Influence of Height, Weight, and Body Mass Index on Optic Disc Parameters

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PURPOSE. To examine the influence of body height, body weight, and body mass index (BMI) on optic disc parameters in a population-based study.

METHODS. The Singapore Malay Eye Study examined 3280 persons of Malay ethnicity, aged 40 to 80 years, of whom 2329 (71.0%) had reliable retinal scanning confocal laser tomography images for analyses. Intraocular pressure (IOP) was ascertained by Goldmann applanation tonometry. Body height and weight were measured with standardized protocols; BMI was calculated as weight (kilograms)/height squared (meters). Sociodemographic information was collected in an interviewer-administered questionnaire.

RESULTS. In univariate analyses, body height, weight, and BMI were significantly associated with optic cup area, rim area, and cup-to-disc area ratio (all with P < 0.05) but none of the anthropometric parameters was significantly associated with optic disc area (all with P > 0.05). In multiple regression analyses after adjustment for age, sex, optic disc size, axial length, education, family income, and IOP, each SD increase in body height was associated with a 0.042-mm² decrease in optic rim area and a 0.020 increase in optic cup-to-disc ratio area; each SD decrease in body weight was associated with a 0.013-mm² decrease in optic rim area and a 0.010 increase in optic cup-to-disc ratio; and each SD decrease in BMI was associated with a 0.021-mm² decrease in optic rim area and a 0.020 increase in optic cup-to-disc area ratio; and higher intraocular pressure (IOP), have been consistently identified in different studies.1,3,4 Uncertainty remains regarding other risk factors for glaucoma.5

The relationships between body height, body mass index (BMI), and primary open angle glaucoma (POAG) are controversial. In some studies an association has been reported between body height and increased optic cup-to-disc ratio, a clinical marker of glaucomatous damage, but in others this relationship was not confirmed.6–10 In addition, increased BMI appears to be a protective factor for OAG,11–13 but this association contradicts findings that increased BMI is associated with elevated IOP.14 Given the heterogeneous results across these studies, we examined the relationships of body height, weight, and BMI with optic disc parameters (in particular the cup-to-disc ratio) as measured quantitatively by confocal scanning laser ophthalmoscopy (CSLO) in a population-based study.

METHODS

Study Population

The Singapore Malay Eye Study was a population-based cross-sectional study conducted in Singapore from 2004 to 2006.15,16 In brief, an age-stratified random-sampling procedure was used to select people of Malay ethnicity aged 40 to 80 years living in the southwestern part of Singapore. Among the 4168 persons eligible to participate, 3280 were examined (participation rate, 78.7%).16 The study was conducted in accordance with the World Medical Association Declaration of Helsinki, and ethics approval was obtained from the Institutional Review Board.

Optic Disc Imaging

CSLO was performed with a system (Heidelberg Retinal Tomograph II [HRT II]; Heidelberg Engineering GmbH, Dossenheim, Germany) that employs a diode laser (670 nm wavelength) to sequentially scan the retinal surface with the field of view set at 15°.17 Optic disc parameters were measured through dilated pupils. The corneal radius of curvature was entered into the system software for all subjects, and cylindrical lens power was adapted for those with astigmatism greater than or equal to 1 D. All CSLO examinations were performed by two operators. The CSLO optic nerve head (ONH) scanning protocol was used. A three-dimensional topographic image consisting of up to 384 × 384 × 64 pixels was constructed. An average of three consecutive scans was obtained and aligned to compose a single mean topography for analysis. Each image was coupled with a standard deviation (SD) to reflect the image quality. An SD higher than 50 μm was used as an exclusion criterion.18 After the study was completed, the optic disc margin was defined and manually outlined by a trained ophthalmologist.14 This critical step was accomplished by plotting a series of dots around the margin of the disc on the reflectance image provided by the computer. The disc margin was defined as the inner edge of Elschnig’s ring. The standard reference plane was defined at 50 μm posterior to the mean retinal height between 350° and 356° along the contour line. Optic nerve head parameters, including optic disc area, neuroretinal rim.
area, cup area, and cup-to-disc area ratio were measured and generated by the system software.

**Anthropometric Measurements and Other Information**

Height was measured with a wall-mounted tape and weight with a digital scale (SECA, model #82 2321009; Vogel & Halke, Hamburg, Germany). BMI was calculated as weight (in kilograms) divided by the square of height (in meters). A detailed, interviewer-administered questionnaire was used to collect information about ocular surgery history, socioeconomic status (e.g., education levels, family income) and other variables. IOP was measured with a Goldmann applanation tonometer (GAT; Haag-Streit, Kôniz, Switzerland) before pupil dilation. Axial length was measured with a noncontact partial coherence laser interferometer (IOL Master, ver. 3.01; Carl Zeiss Meditec, Jena, Germany). Systolic and diastolic blood pressures were measured with an automatic blood pressure monitor (Dinamap model Pro Series 1010XR; 1000V; GE Medical Systems Information Technologies, Inc., Milwau-kee, WI).

**Measurement and Definition of Glaucoma**

The definitions of suspected glaucoma and definitive glaucoma cases are described elsewhere. All participants with suspected glaucoma underwent visual field testing and were defined by any of the following criteria: (1) Goldmann applanation IOP > 21 mm Hg; (2) vertical cup-to-disc ratio (VCDR) > 0.6 or VCDR asymmetry > 0.2, determined by a ×78-D lens, at ×16 magnification, by slit lamp; (3) abnormal anterior segment deposits consistent with pseudoxfolliation or pigment dispersion syndrome; (4) ocular angle, defined as posterior trabecular meshwork seen for ≤180º of the angle circumference during static gonioscopy; (5) peripheral anterior synechiae or other findings consistent with secondary glaucoma; and (6) known history of glaucoma.

Glaucoma was defined according to the International Society for Geographical and Epidemiological Ophthalmology (ISGEO) criteria, based on three categories. Category 1 was defined as optic disc abnormality (VCDR or VCDR asymmetry ≥ 97.5th percentile or neuroretinal rim (NRR) width between 11 and 1 o’clock or 5 and 7 o’clock < 0.1 VCDR) with a corresponding glaucomatous visual field defect. Category 2 was defined as a severely damaged optic disc (VCDR or VCDR asymmetry ≥ 99.5th percentile) in the absence of an adequate visual field test. In diagnosing category 1 or 2 glaucoma, it was required that there be no other explanation for the VCDR finding (e.g., dysplastic disc or marked anisometropia) or visual field defect (e.g., branch retinal vein occlusion, macular degeneration, or cerebrovascular disease). Category 3 cases were defined as subjects without visual field or optic disc data who were blind (corrected visual acuity, < 3/60) and who had undergone glaucoma surgery or had an IOP > 99.5th percentile.

Automated perimetry (SITA Fast 24-2, Humphrey Visual Field Analyzer II; Carl Zeiss) was performed with near refractive correction on all participants with suspected glaucoma as well as one in five consecutive participants with no suspected glaucoma (n = 641 persons). The visual field test was repeated on another occasion if the test reliability criteria were not satisfied (fixation losses > 20%, false positives > 33% and/or false negatives > 33%) or if there was a glaucomatous visual field defect, which is defined as (1) glaucoma hemifield test (GHT) outside normal limits and (2) a cluster of three or more, nonedge, contiguous points, not crossing the horizontal meridian, with a probability of < 5% of the age-matched normal on the pattern deviation plot on two separate occasions.

**Statistical Analysis**

Since the correlations between the two eyes for optic disc parameters were high (e.g., correlation coefficients between right and left eyes for optic disc area = 0.82), only the data from the right eyes were included in further analyses. Univariate and multiple linear regression models were used to estimate the difference in optic nerve head parameters (including disc area, rim area, cup area, and cup-to-disc area ratio) and IOP for each SD change in anthropometric parameters (body height, body weight, and BMI; Stata, ver. 8.2; Stata Corp., College Station, TX).

**RESULTS**

Of 3280 participants, 224 were unable to complete the retinal tomography test or had no tomography imaging data, 195 had a test, but with poor image quality (SD > 50 µm). The image quality SD was 21.6 ± 9.7 µm for the remaining 2861 persons. Of these, 121 had diagnosed glaucoma, 205 had suspected glaucoma (including persons with suspicious glaucomatous changes in the disc), and 206 had a history of ocular surgery (including cataract surgery or retina photocoagulation) and were excluded, leaving 2529 persons (1123 men; mean age, 56.8 ± 10.5 years, and 1206 women; mean age, 55.6 ± 9.9 years) for the final analyses.

Table 1 shows the correlations of height, weight, and BMI with sociodemographic and systemic and ocular biometric variables. Height correlated negatively with age, sex, IOP, and rim area and positively with education level, income level, axial length, disc area, cup area, and cup-to-disc area ratio (all with P < 0.05). Weight and BMI correlated with similar variables as did height, but they were positively associated with elevated IOP level (both P < 0.05).

Higher body height, lower body weight, and lower BMI were associated with larger cup-to-disc area ratio (Fig. 1). In Table 2, each value represents the result of a separate regression model, with individual optic disc parameters or IOP as the dependent variable, and height, weight, and BMI as independent variables in the models. In multiple regression analyses after adjustment for age, sex, axial length, optic disc area, IOP, education, and income level, each SD increase in height was associated with a 0.042-mm² decrease in rim area and a 0.020 increase in cup-to-disc area ratio. In similar multiple regression analyses, each SD decrease in weight was associated with a 0.376-mm² decrease in IOP, a 0.013-mm² decrease in rim area, and a 0.010 increase in cup-to-disc area ratio. None of the anthropometric parame-
In this population, the proportion of persons with myopia (defined as spherical equivalent $< -0.5$ D) and high myopia (spherical equivalent $< -6.0$ D) was 22.0% (95% confidence interval [CI], 20.3%–23.7%) and 2.4% (95% CI, 1.8%–3.0%), respectively. We performed a subsidiary analysis, stratifying the group by the presence or absence of high myopia. In persons without high myopia ($n = 2272$), multivariate adjusted associations were similar. Each SD increase in body height, each SD decrease in body weight, and each SD decrease in BMI was associated with a $0.018 (P < 0.001)$, $0.012 (P < 0.001)$, and $0.011 (P < 0.001)$ increase in cup-to-disc area ratio, respectively. In persons with high myopia ($n = 57$), however, there were no significant associations between anthropometric parameters and optic disc parameters (all $P > 0.05$).

**FIGURE 1.** Relationship of height (A), weight (B), and BMI (C) with cup-to-disc area ratio. The means and 95% CI (error bars) are adjusted for age and sex.

Associations were consistent across subgroups stratified by sex in the multiple regression analyses. In the men, each SD increase in body height, each SD decrease in body weight, and each SD decrease in BMI was associated with a $0.017 (P < 0.001)$, $0.012 (P < 0.001)$, and $0.010 (P < 0.001)$ increase in cup-to-disc area ratio, respectively. In the women, each SD increase in body height, each SD decrease in body weight, and each SD decrease in BMI was associated with a $0.010 (P = 0.003)$, and $0.011 (P = 0.001)$ increase in cup-to-disc area ratio, respectively. Body weight and BMI showed consistent associations with increased IOP across sex subgroups ($P < 0.001$).

In this population-based study of adult ethnic Malay persons, we found that individuals with greater body height, lower body weight, and lower BMI tended to have a smaller neuroretinal rim area and larger cup-to-disc area ratio. The associations persisted after adjustment for age, sex, axial length, optic disc size, and socioeconomic confounding factors and were consistent across the male and female subgroups. Furthermore, lower body weight and BMI were significantly associated with decreased IOP level. However, the magnitude of these associations was small, and the clinical significance of these findings requires further confirmation.

Our findings of the associations between body height, weight, BMI and optic disc parameters are not fully consistent with the results that have been reported by other groups. In the Tajimi study of 2036 Japanese in which the HRT II instrument was used, body height, but not body weight, was associated with larger cup-to-disc area ratio and smaller rim area. Similar associations were reported in the Tanjong Pagar Study on the basis of stereophotographs obtained in 622 ethnic Chinese. These associations, however, were not observed in the hospital-based study by Jonas et al. (517 white subjects, using stereophotographs), the Central Indian Eye and Medical Study (1000 Indians; HRT scan), and the Rotterdam Study (5114 white patients, stereophotographs). The Rotterdam Study also found a positive association between disc area and body height. The discrepancies may be explained by the differences in measurement method, ethnicity, and sample size in the different studies.

The results in the current study are consistent with several cross-sectional and longitudinal reports, in which higher body weight and BMI were associated with elevated IOP levels. Therefore, the association of lower body weight with larger optic cup-to-disc ratio may not be mediated by IOP. The associations between anthropometric factors and optic parameters may be biologically plausible, if genes that determine body growth or weight are also involved in the development of the retinal nerve fiber layer. Nevertheless, it is unclear whether other unmeasured social factors could have affected the associations revealed in this study. The possibility of residual confounding could not be ruled out, although several socioeconomic factors have been adjusted for in our multiple analyses.

Given that persons at risk of glaucoma tend to have a larger cup-to-disc ratio and a smaller optic rim area, our findings appear to support the unproven notion that tall persons with low BMI have a higher risk of glaucoma and other optic neuropathies. The low prevalence rate of late-stage POAG

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**DISCUSSION**

In this population-based study of adult ethnic Malay persons, we found that individuals with greater body height, lower body weight, and lower BMI tended to have a smaller neuroretinal rim area and larger cup-to-disc area ratio. The associations persisted after adjustment for age, sex, axial length, optic disc size, and socioeconomic confounding factors and were consistent across the male and female subgroups. Furthermore, lower body weight and BMI were significantly associated with decreased IOP level. However, the magnitude of these associations was small, and the clinical significance of these findings requires further confirmation.

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Given that persons at risk of glaucoma tend to have a larger cup-to-disc ratio and a smaller optic rim area, our findings appear to support the unproven notion that tall persons with low BMI have a higher risk of glaucoma and other optic neuropathies. The low prevalence rate of late-stage POAG...
substantial, because the mean magnification error from CSLO parameters. We believe that the magnification effect is not to affect the relationship between body height and optic disc tion based on spherical refractive error and keratometry tends ing analysis may help uncovering the relationship of anthropo-
POAG risk in this study. Further large-scale studies using pool-
or BMI (per SD increase) limited

The strengths of this study include its large population-based design and reliable measurement of optic disc parameters. This study, nevertheless, has several limitations. First, Garway-Heath et al.26,27 showed that the magnification correc-
tors. This study, nevertheless, has several limitations. First,

Second, our cross-sectional design prevented inferring causal-
ity or a chronological order of changes. The temporal relation-
ship between anthropometric factors and optic disc parameters remains uncertain. Third, as in other population-based studies that have used the ISGEO scheme to diagnose glaucoma, a small proportion of the persons with pseudonormal optic cups (e.g., minicups) and normal IOP may have been misclassified as nonglaucomatous and could thus have been included in our analyses. Thus, a bias may have arisen if the optic rim area was partially reduced in these pseudonormal subjects and the occurrence of pseudonormal glaucomatous optic change was associated with body height or BMI. Fourth, a bias could have also occurred if eyes with nonglaucomatous optic neuropathy were included in the analyses. However, such inclusions would be unlikely, given that each subject was carefully examined by an experienced ophthalmologist and all fundus images were reviewed by one of the senior authors (AT). Finally, this study was limited by the inclusion of eyes with tilted discs, for which CSLO measurement may be problematic. Nevertheless, the proportion of eyes with a tilted disc may not be substantial as the prevalence of high astigmatic refractive error was relatively low in this population.21

In summary, in our cohort of Malay persons aged 40 to 80 years, persons who are taller and with lower BMI tended to have smaller neuroretinal rim area and larger cup-to-disc area ratio measured by CSLO. However, the magnitude of these associations was quite small and therefore the clinical signifi-
cances require further investigation.

References


