherical refractive error +1/2 cylindrical refractive error. We also performed an examination of ocular motility, slit-lamp-based biomicroscopy assessment of the anterior and posterior ocular segments, and nonmydriatic digital fundus photography (45°; CR-DGI camera; Canon, Inc., Tokyo, Japan). Optical low-coherence reflectometry (Lenstar model LS900 optical biometer; Haag-Streit, Koeniz, Switzerland) was applied to measure central corneal thickness, corneal curvature, anterior chamber depth, lens thickness, and axial length of the right eyes of all subjects. All examinations were carried out by trained ophthalmologists and optometrists. The axial length-to-anterior corneal curvature (AL/CC) ratio, also known as axial length-to-corneal radius (AL/CR) ratio, was used as additional surrogate for refractive error.19

In a standardized interview and referring to the whole previous year, the parents were asked how long the children needed to get to school and how they went (by foot, bicycle, bus, or private car); how much time during school breaks was spent outdoors; and how much time was spent with what kind of sports or with leisure during the week and during the weekends (see Supplementary Table S1). The total time spent outdoors was summarized as time spent in any activity outdoors. Parents were also asked about the time the children spent indoors, including the time spent watching television and playing with electronic devices (see Supplementary Table S2). The average time spent daily on these activities was calculated using the formula: [(hours spent on a weekday) × 5 + (hours spent on a weekend day) × 2]/7. We also inquired about birth weight, mother’s age at birth, whether the children were breast fed, smoking habits and alcohol consumption of father and mother, level of education and profession of both parents, size of the house the family inhabited (in m²), monthly family income, and occurrence of myopia in the parents.

Optic disc photographs were defined as assessable if the optic disc margin could be clearly identified. Using disc photographs and ImageJ version 1.43u software (http://imagej.nih.gov/ij/; provided in the public domain by the National Institutes of Health, Bethesda, MD, USA), we measured the horizontal, vertical, and minimal and maximal optic disc diameters and optic disc areas. The optic disc shape was assessed by its ovality factor, measured as the maximal-to-minimal optic disc diameter ratio.20 Similar to previous studies, an oval optic disc was defined as an optic nerve head with an ovality of ≥1.33 (Fig.).21 The parapapillary region was differentiated into an alpha zone and a beta zone.18 The alpha zone was characterized by irregular pigmentation. On its outer side, it was bounded by the retina, and by the beta zone on its inner side, or if there was no beta zone, with the peripapillary ring of the optic disc margin. Features of the beta zone included thinning of the chorioretinal tissues with good visibility of the large choroidal vessels and the sclera. Magnification by ImageJ system was ×175. Combined with the magnification factor ×1.4 of the fundus camera, total magnification was ×245. We then corrected for the magnification by the optic medium of the eye, applying the method of Littmann, using either axial length measurements or refractive error measurements.22 Measurements were made by a trained ophthalmologist (YG), supervised by two optic nerve head specialists (LX, JBJ). The panel of the two optic nerve head specialists convened at intervals of 1 to 2 months to supervise the main examiner (YG) by checking the results obtained on randomly selected study participants and to discuss the results obtained on images selected by the main examiner. Two years after the baseline examination, the children were invited to be re-examined using the same techniques.23 Inclusion criterion for the present study was the availability of fundus photographs of sufficient quality to assess the optic discs.

Statistical analysis was performed using commercially available statistical software (SPSS version 22.0; SPSS, Chicago, IL, USA; for Windows; Microsoft, Redmond, WA, USA). Parameters were presented as means ± standard deviations. Normal distribution of the parameters was examined by

FIGURE. Oval optic nerve head in 2011 (left) and in 2013 (right) (same magnification); white arrows = parapapillary beta zone; black arrows = optic disc border; blue vertical bars (same length) = vertical disc diameter unchanged; horizontal black bars (same length) = horizontal disc diameter in 2013 (shorter in 2013 than in 2011); green horizontal bars (same length) = horizontal width of parapapillary beta zone in 2011 (shorter in 2011 than in 2013).
applying the Kolmogorov-Smirnoff test. Associations between disc ovality and other ocular and systemic parameters were examined first in univariate analysis and then in multivariate analysis. To examine associations between the prevalence of oval optic discs and other parameters such as refractive error, socioeconomic parameters, and indoor activity, the chi-square test was applied for categorical variables and a logistic regression analysis for continuous variables. After univariate analysis of potential associations, we performed a stepwise multivariate analysis with prevalence of oval optic discs as the dependent variable and, as independent variables, all parameters that showed a significant association with the main parameters in univariate analysis. Odds ratios (OR) were calculated and 95% confidence intervals (CI) were presented. All $P$ values were 2-sided and were considered statistically significant when the values were less than 0.05.

RESULTS

The study included 681 children, consisting of 382 students (56.1%) from grade 1 with a mean age of $6.3 \pm 0.5$ years (range, 5–8 years) and 299 students (43.9%) from grade 4 with a mean age of $9.4 \pm 0.7$ years (range, 8–13 years). Of these 681 children, fundus photographs of sufficient quality to assess the optic nerve head were available for 562 children (82.5%). The children with acceptable fundus photographs, compared to the children without those photographs, were significantly older ($7.8 \pm 1.7$ years of age versus $7.1 \pm 1.6$ years of age; $P < 0.001$), had longer axial lengths ($25.1 \pm 1.0$ mm versus $22.8 \pm 0.9$ mm; $P = 0.005$), a higher AL/CC ratio ($2.95 \pm 0.11$ vs. $2.91 \pm 0.09$; $P < 0.001$), and were more myopic ($-0.64 \pm 1.26$ diopters versus $-0.01 \pm 1.41$ diopters; $P < 0.001$).

Of the 681 students examined at baseline in 2011, 542 individuals (79.6%) returned for a follow-up examination in 2013. In the period from 2011 to 2013, the mean refractive error became more myopic, from $-0.64 \pm 1.26$ diopters by $-0.69 \pm 1.30$ diopters, mean axial length increased from $23.1 \pm 1.0$ mm by $0.58 \pm 0.96$ mm, and mean AL/CC ratio increased from $2.95 \pm 0.11$ by $0.07 \pm 0.10$.

At baseline examination in 2011, the mean optic disc ovality (minimal-to-maximal disc diameter ratio) was $1.17 \pm 0.29$ (median: 1.16; range, 1.00–1.50). Oval optic discs were detected in 37 of 562 children (prevalence: 6.6%; 95% CI: 4.5–8.6%).

In univariate analysis, the optic disc ovality was significantly associated with older age ($P < 0.001$; correlation coefficient $r = 0.19$), female sex ($P < 0.001$; $r = 0.18$), urban region of habitation ($P < 0.001$; $r = 0.17$), physical versus intellectual occupation of the father ($P < 0.001$; $r = 0.16$) and mother ($P = 0.005$; $r = -0.15$), more myopic refractive error ($P = 0.02$; $r = -0.10$), higher AL/CC ratio ($P = 0.01$; $r = 0.11$), greater increase in myopic refractive error from 2011 to 2013 ($P = 0.02$; $r = -0.12$), smaller change in cylindrical refractive error from 2011 to 2013 ($P = 0.02$; $r = -0.11$), larger parapapillary alpha zone ($P = 0.002$; $r = 0.13$) and larger parapapillary beta zone ($P < 0.001$; $r = 0.28$), smaller horizontal optic disc diameter ($P < 0.001$; $r = -0.51$), larger vertical optic disc diameter ($P < 0.001$; $r = 0.24$), smaller optic cup diameter ($P < 0.001$; $r = -0.15$), and smaller neuroretinal rim area ($P < 0.001$; $r = -0.18$). It was not significantly associated with body mass index ($P = 0.83$), birth weight ($P = 0.16$), breast feeding of the child during infancy ($P = 0.32$), maternal age at birth ($P = 0.95$), alcohol consumption ($P = 0.24$) and smoking ($P = 0.79$) by the mother during pregnancy, time spent outdoors ($P = 0.18$), time spent with indoors studying ($P = 0.20$), vertical optic cup diameter ($P = 0.74$), cylindrical refractive error ($P = 0.14$), change in AL/CC ratio ($P = 0.34$), best corrected visual acuity (logMAR) ($P = 0.26$), central corneal thickness ($P = 0.13$), corneal curvature radius ($P = 0.10$), paternal myopia ($P = 0.66$), maternal myopia ($P = 0.50$), and body weight ($P = 0.15$) (Table 1).

In multivariate linear regression analysis, higher optic disc ovality index remained significant (overall correlation coefficient $r = 0.42$; associated with older age ($P = 0.001$), female sex ($P = 0.005$) and larger parapapillary beta zone ($P < 0.001$), shorter time spent indoors studying ($P = 0.003$), and marginally significantly ($P = 0.057$) associated with greater increase in myopic refractive error from 2011 to 2013 (Table 2).

If the study population was stratified by the presence of an oval optic disc in 2011, the mean refractive error at the initial examination was $-1.15 \pm 1.43$ diopters in the oval optic disc group and $-0.62 \pm 1.25$ diopters in the nonoval optic disc group. The increase in myopic refractive error was $1.03 \pm 0.99$ diopters in the oval optic disc group compared to $0.67 \pm 1.31$ diopters in the nonoval group. In univariate analysis, presence of oval optic discs was significantly associated with older age ($P < 0.001$), female sex ($P = 0.004$), heavier body weight ($P = 0.002$), taller body height ($P = 0.02$), higher body mass index ($P = 0.04$), physical versus intellectual occupation of the father ($P < 0.001$) and mother ($P < 0.001$), more myopic refractive error ($P = 0.01$), larger cylindrical refractive error ($P = 0.048$), larger change in cylindrical refractive error ($P = 0.02$), higher AL/CC ratio ($P < 0.001$), larger parapapillary beta zone ($P < 0.001$), shorter vertical optic disc diameter ($P < 0.001$), and smaller vertical optic cup diameter ($P < 0.001$). It was not significantly associated with region of habitation ($P = 0.10$), best corrected visual acuity ($P = 0.54$), change in myopic refractive error from 2011 to 2013 ($P = 0.55$), axial length ($P = 0.08$), higher change in AL/CC ratio ($P = 0.05$), parapapillary alpha zone ($P = 0.06$), horizontal optic disc diameter ($P = 0.78$), vertical optic cup diameter ($P = 0.06$), and neuroretinal rim area ($P = 0.43$) (Table 3).

Multivariate regression analysis included the presence of oval optic discs as dependent variable and all those parameters as independent variables which were (defined here as $P$ value of $<0.10$) associated with the presence of oval optic disc in the univariate analysis. In the final model, presence of oval optic discs remained significantly associated with older age ($P = 0.03$; OR: 1.31 [95% CI: 1.04–1.66]), larger beta zone parapapillary atrophy ($P < 0.001$; OR: 12.8 [95% CI: 5.14–31.7]), and smaller cylindrical refractive error ($P = 0.04$; OR: 0.38 [95% CI: 0.15–0.97]).

DISCUSSION

In our school-based study population, the prevalence of oval optic discs, defined as a maximal-to-minimal disc diameter ratio of $\geq 1.33$ was 6.6%. A higher optic disc ovality was significantly associated with older age ($P = 0.001$), female sex ($P = 0.005$), larger parapapillary beta zone ($P < 0.001$), shorter time spent indoors studying ($P = 0.003$), and marginal significance ($P = 0.057$) associated with greater increase in myopic refractive error from 2011 to 2013 (Table 1). In univariate analysis, the prevalence of oval optic discs was additionally associated with higher AL/CC ratio and more myopic refractive error.

The prevalence of oval optic discs of 6.6% in our study population was higher than the prevalence reported in the Australian population-based Blue Mountains Eye Study$^6$ of an elderly population with a prevalence of oval or tilted discs of 1.6%, and it was higher than in the elderly population of the Beijing Eye Study with an oval optic disc prevalence of 0.36%.$^{6,21}$ The oval optic disc prevalence in our study was lower than that in a recent study from Singapore by Samarawickrama et al.$^{11}$ with a prevalence of 37%. Reasons for the differences between the prevalence rates of oval optic
In univariate analysis in our study, a higher optic disc ovality and, subsequently, a higher prevalence of oval optic discs were related to more marked myopia, in agreement with previous studies. Interestingly, multivariate analysis revealed that in our study population, the prevalence of oval optic discs and the disc ovality were no longer associated with age, sex, larger area of parapapillary beta zone, and shorter time spent indoors studying. Adding axial length to the model did not reveal significant associations. If the change in refractive error was added, the association with the disc ovality was marginally significant ($P = 0.06$) (Table 1). It suggests that in our study population, factors associated with older age, female sex, and potentially with lifestyle may have had a stronger influence on the prevalence of oval optic discs between the studies may have been differences in the prevalence of myopia, with a lower prevalence of myopia in the elderly populations from Beijing and Australia and higher myopia prevalence in the school children from Singapore and Beijing, and differences in the definition of oval optic discs. In the Singapore Cohort Study of Risk Factors for Myopia, optic disc tilting or ovality was diagnosed when an optic disc margin was raised above the opposite margin as seen on stereoscopic optic disc photographs. In other studies, a minimal-to-maximal optic disc diameter ratio of $0.7$ (equivalent to a maximal-to-minimal optic disc diameter ratio of $0.76$), or values of a minimal-to-maximal optic disc diameter ratio between $0.7$ and $0.8$ were used to define an oval optic disc. In our study, a higher optic disc ovality and, subsequently, a higher prevalence of oval optic discs were related to more marked myopia, in agreement with previous studies. Interestingly, multivariate analysis revealed that in our study population, the prevalence of oval optic discs and the disc ovality were no longer associated with age, sex, larger area of parapapillary beta zone, and shorter time spent indoors studying. Adding axial length to the model did not reveal significant associations. If the change in refractive error was added, the association with the disc ovality was marginally significant ($P = 0.06$) (Table 1). It suggests that in our study population, factors associated with older age, female sex, and potentially with lifestyle may have had a stronger influence on the prevalence of oval optic discs between the studies may have been differences in the prevalence of myopia, with a lower prevalence of myopia in theelderly populations from Beijing and Australia and higher myopia prevalence in the school children from Singapore and Beijing, and differences in the definition of oval optic discs. In the Singapore Cohort Study of Risk Factors for Myopia, optic disc tilting or ovality was diagnosed when an optic disc margin was raised above the opposite margin as seen on stereoscopic optic disc photographs. In other studies, a minimal-to-maximal optic disc diameter ratio of $0.7$ (equivalent to a maximal-to-minimal optic disc diameter ratio of $0.76$), or values of a minimal-to-maximal optic disc diameter ratio between $0.7$ and $0.8$ were used to define an oval optic disc.
optic disc shape than axial length or myopic refractive error had.

One may assume that the association between oval optic discs and parapapillary beta zone was secondary to the strain exerted on the temporal parapapillary region by the abnormal shape, and presumably by the abnormal rotation of the optic nerve head in eyes with ovaly configured optic discs. Optic discs which appear to be oval in the ophthalmoscopic view are often rotated around the vertical optic disc axis, leading to a perspective shortening of the horizontal disc diameter. Due to this vertical optic disc rotation, the nasal edge of the optic disc, compared to its temporal margin, is more prominent so that the definition of an oval or tilted optic disc as applied in clinical practice is at times not justified. A perspective image of a normally shaped optic nerve head is shown in Figure. 28 If the nasal margin of the optic disc, compared to its temporal margin, is more prominent so that the definition of an oval or tilted optic disc as applied in clinical practice is at times not justified. A perspective image of a normally shaped optic nerve head is shown in Figure. 28

Interestingly, the prevalence of oval optic discs in our young study population (prevalence: 6.6%) was markedly higher than in the adult population of the Beijing Eye Study (prevalence: 0.36%), with a mean age of 64.6 ± 9.8 years (range, 50–93 years).21 Both of the populations did not markedly differ in refractive error (–0.62 ± 1.42 diopters [range, –7.38 to +7.25 diopters]) of our study population versus –0.20 ± 2.07 diopters (range, –22.0 to +7.50 diopters); Beijing Eye Study population, axial length of 23.03 ± 0.96 mm [range, 19.01–26.17 mm] vs. 23.25 ± 1.14 mm (range, 18.96–30.88 mm) and mean AL/CC ratio (2.94 ± 0.11 vs. 3.05 ± 0.15). Because the supervising panel for the assessment of oval optic discs in both studies consisted of the same members (LX, JBJ), it is unlikely that the marked differences in prevalence of oval optic discs between both of the Chinese groups of different ages were due mainly to a measurement artifact. In view of the marked differences in age between both age groups and because the prevalence of oval optic discs increased with older age in our study, one may assume that the differences in the prevalence of oval optic discs between the study populations will further increase when the children of our study grow older.

Potential limitations of our study should be mentioned. First, the study was not population-based so that the possibility of a selection bias existed. Second, refractometry was not performed under cycloplegic conditions, so that involuntary accommodation during refractometry may have covered latent hyperopia. Instead of cycloplegic refractometry, however, we measured axial length and corneal curvature and took the ratio of both parameters as surrogate for refractive error. Third, a 2-year follow-up period might have been too short to determine longitudinal changes. Fourth, the study depended on the accuracy of answers to the standardized questionnaire given by the parents in the interview. Although a test of plausibility was performed in the sense that the total amount of time spent outdoors and indoors had to make sense in terms of the total time available, the reliability of the answers could not truly be assessed. Fifth, because optical coherence tomographic (OCT) images of the optic nerve head were not available, the study assessed the optic disc shape only in a 2-dimensional manner. An ophthalmoscopically oval optic disc, however, can just be the distorted perspective image of a normally shaped optic nerve head.28 If the position of the optic disc shifted from a location close to

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<th>Parameter</th>
<th>P Value</th>
<th>Regression Coefficient</th>
<th>Odds Ratio</th>
<th>95% CI</th>
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<td>0.35</td>
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<td>1.00–1.07</td>
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<td>Horizontal optic disc diameter, mm</td>
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<td>Vertical optic cup diameter, mm</td>
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<td>2.33–5.90</td>
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the center of the posterior pole to a location at the nasal side of the eye globe wall, the ophthalmoscopic view will no longer meet the optic disc in a perpendicular but at an oblique angle. As also pointed out in a previous study, this viewing of the optic disc in an oblique angle will lead to a change in the two-dimensionally assessed optic disc shape. The vertical disc diameter will remain unchanged, whereas the horizontal disc diameter in the 2-dimensional measurement will become shorter. In that constellation, the vertical disc diameter is the maximal diameter, and the horizontal disc diameter is the minimal disc diameter. Subsequently, the disc shape changes from a circular shape to a vertically oval shape. It reflects the rotation of the optic disc image around the vertical disc axis. The optic disc can rotate also around the horizontal axis with the superior disc pole compared with the inferior disc pole coming closer to the cornea. Finally, the optic disc can rotate around the sagittal axis, in which case the maximal disc diameter is oriented in an oblique angle to the horizontal and in which the vertical disc diameter is shorter than the maximal disc diameter. Disc rotation around the sagittal axis does not lead to a perspective distortion of the ophthalmoscopic optic disc image. In clinical practice, often a combination of a rotation around all three axes can be present. In summary, rotation of optic nerve heads may preclude the accurate characterization of their real shape and size from 2-dimensional fundus photographs, requiring instead 3-dimensional imaging, such as OCT. Sixth, the main goal of the study was to assess associations between optic disc shape (and the presence of abnormally shaped optic discs as defined by the ovality) and other ocular and systemic parameters, with special reference to myopia. We did not measure the orientation of the optic disc as defined by the angle between the maximal disc diameter and the horizontal. Future studies may determine that angle and may then differentiate between optic disc which were rotated mostly around the vertical axis and optic discs which were rotated predominantly around the horizontal axis. One could then address the question whether vertically rotated discs as compared to horizontally rotated discs show a stronger or weaker correlation with axial myopia associated parameters.

In conclusion, ovaly configured optic discs occurred in approximately 7 of 100 Beijing school children. This prevalence was higher than in adults in Beijing or in Australia, and it was lower than in Singaporean school children. It is consistent with the association between oval optic discs and axial myopia and the myopic shift taking place in the young generations in East Asia. The association between oval optic discs and the ophthalmoscopic parapapillary beta zone may be explained by the rotation of the optic disc around its vertical axis in eyes with oval optic discs potentially leading to a strain on the temporal disc margin. The association between a higher optic disc oval shape and less time spent indoors studying after adjusting for older age, female sex, larger parapapillary beta zone, and greater increase in myopic refractive error over two years may warrant further exploration of external factors potentially associated with oval-shaped optic discs.

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