African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

Effect of age and gender on the vertical cup-to-disc ratio in a normotensive population

Authors:
Victor C. Egbusim[1]
Christian C. Duru[1]
Obinna P. Anyatonwu[2]
Udo U. Ahanna[3]
Magnus C. Nsonwu[1]
Anthony O. Kamalu[4]
Uchenna Anyanwu[5]
Chiemeka B. Ukoh[6]

Affiliations:
[1]Department of Optometry, Faculty of Health Sciences, Imo State University, Owerri, Nigeria

[2]Department of Public Health and Clinical Medicine, Faculty of Epidemiology and Global Health Unit, Umea University, Umea, Sweden

[3]Department of Optometry, Faculty of Health Sciences, Abia State University, Uturu, Nigeria

[4]Department of Public Health, Louisiana State University Shreveport, Shreveport, Louisiana, United States of America

[5]Swiss Tropical and Public Health Institute, University of Basel, Basel, Switzerland

[6]Department of Public Health, Western Illinois University, Illinois, United States of America

Corresponding author:
Christian Duru,
chrisduruc@gmail.com

Dates:
Received: 02 Sept. 2023
Accepted: 15 Apr. 2024
Published: 19 July 2024

Read online:
Scan this QR code with your smart phone or mobile device to read online.

Background: Evaluation of the optic disc is an important clinical practice among eyecare practitioners. Inter-observer variability makes it difficult to establish a clear conclusion regarding the estimation of the vertical cup-to-disc ratio (VCDR), especially in the context of glaucoma.

Aim: To determine the effect of age and gender on VCDR in a normotensive population and to estimate the mean VCDR of individuals of African descent.

Setting: The University Eye Clinic, Imo State University, Owerri, Nigeria.

Methods: A cross-sectional study was used to assess the VCDR morphology of participants. The mean age was 36.7 ± 12.98 years (range: 18 years – 60 years). Descriptive statistics were used to summarise the data characteristics while linear regression was used to determine the correlation of age, gender and VCDR. Data were analysed using Statistical Package for the Social Sciences (SPSS) version 21.

Results: From 102 participants selected for the study, 82 eyes were objectively examined in this study. The mean VCDR was 0.34 (95% confidence interval [CI]: 0.23–0.52, standard deviation [s.d.] = 0.09). Although the mean VCDR for men (0.35 ± 0.08) was slightly larger than that of women (0.33 ± 0.10), the difference was only 2%. Simple regression analysis showed a weak positive but significant correlation between age and VCDR ($R = 0.24$, $R^2 = 0.057$, $p = 0.031$), while the multiple regression revealed no interaction between age, gender and VCDR (all $p > 0.05$).

Conclusion: Our study did not provide statistically significant evidence to support a correlation between VCDR, age and gender. However, age and VCDR are weakly correlated ($R = 0.24$, $p = 0.031$), with a small increase in VCDR with age.

Contribution: This study sheds light on the correlation between demographic factors and the optic disc or nerve head, which could have implications for glaucoma diagnosis, especially concerning the African population.

Keywords: vertical cup-to-disc ratio (VCDR); optic disc; optic nerve disease; glaucoma; African eyes.

Introduction

Age and gender can have an impact on the ocular health of a normotensive population, particularly concerning certain eye diseases.[1,2,3] Normotensive population refers to individuals who have normal intraocular pressure (IOP) or people whose eye pressure is not high, which is a key characteristic of glaucoma. The normal IOP is generally considered to be between 10 mmHg and 21 mmHg, with an average of 16 mmHg and a standard deviation (s.d.) of 2.5 mmHg.[4] The balance between aqueous production and aqueous outflow plays a role in maintaining the IOP, and an increase in the quantity of aqueous produced or a resistance to its outflow may result in high IOP.[5] Although high IOP is a significant risk for developing glaucoma, some people with normal IOP can still be susceptible to normotensive glaucoma.[6] Clinically, the vertical cup-to-disc ratio (VCDR) and horizontal cup-to-disc ratio (HCDR) are quantitative measurements that evaluate the optic nerve head and compare the size of the optic cup to the size of the disc in the eye. They play an important role in assessing and diagnosing glaucoma and other optic nerve disorders.[7] The degree of pallor and excavation on the disc, along with other morphological changes, has proven

How to cite this article: Egbusim VC, Duru CC, Anyatonwu OP, et al. Effect of age and gender on the vertical cup-to-disc ratio in a normotensive population. Afr Vision Eye Health. 2024;83(1), a880. https://doi.org/10.4102/aveh.v83i1.880

Copyright: © 2024. The Author(s). Licensee: AOSIS. This work is licensed under the Creative Commons Attribution License.

to be the most reliable guide to evaluate glaucoma disease and optic neuropathies.[7,8,9,10] This study involves VCDR in African eyes.

Several studies suggest that VCDR varies across different age groups and gender categories.[1,11,12,13] One such study revealed that males had 2% and 3% larger optic discs compared to their female counterparts, and there was no association between refractive error and the optic disc measurements. The participants of this study were 40 years or older, and the researchers concluded that there was no progressive age-related decline in neural retinal rim area.[1] Analysis of the biological basis for the relationship between eye diseases and sex hormones showed that some types of hormones can modulate ocular blood flow and exert a protective effect on the optic nerve.[3] Evidence from research found that the incidence of glaucoma and optic nerve diseases, such as optic neuritis, optic atrophy and Leber's hereditary optic neuropathy[2,14,15] may cause the VCDR to deviate from the normal range and mimic the physiological large cups or glaucoma; however, sometimes indicating the presence of an underlying neuropathy or disease. However, a Mendelian randomisation (MR) method may identify genetic variants and provide a large-scale data on genome association between optic neuropathies and disc enlargement, which is unaffected by potential confounding factors.[16]

Evaluating the optic disc is an important clinical practice among eyecare practitioners, particularly optometrists, ophthalmologists and neurologists. The assessment and estimation of VCDR may vary among practitioners because of differences in measurement techniques, imaging technologies and subjective interpretations. This variability makes it difficult to establish a clear conclusion regarding the effect of age and gender on VCDR, especially in the context of diagnosing glaucoma among African populations. Given the paucity of research in this area, this study aimed to provide data on the mean VCDR in a population with normal IOP and determine the influence of age and gender on the cup-to-disc ratio (CDR) of individuals of black ethnicity. The findings will enable practitioners to understand the relationship between age, gender and CDR and improve ability to identify changes in the optic disc morphology, which will contribute towards the diagnostic modalities for evaluating and monitoring optic nerve-related diseases.

Research methods and design

Study design

This study used a cross-sectional design to assess the VCDR of the eligible population, particularly individuals of African ethnicity. Participants were recruited through a random sampling method across different age groups and genders, ensuring a diverse representation of persons. The study was focussed on normotensive individuals (those with normal IOP), and therefore, findings may not be generalisable to people with existing ocular conditions such as glaucoma.

Study procedure

A standard Snellen acuity chart was used to measure the distance and near visual acuity of subjects, performed at 6 m and 40 cm, respectively. Participants' information was obtained through a clinical record sheet, while a comprehensive eye examination was conducted to assess the internal and external ocular structures. Standard Keeler direct ophthalmoscope was used to objectively examine the posterior segment of the eye to rule out any underlying pathology, such as media opacities, optic neuropathies, retinal diseases and congenital anomalies of the optic disc. All instruments were sterilised with cotton wool and methylated spirits, consisting of 95% hydrous ethanol. Prior to measuring the IOP, the corneal was numbed using one drop per eye of 0.5% Tetracaine HCl solution. The VCDR was estimated with the ophthalmoscope graticule. The graticule consists of an outer circle that coincides with the edge of the optic disc. The concentric circles are calculated to represent a cup/disc ratio of 0.5 for the middle circle and 0.25 for the inner circle. The notches between the outer and the middle circle represent a cup/disc ratio of 0.75. We examined the optic disc of the subjects in a dim-illuminated environment while their eyes were semi-dilated. Clinical findings were documented, including visual acuities for each eye and observations of the optic disc morphology. The size, shape, depth and symmetry of both eyes were assessed, noting any abnormalities such as exudates, nerve fibre layer defects and haemorrhages. Also, we calculated the VCDR by comparing the vertical diameter of the optic cup with the vertical disc diameter.

Data collection and setting

The data in this study were derived from the baseline eye examinations performed on 82 (of 102) individuals who volunteered for the study. The mean age was 36.7 ± 12.98 years (range: 18 years – 60 years). Out of the 102 selected participants, 20 subjects were excluded, allowing only 33 females and 49 males (n = 82, 80.4% response rate). Study participants were excluded if: they had any ocular pathology or media opacities, age was < 18 years or > 60 years, IOP exceeded 22 mmHg at the time of recruitment and refractive error greater than ± 2 D. The study was conducted at the University Eye Clinic, Imo State University, Owerri, Nigeria.

Statistical analysis

Two independent observers assessed the VCDR of the study participants, while interobserver variability was resolved by a repeated evaluation of the optic nerve head and recalculation of the quantitative sample data. The validated data were exported to Stats.Blue online statistical software (California, USA) and Statistical Package for the Social Sciences (SPSS) version 21.0 software (IBM Corp. Armonk, NY, USA) for analysis. Descriptive statistics were used to summarise the characteristics of data and group means. Simple and multiple regression models were used to determine the correlation between variables, with VCDR as the continuous dependent variable, while age and gender were the co-variate independent factors. We adjusted for the confounding factor of age vis-a-vis gender when analysing their correlation with VCDR, respectively. Statistical significance was considered when $p < 0.05$. Results were presented in group tabulation and reported as mean ± s.d.

Ethical considerations

Ethical approval was sought and obtained from the Ethical Committee of Imo State University, through the Department of Optometry (No. IMSU/FHS/OPT/030), and the study complied with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written and verbal consent were obtained from all individuals involved in this study, with the utmost protection of privacy, confidentiality and anonymity. Participants were duly informed about their right to withdraw from the study if they were uncomfortable or had other related concerns.

Results

Initially, 102 participants were selected for the study, but data from 82 eligible subjects were eventually included in this study. The males were more prevalent (approximate ratio 5:3) compared to females, with percentages of 59.8% and 40.2%, respectively. The global VCDR was 0.34 (95% confidence interval [CI]: 0.23–0.52, s.d. = 0.09). There were no complications caused by the procedures concerned. Table 1 shows the frequency of men and women who participated in the study (49 vs. 33). The mean VCDR for men and women were 0.35 ± 0.08 and 0.33 ± 0.10, respectively. In Table 2, the age group with the highest number of subjects was for the group 43 years – 47 years, contributing a percentage of 20.7%. The men were more in number (49 vs. 33) and had a slightly larger average VCDR than the women, with a relative difference of only 0.02 or 2.0%. Overall, the VCDR mean was 0.34 ± 0.09. In Figure 1, the line chart shows the interaction between the VCDR for both genders across different age groups. Group 58 years – 62 years had the largest VCDR for both men and women (0.49 vs. 0.55), while the least VCDR was found among the women (0.2). A wider range of VCDR was found in women compared to men (0.35 vs. 0.24), indicating a broader spread of values in the women. Figure 2 shows the distribution of age against VCDR.

In simple regression analysis, variability in VCDR showed a weak positive correlation of $R = 0.24$ with age ($Y = 0.003 \times \text{Age} + 0.246$; $R^2 = 0.057$; $p = 0.031$). From the regression model, the coefficient of determination shows that only about 5.7% of the variability in the CDR can be explained by age. The low R^2 value shows that the model does not capture much of the variability in the data using only age as a predictor. Both the t-statistics (2.198) and p-value (0.031, $\alpha = 0.05$) reinforce the idea that the coefficient for age might be significant in predicting changes in the VCDR of the sample population.

When VCDR was used as the dependent variable, with age and gender as the co-variate independent factors, we noted no interaction between VCDR and age ($p = 0.144$) and gender ($p = 0.221$). In the overall fit for the multiple regression model ($Y = 0.072 + 0.004 \times \text{Age} + 0.011$ [Gender]; $R^2 = 0.344$; residual s.d. = 0.085), only 34.4% of the VCDR variance was associated with age and gender combined. In the analysis of variance (ANOVA), the F-statistics and corresponding p-value (1.576; 0.282) collectively suggest that the independent variables do not influence the CDR. Therefore, there is insufficient evidence to confirm a statistically significant relationship among age, gender and CDR (all p-values > 0.05).

TABLE 2: Frequency distribution of age, gender and vertical cup-to-disc ratio of participants.

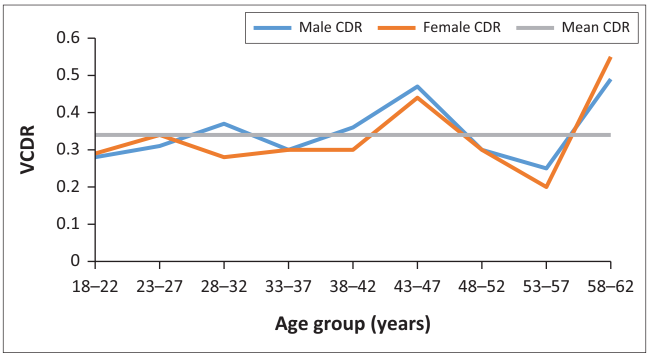
Demographic categories	n	Percentage (%)	Average VCDR (M&F)
Age Groups (years)			
18–22	13	15.85	0.285
23–27	14	17.07	0.325
28–32	7	8.54	0.325
33–37	8	9.76	0.300
38–42	6	7.32	0.330
43–47	17	20.73	0.455
48–52	8	9.76	0.300
53–57	4	4.87	0.225
58–62	5	6.10	0.520
Gender			
Males	49	59.75	0.350
Females	33	40.25	0.330
Totals	**82**	**100.00 %**	-

Note: Global mean and s.d. = 0.34 ± 0.09.
VCDR, vertical cup-to-disc ratio; M&F, male and female; s.d., standard deviation.

TABLE 1: Age, gender frequency and average vertical cup-to-disc ratio distribution of subjects.

Age group (years)	Male (n)	Average male VCDR	Female (n)	Average female VCDR
18–22	7	0.28	6	0.29
23–27	6	0.31	8	0.34
28–32	5	0.37	2	0.28
33–37	5	0.30	3	0.30
38–42	4	0.36	2	0.30
43–47	12	0.47	5	0.44
48–52	4	0.30	4	0.30
53–57	2	0.25	2	0.20
58–62	4	0.49	1	0.55
Total	**49**	-	**33**	-

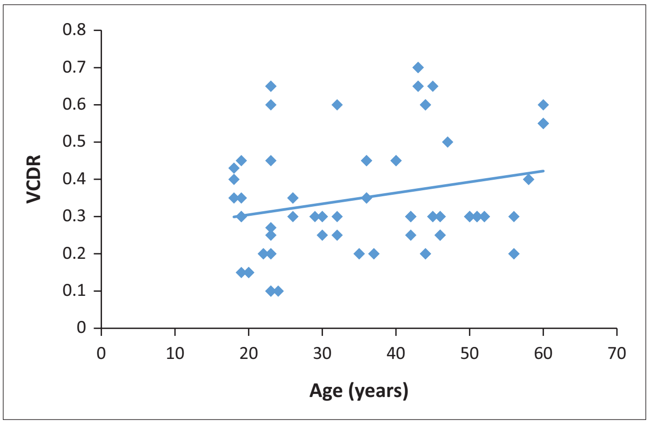
Note: Global average for male VCDR = 0.35 and global average for female VCDR = 0.33.
VCDR, vertical cup-to-disc ratio.



Note: The group 58 years – 62 years had the largest mean VCDR for both men (0.49) and women (0.55), while the smallest mean VCDR (0.2) was found in women (group 53 years – 57 years).

VCDR, vertical cup-to-disc ratio; CDR, cup-to-disc ratio.

FIGURE 1: A line chart showing the interaction between vertical cup-to-disc ratio for both genders across different age groups.



VCDR, vertical cup-to-disc ratio.

FIGURE 2: A scatter of the distribution of the age in years and vertical cup-to-disc ratio (VCDR). Each dot represents an individual VCDR, and variability in VCDR was weakly associated with an increase in age.

Discussion

We estimated the normative means and variations in the VCDR of a healthy population, consisting exclusively of African descent. Our findings indicate that age had a low positive correlation of 0.24 with VCDR (95% CI: R^2 = 0.057; p = 0.031). However, the coefficient of determination showed that only about 5.7% variability in the VCDR can be explained by age. This is similar to a study conducted by Garway-Heath et al.,[11] who found that vertical optic cup diameter and optic disc area increased with age by approximately 0.1 between the ages of 30 years and 70 years. However, they noted that the neuro-retinal rim area declined at a rate between 0.28% and 0.39% per year. In the Rotterdam population-based study, where a total of 5114 white patients, aged 55 years or older, were examined, Ramrattan et al.[17] estimated the mean VCDR at 0.49 (s.d.: 0.14). Similarly, the YAZD Eye Study that assessed the distribution of IOP, central corneal thickness and VCDR among healthy Iranian population in 2010–2011, Pakravan et al.[18] reported the mean VCDR as 0.32 ± 0.14, while we estimated the mean VCDR to be 0.34 ± 0.09 in an African population.

In multiple regression analysis, we noted no significant interaction between VCDR and variation in age and gender (all $p > 0.05$). This aligns with a large epidemiological study that investigated variations in the normal optic disc, based on race, age, gender and refractive error. Among the individuals who volunteered for this study, all of whom were 40 years and older, no progressive age-related decline was detected in the neural rim area and disc measurements. In addition, neither gender nor refractive error was significantly associated with the size and topography of the optic disc.[1] Ramrattan et al., in their study, reported that age was not a determinant of disc characteristics. They also found that refractive error was weakly related to disc area and neural rim area.[17] Considering the influence of gender on the evaluation of the optic disc, our study found that the VCDR for men was slightly larger than that of women by 2%, which corresponds to a previous study that reported that male subjects had 2% to 3% larger optic disc compared with female subjects.[1] Another research conducted in the Netherlands, which evaluated the determinants of optic disc characteristics in a general elderly population found that the optic disc was 3.2% larger in men than in women.[17] Similarly, Quigley et al.[19] also concluded that women's eyes and discs were smaller than those of men, possibly explaining the smaller cup/disc ratio in women.

In contrast, some research suggests that age may have an effect on VCDR. A study by Kim et al., which investigated the association between optic-CDR and systemic factors in a healthy Korean population, found that the mean vertical VCDR increases with age regardless of gender.[20] Another genome-wide association study also identified multiple genetic variants associated with VCDR. They stated that genetic risk score (GRS) was significantly associated with VCDR ($p < 0.0001$), including factors such as age, gender, central corneal thickness and IOP. In their study, they reported that the weighted GRS explained an additional 2.7% of the variation in VCDR.[21]

Limitations

The limitations encountered during this research include low volunteer turn-out and difficulty with examining the VCDR of both eyes simultaneously. However, to our knowledge, we meticulously evaluated the VCDR variation in relation to age and gender, as well as estimated the mean VCDR, exclusively for a population of African descent, which should be considered in the evaluation of glaucoma and monitoring of progressive changes in the optic-disc morphology.

Conclusion

Our study did not find statistically significant evidence to support a correlation between age, gender and VCDR. We did find a weak but significant positive correlation between age and VCDR (R = 0.24, p = 0.031). Future studies should explore the complex interplay between the optic disc and other variables to gain a deeper understanding of their influence on glaucoma and optic nerve-related diseases.

Acknowledgements

The authors would like to extend their thanks to the staff of Imo State University Eye Center, for providing the necessary facilities and research materials. This article is partially based on the author's thesis entitled 'Effect of age and gender on vertical cup-to-disc ratio in a normotensive population' towards the degree of Doctor of Optometry in the Department of Optometry, Imo State University, Owerri, Nigeria on 15th September, 2016 with supervisor Dr Okechukwu Akogu.

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

V.C.E. and C.C.D. conceived the idea and wrote the proposal. O.P.A. and U.U.A. developed the theory and concept, and C.C.D. performed the analysis. M.C.N. and A.O.K. performed the verifications, while V.C.E., U.A. and C.B.U. validated the analytical methods developed by C.C.D. and O.P.A. The work was supervised by M.C.N. and U.U.A. All authors discussed the results and contributed to the final manuscript.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

The data that support the findings of this study are openly available in figshare at https://figshare.com/s/f43a5c9e81b6b4b97773.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors and the publisher.

References

1. 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(8): 1068–1076. https://doi.org/10.1001/archopht.1994.01090200074026
2. Moon Y, Kim US, Han J, Ahn H, Lim HT. Clinical and optic disc characteristics of patients showing visual recovery in leber hereditary optic neuropathy. J Neuro-Ophthalmol. 2020;40(1):15–21. https://doi.org/10.1097/WNO.0000000000000830
3. Nuzzi R, Scalabrin S, Becco A, Panzica G. Sex hormones and optic nerve disorders: A review. Front Neurosci. 2019;13:57. https://doi.org/10.3389/fnins.2019.00057
4. Mark RL. Chapter 3: The intraocular pressure in glaucoma. In: Azuara-Blanco A, Costa VP, Wilson RP, editors. Handbook of glaucoma. London: Taylor and Francis, 2001; p. 22–27. https://doi.org/10.3109/9780203215616
5. Saito H, Tomidokoro A, Tomita G, Araie M, Wakakura M. Optic disc and peripapillary morphology in unilateral nonarteritic anterior ischemic optic neuropathy and age- and refraction-matched normals. Ophthalmology. 2008; 115(9):1585–1590. https://doi.org/10.1016/j.ophtha.2008.01.012
6. Gosling D, Meyer JJ. Normal tension glaucoma. In: StatPearls [homepage on the Internet]. Treasure Island, FL: StatPearls Publishing; 2023 [updated 2022 Dec 12; cited 2023 Aug 18]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK576377/
7. Dietze J, Blair K, Havens SJ. Glaucoma. In: StatPearls [homepage on the Internet]. Treasure Island, FL: StatPearls Publishing; 2023 [updated 2022 Jun 27]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK538217/
8. Schuster AK, Erb C, Hoffmann EM, Dietlein T, Pfeiffer N. The diagnosis and treatment of glaucoma. Dtsch Arztebl Int. 2020;117(13):225–234. https://doi.org/10.3238/arztebl.2020.0225
9. Waisberg E, Micieli JA. Neuro-ophthalmological optic nerve cupping: An overview. Eye Brain. 2021;13:255–268. https://doi.org/10.2147/EB.S272343
10. McMonnies CW. Glaucoma history and risk factors. J Optom. 2017;10(2):71–78. https://doi.org/10.1016/j.optom.2016.02.003
11. Garway-Heath DF, Wollstein G, Hitchings RA. Aging changes of the optic nerve head in relation to open angle glaucoma. Br J Ophthalmol. 1997;81(10):840–845. https://doi.org/10.1136/bjo.81.10.840
12. Garway-Heath D, Ruben S, Viswanathan A, Hitchings R. Vertical cup/disc ratio in relation to optic disc size: Its value in the assessment of the glaucoma suspect. Br J Ophthalmol. 1998;82(10):1118–1124. https://doi.org/10.1136/bjo.82.10.1118
13. Hossam EK, Mohamed SS, Mohamed OA, et al. Variations of cup-to-disc ratio in age group (18–40) years old. Res Ophthalmol. 2013;2(1):4–9.
14. Rebolleda G, Noval S, Contreras I, et al. Optic disc cupping after optic neuritis evaluated with optic coherence tomography. Eye. 2009;23:890–894. https://doi.org/10.1038/eye.2008.117
15. Kılıçarslan O, Yılmaz ÇA, Batu OB, et al. Demographics and etiologic characteristics of non-glaucomatous optic atrophy: A single-center cross-sectional study from Turkey. Int Ophthalmol. 2022;42:3521–3529. https://doi.org/10.1007/s10792-022-02350-1
16. Li J, Li C, Huang Y, et al. Mendelian randomization analyses in ocular disease: A powerful approach to causal inference with human genetic data. J Transl Med. 2022;20(1):621. https://doi.org/10.1186/s12967-022-03822-9
17. Ramrattan RS, Wolfs RC, Jonas JB, Hofman A, De Jong PT. Determinants of optic disc characteristics in a general population: The Rotterdam Study. Ophthalmology. 1999;106(8):1588–1596. https://doi.org/10.1016/S0161-6420(99)90457-8
18. Pakravan M, Javadi MA, Yazdani S, et al. Distribution of intraocular pressure, central corneal thickness and vertical cup-to-disc ratio in a healthy Iranian population: The Yazd Eye Study. Acta Ophthalmol, 2017;95(2):e144–e151. https://doi.org/10.1111/aos.13231
19. Quigley HA, Brown AE, Morrison JD, Drance SM. The size and shape of the optic disc in normal human eyes. Arch Ophthalmol. 1990;108(1):51–57. https://doi.org/10.1001/archopht.1990.01070030057028
20. Kim YJ, Kim JM, Shim SH, Bae JH, Park KH; Epidemiologic Survey Committee of the Korean Ophthalmological Society. Associations between optic cup-to-disc ratio and systemic factors in the healthy Korean population. Korean J Ophthalmol. 2015;29(5):336–343. https://doi.org/10.3341/kjo.2015.29.5.336
21. Nannini DR, Kim H, Fan F, Gao X. Genetic risk score is associated with vertical cup-to-disc ratio and improves prediction of primary open-angle glaucoma in Latinos. Ophthalmology. 2018;125(6):815–821. https://doi.org/10.1016/j.ophtha.2017.12.014