

## SCIENTIFIC REPORT

## Axial length and optic disc size in normal eyes

C Oliveira, N Harizman, C A Girkin, A Xie, C Tello, J M Liebmann, R Ritch

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**Aim:** To investigate the relationship between optic disc area and axial length in normal eyes of white and black people.

**Methods:** Consecutive eligible normal subjects were enrolled. Ocular biometry was obtained using A-scan ultrasonography, and reliable images of the optic disc were obtained using a confocal scanning laser ophthalmoscope. The relationship between optic disc area and axial length was assessed using univariate and multivariate models.

**Results:** 281 eyes of 281 subjects were enrolled. Black subjects ( $n=157$ ) had significantly larger discs (mean (SD) disc area,  $2.12$  ( $0.5$ )  $\text{mm}^2$ ) than white subjects ( $n=124$ ;  $1.97$  ( $0.6$ )  $\text{mm}^2$ ;  $t$  test,  $p=0.02$ ). Optic disc area increased with axial length (Pearson's correlation coefficient,  $r=0.13$ ,  $p<0.035$ ) for the entire study population. Multivariate regression models including race, disc area and axial length showed that a significant but weak linear relationship exists between axial length and disc area (partial correlation coefficient  $0.14$ ;  $p<0.024$ ), and with race and disc area (partial correlation coefficient  $0.19$ ;  $p<0.017$ ) when adjusted for the effects of other terms in the model.

**Conclusion:** Increased disc area is associated with longer axial length measurements and African ancestry. This may have implications for pathophysiology and risk assessment of glaucoma.

Morphological characteristics of the optic disc are routinely assessed during glaucoma screening, diagnosis and longitudinal disease management. Controversy remains over the importance of optic disc size as an independent risk factor for the onset and progression of glaucomatous optic neuropathy.<sup>1</sup> The optic disc area is significantly larger in eyes with high myopia compared with those with emmetropia and hyperopia.<sup>1–6</sup> There is a possible link between open-angle glaucoma and myopia, but the mechanism responsible for this relationship is still unknown.<sup>7–8</sup>

Further, black people are known to have relatively larger discs compared with white people,<sup>9–14</sup> and there is a higher prevalence of primary open-angle glaucoma with higher rates of blindness in the first group.<sup>7–15–17</sup>

The purpose of this study was to assess optic disc topography and axial length in a population of black and white normal subjects, and to determine whether optic disc area is related to axial length.

## METHODS

This study was approved by the Institutional Review Board for Human Research of the New York Eye and Ear Infirmary and by the University of Alabama at Birmingham Human Subjects Committee, and all subjects provided signed informed consent. Consecutive eligible volunteers underwent complete ophthalmologic examination including slit-lamp biomicroscopy, intraocular pressure (IOP) measurement, stereoscopic fundus examination, simultaneous stereoscopic photographs of the optic disc (Nidek 3-Dx Stereo disc camera, Nidek, Fremont,

California, USA), bilateral standard, achromatic 24-2 perimetry using the Swedish interactive thresholding algorithm testing strategy (Humphrey Field Analyzer II, Carl Zeiss Meditec, Dublin, California, USA), ocular biometry (A-scan, A 2500, Sonomed, Lake Success, New York, USA) and confocal scanning laser ophthalmoscopy (Heidelberg Retina Tomograph II (HRT II), Heidelberg Engineering, Dossenheim, Germany).

Eligible subjects were aged  $\geq 18$  years, had a normal ophthalmic examination including a best corrected visual acuity of  $\geq 20/40$ , refractive error  $< 5\text{D}$  sphere and  $< 3\text{D}$  cylinder, normal slit lamp biomicroscopy and IOP  $< 22$  mm Hg. Achromatic perimetry was unremarkable and reliable ( $\leq 33\%$  false positives,  $33\%$  false negatives and  $33\%$  fixation losses, pattern standard deviation within  $95\%$  normal limits and glaucoma hemifield test results normal). Subjects with a history of intraocular surgery, other intraocular disease and diseases affecting the visual field or colour vision were excluded. Racial groups were defined by self-report, determined by an interviewer-administered questionnaire defining self-described race as African-American, Caucasian, or other. Only those from the first two races were eligible for the study.

The HRT II confocal scanning laser ophthalmoscope employs a diode laser (670 nm wavelength) to produce three-dimensional measurements of optic disc topography on the basis of reflectance from the retinal and optic disc surfaces. It provides topographic measurements of the optic nerve and peripapillary retina. The topographic image is derived from 32–64 transverse optical section images taken at consecutive focal depth planes.

Although pupil dilation is often not required, all subjects were imaged after dilation. Keratometry measurements were used to correct for magnification error. Three  $15^\circ$  images of one eye were obtained in sequence per imaging session automatically by the instrument. A mean topography image adjusted for alignment and rotation was created automatically with the existing software and used for all analyses. Good image quality was evaluated by an experienced operator who outlined the disc margin while viewing the respective stereoscopic photograph, and was defined as follows: acquisition sensitivity  $< 90\%$ , topography standard deviation (SD)  $< 40$   $\mu\text{m}$ , more than three quarters of the disc within the target circle, minimal movement during the acquisition movie, no floaters over the disc, and good imaging clarity and exposure. The HRT II software was used to calculate disc area during image analysis.

One eye was randomly selected for the statistical analyses performed using SPSS for Windows V.13.0 and SAS for window V.9.0. Student's  $t$  test was used for comparison of characteristics between black and white subjects, with respect to continuous variables such as age, axial length and disc area. Spearman's partial correlations were calculated from general linear models to determine whether a significant independent linear relationship exists between axial length and disc area,

**Abbreviations:** HRT II, Heidelberg Retina Tomograph II; IOP, intraocular pressure

controlling for the influences of race;  $p < 0.05$  was considered significant.

## RESULTS

A total of 281 eyes of 281 eligible subjects (124 (44%) white subjects and 157 (56%) black subjects) were enrolled. Their mean (SD, range) age was 42.6 (12.7, 18–77) years, mean (SD, range) axial length was 23.67 (0.9, 21.68–27.36) mm and mean (SD, range) disc area was 2.05 (0.5, 0.95–4.8)  $\text{mm}^2$ . Table 1 gives the distributions for age, axial length and disc area for the whole study group, for black and white subjects.

Univariate regression models showed that optic disc area increased with axial length (Pearson's correlation coefficient  $r = 0.13$ ,  $p < 0.035$ ), for the entire study population ( $n = 281$ ; fig 1). As a separate group, black subjects presented a similar significant correlation between axial length and disc area ( $r = 0.17$ ,  $p < 0.037$ ; fig 2). Among white subjects the correlation between axial length and disc area did not reach significance ( $r = 0.1$ ,  $p < 0.250$ ; fig 3).

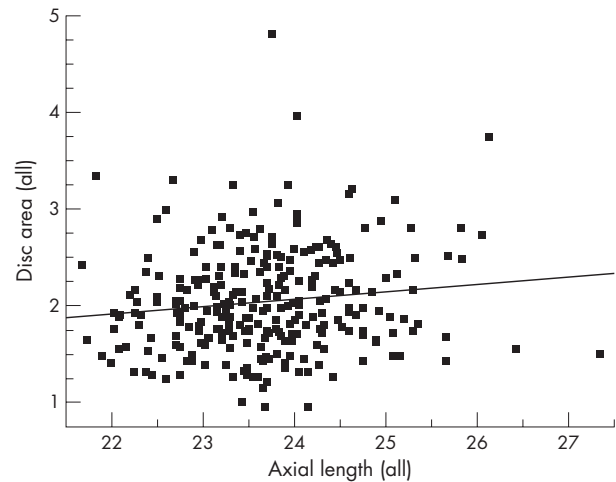
Multiple linear regression models including race, disc area and axial length showed that a significant but weak linear relationship exists between axial length and disc area (partial correlation coefficient 0.14;  $p < 0.024$ ), and with race and disc area (partial correlation coefficient 0.19;  $p < 0.017$ ) when adjusted for the effects of other terms in the model.

## DISCUSSION

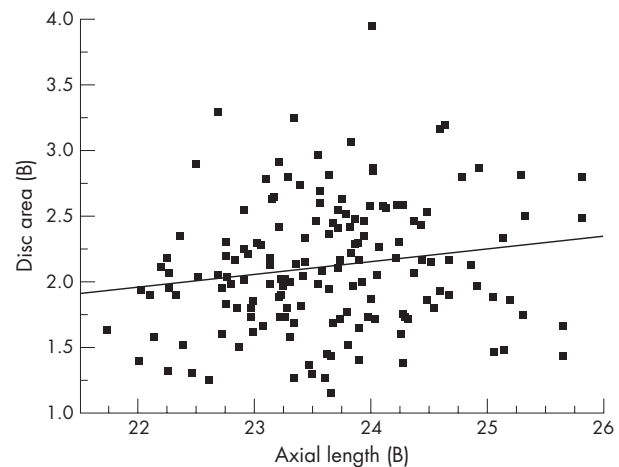
We were able to show a significant and positive correlation between axial length and disc area assessed with HRT II in the normal eyes of black and white subjects. Increased disc area was associated with longer axial length measurements and African ancestry.

Previous reports assessing the relationship between disc area and myopia vary. Disc area increased with increasing myopia in highly myopic eyes ( $> -8.00$  D) of both normal white subjects and those with glaucoma whose optic discs were evaluated with stereophotographs, but not in highly myopic eyes.<sup>5–6, 18</sup> In a population-based study including normal white subjects and those with glaucoma, disc and rim area measured in projections of stereophotographs had a negative correlation with refractive error even in patients with lower myopia.<sup>3</sup> Optic disc and rim areas measured with the Rodenstock Optic Disc Analyzer in normal eyes of white subjects correlated with axial length.<sup>19</sup>

Many investigators, in both selected cohorts and population-based studies, have reported that there is no significant difference in rim area between black and white subjects.<sup>10–11, 13–14</sup> In the only study that found smaller rim area in black subjects, the investigators evaluated the optic disc of ocular hypertensives using HRT,<sup>9</sup> in contrast with the other studies that evaluated normal subjects. Some of the subjects in the first study may have presented early structural damage,<sup>20</sup> which probably accounts for the discrepancy in results. These studies found that black subjects have a larger disc area than white



**Figure 1** Scatter plot showing the relationship between disc area and axial length for the entire study population ( $n = 281$ );  $r = 0.13$ ,  $p < 0.035$ .



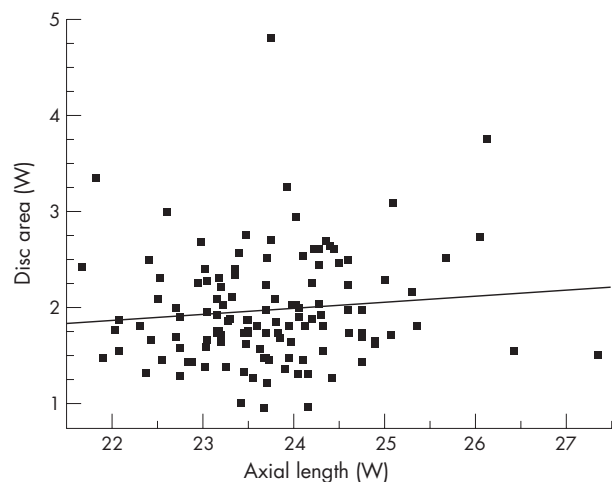
**Figure 2** Scatter plot showing the relationship between disc area and axial length in black (B) subjects ( $n = 157$ );  $r = 0.17$ ,  $p < 0.037$ .

subjects.<sup>9–11, 13–14</sup> The relationship between these anatomical differences in optic disc structure between black and white subjects and the more aggressive disease seen in black populations is unclear.<sup>7, 15–16</sup> There is a biomechanical disadvantage of the larger disc.

The role of optic disc size in glaucoma is still unclear. There are several studies supporting the theory that a larger disc may impart a greater risk for developing and progressing with

**Table 1** Distribution of age, axial length and disc area of the entire study population ( $n = 281$ ) comprising black ( $n = 157$ ) and white ( $n = 124$ ) subjects

	All		Black subjects (B)		White subjects (W)		p Value (t test) B v W
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	
Age (years)	42.6 (12.7)	18–77	43.9 (13)	19–77	41 (12.2)	18–69	0.06
Axial length (mm)	23.67 (0.9)	21.68–27.36	23.6 (0.8)	21.72–25.82	23.7 (0.9)	21.68–27.36	0.4
Disc area ( $\text{mm}^2$ )	2.05 (0.5)	0.95–4.8	2.12 (0.5)	1.15–3.95	1.97 (0.6)	0.95–4.8	0.02



**Figure 3** Scatter plot showing the relationship between disc area and axial length in white (W) subjects ( $n = 124$ );  $r = 0.1$ ,  $p < 0.25$ .

glaucomatous damage. Jonas *et al*<sup>21, 22</sup> have reported a higher susceptibility for neuroretinal rim loss in areas with a longer distance to the exit of the central retinal vessels than in areas with a short distance. Also, computational finite element models developed using idealised posterior scleral shells suggested that a larger disc and consequent larger lamina cribrosa surface area would undergo greater displacement in the presence of increased IOP.<sup>10</sup> In highly myopic eyes the lamina cribrosa is thinner and its posterior surface is more exposed to the cerebrospinal fluid space, which may increase the translaminal pressure gradient at a given IOP.<sup>23</sup> Black subjects are known to have larger discs and a worse natural history of glaucoma than white subjects.<sup>7, 15, 16</sup> In contrast with the supporting evidence, there are reports that (1) optic nerve fibres are more crowded and are thus possibly more susceptible to mechanical deformation in small discs<sup>24</sup>; (2) small discs have a smaller anatomical reserve because they contain fewer axons<sup>25</sup>; and (3) optic disc size is not associated with the frequency of progression of glaucomatous visual field defect.<sup>26</sup>

According to a cross-sectional study with magnetic resonance imaging analysis of normal living eyes with myopia and emmetropia grouped by refractive correction, eyes with myopia have greater dimensions (length, width and height), predominantly in length, than those with emmetropia.<sup>27</sup> The differences in length, height and width significantly correlated with best sphere correction, suggesting that an eye with myopia, while developing, grows in all directions.<sup>27</sup> The relative weakness of axial length as a predictor for disc area may be explained by the variable patterns of eye growth associated with myopia, as a long eye may have a small disc if its width and height do not increase as much as its length.

In summary, both axial length and race have a significant but weak independent correlation with disc area. Further investigation taking into consideration the differences in patterns of eye expansion could contribute to the elucidation of differences in disc morphology and therefore in susceptibility to glaucomatous damage between black and white subjects.

#### Authors' affiliations

**C Oliveira, N Harizman, C Tello, R Ritch**, Department of Ophthalmology, The New York Eye and Ear Infirmary, New York, New York, USA

**C A Girkin, A Xie**, School of Medicine, University of Alabama, Birmingham, Alabama, USA

**J M Liebmann**, Manhattan Eye Ear and Throat Hospital, New York, New York, USA

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Correspondence to: J M Liebmann, New York University School of Medicine, 310 East 14th Street suite 304, New York, NY 10003, USA; jml18@earthlink.net

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