EXTENDED REPORT

Optic disc size in a population based study in northern China: the Beijing Eye Study

Y Wang, L Xu, L Zhang, H Yang, Y Ma, J B Jonas

Br J Ophthalmol 2006;**90**:353–356. doi: 10.1136/bjo.2005.081521

See end of article for
authors' affiliations

Correspondence to:
Dr J Jonas, Universitäts-
Augenlinik, Theodor-
Kutzer-Ufer 1-3, 68167
Mannheim, Germany; jost.
jonas@augen.ma.uni-
heidelberg.de

Accepted for publication
3 November 2005

Aim: To determine the optic disc size in the adult Chinese population in an urban and a rural region of Beijing.

Methods: The population based, cross sectional cohort study included 4439 subjects out of 5324 subjects invited to participate (response rate 83.4%). It was divided into a rural part (1973 (44.4%) subjects) and an urban part (2466 (55.6%) subjects). Mean age was 56.2 (SD 10.6) years (range 40–101 years). Colour optic disc photographs were morphometrically examined. Main outcome measure was optic disc area.

Results: Optic disc photographs were available for 4027 (90.7%) subjects. Mean optic disc area measured 2.65 (0.57) mm² (range 1.03 mm²–7.75 mm²). Optic disc area was significantly ($p < 0.001$) correlated with myopic refractive error, with a steep decrease in optic disc area from high myopia to the mid-range of refractive error, a slightly horizontal course in the refractive error range between –8 dioptres and +4 dioptres, and a further decrease in optic disc area towards higher hyperopia. Optic disc area was not related to age ($p = 0.14$) or sex ($p = 0.93$) (optic disc area, males: 2.65 (0.56) mm² versus females: 2.65 (0.57) mm²). "Microdiscs" may be defined as smaller than 1.51 mm², and "macrodiscs" as larger than 3.79 mm².

Conclusions: Compared with data of preceding studies, mean optic disc size is larger in Chinese people than in white people. In Chinese people highly hyperopic eyes have significantly smaller optic discs, and highly myopic eyes have significantly larger optic discs than emmetropic eyes.

The size of the optic nerve head, showing a pronounced interindividual variability,^{1–6} depends on the ethnic background. Previous studies have shown that white people have smaller optic discs than Afro-Americans.^{4–9} Mansour found in a small sample of Oriental medical and paramedical students (Chinese, Vietnamese, Korean) to have a larger disc area than white students using the same camera, photographer, and measuring technique.⁸ Since the data on disc area are scanty in Chinese people, the present investigation was conducted to examine the optic disc area in Chinese people in a population based study. Additional goals of the study were to evaluate the relation between optic disc size and sex, refractive error, visual acuity, and socioeconomic data.

METHODS

The Beijing Eye Study, a population based cohort study in northern China, was carried out in seven communities, four communities from the urban district Haidian in the northern part of central Beijing, and three communities from a rural district in the village area of Yufa (Daxing District) in the south of Beijing. The reason to include rural and urban groups was to account for socioeconomic differences. The medical ethics committee of the Beijing Tongren Hospital had approved the study protocol and all participants had given informed consent, according to the Declaration of Helsinki. The study has been described in detail recently.^{10–12}

At the time of the survey in 2001, there were 5324 individuals aged 40 years or older residing in those seven communities. In total, 4439 individuals (8878 eyes; 2505 women) participated in the eye examination, corresponding to an overall response rate of 83.4%. All examinations were carried out in the communities, either in schoolhouses or in community houses. After obtaining the informed consent, visual acuity and intraocular pressure were measured as

described in detail recently.^{10–12} Uncorrected visual acuity was measured (Snellen charts) in a distance of 5 metres. Near vision was evaluated in a distance 25–30 cm using Jaeger charts, unaided and then using an addition for near vision. Automatic refractometry (Auto Refractometer AR-610, Nidek Co, Ltd, Tokyo, Japan) was performed, if uncorrected visual acuity was lower than 1.0. The values obtained by automatic refractometry were verified and refined by subjective refractometry. The spherical equivalent of refractive error was calculated as the spherical value of refractive error plus half of the cylindrical value. The pupil was dilated using tropicamide once or twice, until the pupil diameter was at least 6 mm. Photographs of the macula and optic disc were taken using a fundus camera (Type CR6-45NM, Canon Inc, USA).

The digitised optic disc photographs were measured by outlining the optic disc border on the computer screen and using a planimetric software program. The measurements were performed by a single examiner (YW) after a training period in which optic disc photographs of about 900 subjects had been examined and discussed with two glaucoma specialists (LX, JBJ). The magnification by the optic media of the eye were corrected according to Littmann's method taking into account the refractive error.¹³ The anterior corneal curvature radius was set at 7.8 mm, which is the reported mean for white people and Chinese people.¹⁴ To check the correction of the magnification of the optic disc photographs including the magnification by the fundus camera, the optic discs of 52 eyes were additionally imaged using a confocal laser scanning tomograph (Heidelberg retina tomograph, HRT; Heidelberg Engineering, Dossenheim, Germany). Measurements obtained by both techniques were compared with each other.

Statistical analysis was performed by using a commercially available statistical software package (SPSS for Windows,

Figure 1 Histogram showing the distribution of optic disc area in the Beijing Eye Study.

version 11.5, SPSS, Chicago, IL, USA). Only one eye per subject was taken for statistical analysis unless indicated otherwise. The data are given as mean (SD). The statistical strength of correlations were reported as correlation coefficient r or r^2 . Confidence intervals (95%) were presented. All p values were two sided and were considered statistically significant when the values were less than 0.05.

RESULTS

From the 4439 individuals, readable optic disc photographs were available for 4027 (90.7%) subjects. The rural part of the study included 1735 (43.1%) subjects and the urban part 2292 (56.9%) subjects. Mean age was 55.2 (SD 10.0) years (median 55 years; range 40–101 years), mean refractive error was -0.33 (2.07) dioptres (median 0 dioptres; range -18.75 dioptres to $+7.50$ dioptres).

Mean optic disc area measured 2.65 (0.57) mm^2 (median 2.60 mm^2) and showed an interindividual variability ranging from 1.02 mm^2 to 7.75 mm^2 or $1:7.6$ (fig 1). Excluding high myopia (less than -8.00 dioptres) and high hyperopia (more than $+4$ dioptres), optic disc area (mean (SD) 2.64 (0.52) mm^2) ranged between 1.02 mm^2 and 6.50 mm^2 (ratio 1:6.4).

Optic disc area was significantly ($p < 0.001$) larger in highly myopic eyes, and optic disc size was significantly ($p < 0.001$) smaller in highly hyperopic eyes than in the remaining eyes with a refractive error ranging between -8 dioptres and $+4$ dioptres. The correlation between optic disc area and refractive error showed a non-linear association with a steep decrease in optic disc area from high myopia to the mid-range of refractive error, a slightly horizontal course in the

Figure 2 Scattergram showing the correlation between optic disc area and refractive error in the Beijing Eye Study.

refractive error range between -8 dioptres and $+4$ dioptres, and a further decrease in optic disc area towards higher hyperopia (fig 2).

Optic disc area increased significantly with decreasing uncorrected visual acuity ($r = -0.13$; $p < 0.001$; 95% CI: -0.30 to -0.187) and decreasing best corrected visual acuity ($r = 0-0.09$; $p < 0.001$; 95% CI: -0.401 to -0.203). Excluding the highly myopic eyes and the highly hyperopic eyes, mean optic disc size was not associated with best corrected visual acuity ($r = -0.029$; $p = 0.069$). In the highly myopic group, best corrected visual acuity decreased, however not statistically significantly ($r = -0.25$; $p = 0.077$; 95% CI: -2.41 to $+0.13$), with enlarging optic disc area, parallel to an increase in optic disc area with increasing myopic refractive error ($r = -0.62$; $p < 0.001$; 95% CI: -0.35 to -0.16). In a multivariate analysis, with best corrected visual acuity as dependent variable, and disc area and refractive error as independent variables, best corrected visual acuity was significantly correlated with a lower degree of high myopia ($p = 0.003$; 95% CI: 0.16 to 0.76). It was statistically not associated with disc area ($p = 0.70$). In the highly hyperopic group, optic disc area increased, however not statistically significantly ($r = 0.38$; $p = 0.085$; 95% CI: -0.07 to 0.97) with best corrected visual acuity. Optic disc area decreased significantly with increasing hyperopia ($r = -0.45$; $p = 0.034$, 95% CI: -0.18 to -0.01). In a multivariate analysis, including best corrected visual acuity as dependent variable, and disc area and refractive error as independent variables, none of the associations remained statistically significant ($p > 0.10$).

Optic disc size was statistically independent of age ($p = 0.14$; 95% CI: 0.000 to 0.003). It did not vary significantly between males (2.65 (0.56) mm^2) and females (2.65 (0.57) mm^2 ; $p = 0.93$; 95% CI: -0.04 to 0.03). It was not associated with intraocular pressure ($r = 0.02$; $p = 0.13$, 95% CI: -0.001 to 0.010).

Based on the Gaussian-like distribution curve of the optic disc area, very small discs or “microdiscs” were defined as smaller than the mean minus twofold standard deviations (that is, 1.51 mm^2), and very large discs or “macrodiscs” were defined as larger than the mean plus twofold standard deviations—that is, 3.79 mm^2 . Refractive error was significantly ($p < 0.001$; 95% CI: 2.84 to 6.56) more hyperopic in eyes with minidiscs (0.49 (3.47) dioptres; range -8.13 dioptres to $+7.50$ dioptres) than in eyes with macrodiscs (-4.21 (5.65) dioptres; range -18.75 to $+2.88$ dioptres). The group of subjects with macrodiscs ($n = 127$ subjects) was further subdivided into highly myopic eyes with a myopic refractive error exceeding -8 dioptres (so called “secondary macrodiscs”; $n = 29$ (22.8%) subjects), and into eyes with a refractive error of -8 dioptres or less (“so called primary macrodiscs”; $n = 98$ (77.2%) subjects). Optic disc size in the eyes with primary macrodiscs (4.18 (0.50) mm^2 ; median, 4.00 mm^2 ; range, 3.80 mm^2 to 6.50 mm^2) was significantly ($p < 0.001$; 95% CI: -1.26 to -0.46) smaller than in the eyes with secondary macrodiscs (5.04 (1.01) mm^2 ; median 4.75 mm^2 ; range 3.87 mm^2 to 7.75 mm^2). For the eyes with primary macrodiscs, size of the optic disc was not associated with refractive error ($p = 0.25$). For the eyes with secondary macrodiscs, optic disc area increased significantly ($r = 0.49$; $p = 0.008$) with myopic refractive error within the highly myopic group.

Comparing the measurements obtained by planimetry of the digitised optic disc photographs and the measurements performed by confocal laser scanning tomography differed by a linear factor of $1:1.02$ from each other.

DISCUSSION

Mean optic disc area as measured on the optic disc photographs was 2.65 (0.57) mm^2 . Considering that confocal

laser scanning tomographic measurements of the optic nerve head revealed almost identical measurements as planimetry of digitised optic disc photographs, and comparing the measurements obtained in the present study with data in the literature, reveals that the Chinese people examined in the present investigation had larger optic discs than white people included in previous population based studies and in hospital based investigations.⁴⁻⁸

As in white people, the Gaussian-like distribution curve of the optic disc area in the present study (fig 1) may allow to define very small discs or "microdiscs" as being smaller than the mean minus twofold standard deviations (that is, 1.51 mm²).^{3 15} Very large discs or "macrodiscs" may be defined as being larger than the mean plus twofold standard deviations—that is, 3.79 mm². Since ethnic groups vary in optic disc size, the definition of microdiscs and macrodiscs depends on the ethnic group and the values may not be transferred from one ethnic group to the other. As in white people, the group of macrodiscs may further be subdivided into primary macrodiscs and secondary acquired macrodiscs.¹⁵ As in white people, primary macrodiscs were independent of refractive error in the present study, while secondary macrodiscs increased in size with increasing myopic refractive error (fig 2). Future studies in Chinese can shed light on the relation between disc size and optic nerve drusen, and optic disc size and non-arteritic ischaemic optic neuropathy.¹⁵⁻¹⁷

In white people, optic disc size is correlated with additional parameters such as neuroretinal rim area,^{2-5 15 18-21} retinal surface area, horizontal and vertical globe diameters, optic nerve fibre count, decreasing optic nerve fibre crowding in the disc, count and size of lamina cribrosa pores, and number of cilioretinal arteries, photoreceptors, and retinal pigment epithelium cells.^{15 22 23} Considering the ethnic differences in optic disc size, the question arises whether the relation between optic disc size and the parameters mentioned are valid also for Chinese people, and whether Chinese people, having a larger mean optic disc size than white people, have a lower frequency of diseases associated with a small optic disc in white people.

As in white people, optic disc area was associated with refractive error in Chinese people examined in the present study. Beyond a myopic refractive error of -8 dioptres, and beyond a hyperopia of +4 dioptres, respectively, the optic discs were significantly larger and smaller, respectively, than the optic discs of eyes with a refractive error ranging between -8 dioptres and +4 dioptres. The relation between optic disc area and refractive error may be taken as an aid to define high myopia (beyond -8 dioptres) and high hyperopia (beyond +5 dioptres). Similar values were found and proposed for white people.²⁴

In the present studies including Chinese with an age of 40+ years, optic disc area was not associated with age. Similar findings were reported for white people.^{3-5 15 21} With regard to sex, the results of several studies are partially contradictory. Some hospital based investigations suggested that optic disc size does not vary between women and men,^{3 4 15} while in the Rotterdam study, mean optic disc area was 3.2% larger in men than in women.⁵

In a similar manner, optic disc size was statistically independent of ametropia within a range of -8 dioptres to +4 dioptres of refractive error in the present study as well as in previous hospital based studies on white people.^{3 15 25} The Rotterdam study as epidemiological investigation on white people, however, revealed that disc area linearly increased by 1.2% (0.15%) for each dioptre increase towards myopia.⁵ Future studies may, therefore, address the question of whether the relation between optic disc size and refractive error is purely linear or curvilinear (fig 2).

There are limitations of the present study. For many studies on the size of the optic disc, the correction of the magnification of the optic disc image by the optic media of the eye and by the fundus camera has not been completely clear.²⁶⁻²⁹ The actual size of a fundus landmark is dependent on magnification due to the camera and the magnification due to the eye. Coleman and Mansour found that Littmann's mathematical approximation have less than 4% bias in correcting for eye magnification.^{27 28} Meyer found a difference between the Zeiss fundus camera and Topcon fundus camera, which is similar to the Canon fundus camera used in the present study, to be less than 4%.²⁹ So the various cumulative errors combined tend to be less than 8%, much less than the larger difference between the reported white people's disc area and the present Chinese disc area.²⁶

Additionally, the comparison of the optic disc size as measured by the confocal laser scanning tomograph HRT and as measured by the fundus camera used in the present study did not reveal a significant difference. It was another reason to conclude that the mean optic disc in Chinese is larger than in white people by the indirect comparison of studies.^{4-6 15} Another possible limitation of the study that the mean anterior corneal curvature radius was assumed to be 7.8 mm. It may imply an error in eliminating the variation and an error in ascertaining that the Chinese have an average radius like white people. The latter, however, has been shown in a previous study by Cheung and colleagues.¹⁴ Even if one assumes, that the correction of the magnification of the optic disc images in the present study did not lead to correct size measures in absolute units (that is, mm²), the other conclusions of the study may not have been directly affected, such as the differentiation between microdiscs and macrodiscs, the non-linear dependence of the optic disc on refractive error, and the lack of an association between optic disc area and age or sex.

In conclusion, the present population based study suggests that in Chinese people the optic disc is larger than in white people; that, as in white people, the optic disc size may show a non-linear relation with refractive error; and that the optic disc is independent of age beyond an age of 40 years. It appears that the present study performed in adults also applies to other age groups as Mansour showed that children have the same racial difference in disc area as adults.³⁰

Authors' affiliations

Y Wang, L Xu, L Zhang, H Yang, Y Ma, Department of Ophthalmology and Eye Hospital, Tongren Hospital, Beijing, China

J B Jonas, Department of Ophthalmology, Faculty of Clinical Medicine Mannheim, University of Heidelberg, Mannheim, Germany

Proprietary interest: none.

REFERENCES

- Franceschetti A, Bock RH. Megalopapilla: a new congenital anomaly. *Am J Ophthalmol* 1950;**33**:227-35.
- Bengtsson B. The variation and covariation of cup and disc diameters. *Acta Ophthalmol* 1976;**54**:804-18.
- Jonas JB, Gusek GC, Naumann GOH. Optic disc, cup and neuroretinal rim size, configuration, and correlations in normal eyes. *Invest Ophthalmol Vis Sci*. 1988;**29**: 1151-8. Correction: *Invest Ophthalmol Vis Sci*, 1991;**32**:1893.
- Varma R, Tielsch JM, Quigley HA, et al. Race-, age-, gender-, and refractive error-related differences in the normal optic disc. *Arch Ophthalmol* 1994;**112**:1068-76.
- Ramrattan RS, Wolfs RCW, Hofmann A, et al. Determinants of optic disk characteristics in a general population. The Rotterdam Study. *Ophthalmology* 1999;**106**:1588-96.
- Healey PR, Mitchell P. Optic disk size in open-angle glaucoma: the Blue Mountains Eye Study. *Am J Ophthalmol* 1999;**128**:515-17.
- Chi T, Ritch R, Stickler D, et al. Racial differences in optic nerve head parameters. *Arch Ophthalmol* 1989;**107**:836-9.
- Mansour AM. Racial variation of optic disc size. *Ophthalmic Res* 1991;**23**:67-72.

- 9 Tsai CS, Zangwill L, Gonzales C, et al. Ethnic differences in optic nerve head topography. *J Glaucoma* 1995;**4**:248–57.
- 10 Xu L, Li J, Cui T, et al. Visual acuity in Northern China in an urban and rural population. The Beijing Eye Study. *Br J Ophthalmol* 2005;**89**:1089–93.
- 11 Xu L, Li J, Zheng Y, et al. Intraocular pressure in Northern China in an urban and rural population. The Beijing Eye Study. *Am J Ophthalmol* 2006;**140**:913–15.
- 12 Xu L, Li J, Cui T, et al. Refractive error in urban and rural adult Chinese in Beijing. *Ophthalmology* 2005;**112**:1676–83.
- 13 Littmann H. Zur Bestimmung der wahren Größe eines Objektes auf dem Hintergrund des lebenden Auges. *Klin Monatsbl Augenheilkd* 1982;**180**:286–9.
- 14 Cheung SW, Cho P, Douthwaite W. Corneal shape of Hong Kong-Chinese. *Ophthalmic Physiol Opt*, 2000;**20**:119–25.
- 15 Jonas JB, Budde WM, Panda-Jonas S. Ophthalmoscopic evaluation of the optic nerve head. *Surv Ophthalmol* 1999;**43**:293–320.
- 16 Mullie MA, Sanders MD. Scleral canal size and optic nerve head drusen. *Am J Ophthalmol* 1985;**99**:356–9.
- 17 Beck RW, Savino PJ, Repka MX, et al. Optic disc structure in anterior ischemic optic neuropathy. *Ophthalmology* 1984;**91**:1334–7.
- 18 Betz Ph, Camps Fr, Collignon-Brach C, et al. Photographie stéréoscopique et photogrammétrie de l'excavation physiologique de la papille. *J Fr Ophtalmol* 1981;**4**:193–203.
- 19 Britton RJ, Drance SM, Schulzer MD, et al. The area of the neuroretinal rim of the optic nerve in normal eyes. *Am J Ophthalmol* 1987;**103**:497–504.
- 20 Caprioli J, Miller JM. Optic disc rim area is related to disc size in normal subjects. *Arch Ophthalmol* 1987;**105**:1683–85.
- 21 Jonas JB, Budde WM. Diagnosis and pathogenesis of glaucomatous optic neuropathy: morphological aspects. *Progr Ret Eye Res* 2000;**19**:1–40.
- 22 Panda-Jonas S, Jonas JB, Jakobczyk-Zmija M. Retinal pigment epithelium cell count, density and correlations in normal human eyes. *Am J Ophthalmol* 1996;**121**:181–9.
- 23 Panda-Jonas S, Jonas JB, Jakobczyk M, et al. Retinal photoreceptor count, retinal surface area, and optic disc size in normal human eyes. *Ophthalmology* 1994;**101**:519–23.
- 24 Jonas JB. Optic disc size correlated with refractive error. *Am J Ophthalmol* 2005;**139**:346–8.
- 25 Jonas JB, Gusek GC, Naumann GOH. Optic disk morphometry in high myopia. *Graefes Arch Clin Exp Ophthalmol* 1988;**226**:587–90.
- 26 Garway-Heath DF, Rudnicka AR, Lowe T, et al. Measurement of optic disc size: equivalence of methods to correct for ocular magnification. *Br J Ophthalmol* 1998;**82**:643–9.
- 27 Coleman AL, Haller JA, Quigley HA. Determination of the real size of fundus objects from fundus photographs. *J Glaucoma* 1996;**5**:433–5.
- 28 Mansour AM. Measuring fundus landmarks. *Invest Ophthalmol Vis Sci* 1990;**31**:41–2.
- 29 Meyer T, Howland HC. How large is the optic disc? Systematic errors in fundus cameras and topographers. *Ophthalmic Physiol Opt* 2001;**21**:139–50.
- 30 Mansour AM. Racial variation of optic disc parameters in children. *Ophthalmic Surg* 1992;**23**:469–71.