Original Article

Optic disc characteristics on digital fundus photographs in Saudi children

Lina H. Raffa, MD, PhD, Esraa A. Basalem, MD.

ABSTRACT

الأهداف: تقييم معايير العصب البصري في الأطفال السعوديين الأصحاء.

المنهجية: تم اختيار 85 طفلا صحيحا ناتج حمل كامل، وتتراوح أعمارهم بين ٣ و١٨ عامًا. خضع جميع الأطفال لفحص عيون كامل في عيادة العيون في مستشفى جامعة الملك عبدالعزيز في جدة، ويشمل ذلك تقييم حدة الابصار، وفحص باستخدام مجهر المصباح الشقي، وفحص انكسار العدسة بعد استخدام قطرات توسعة البؤبؤ. بعد ذلك تم أخذ صور الشبكية بواسطة كاميرا خاصة لشبكية العين (فيسوكام ٥٠٠ من زايس، ألمانيا) وتم تقييمها باستخدام برنامج أداة حجم الشبكية.

النتائج: كان هناك ٤٨ ذكرًا (56.5%). كان متوسط وزن الولادة 2.97±0.8 كجم، وكان متوسط فترة الحمل 39 أسبوعًا (يتراوح ما بين= 37–40 أسبوعًا .(كانت مساحة الهالة العصبية، والكوب، وقرص البصر هي 1.82 مم مربع (يتراوح ما بين= 0.84 إلى 2.83)، و 0.47 مم مربع (يتراوح ما بين=0.18 إلى 1.25)، و 2.33 مم مربع (يتراوح ما بين= 1.15 إلى 3.52) على التوالي. مع نمو قرص البصر، نما حجم الكوب والهالة العصبية أيضًا. لم يكن هناك أي ترابط بين العمر أو الجنس أوالعيوب الانكسارية مع أي من العوامل المدروسة.

الخلاصة: يمكن استخدام البيانات كمعطيات معيارية لقياسات العصب البصري لدى الأطفال السعوديين الأصحاء، لتكون مرجعًا في عيادة طب العيون الأطفال للمساعدة في تحديد اي خلل في العصب البصري.

Objectives: To assess the optic disc parameters in healthy Saudi children.

Methods: This study recruited 85 children who were medically free, born full-term, cooperative, and aged 3–17 years. The children underwent a thorough ophthalmological examination (visual acuity, refraction post-cycloplegia, fundus photography) at the ophthalmology clinic of King Abdulaziz University Hospital, Jeddah. Fundus photographs obtained by a fundus camera were evaluated by the Retinal Size Tool program.

Results: Forty-eight participants were male (56.5%). The mean birth weight was 2.97±0.8 kg and the median gestational age was 39 weeks (range, 37–40 weeks). The median areas of the neuroretinal rim, cup, and optic disc were 1.82 mm^2 (range, 0.84–2.83 mm^2), 0.47 mm^2 (range, 0.18–1.25 mm^2), and 2.33 mm^2 (range, 1.15–3.52 mm^2), respectively. The older age group had smaller neuroretinal areas compared to the younger age groups. The variables demonstrated no apparent correlation to axial length, refraction, or birth parameters. The cup size increased together with the optic disc (r=0.659, p<0.001). Sex and refraction did not correlate with any of the studied factors.

Conclusion: This study yielded normative data for the optic disc parameters of healthy Saudi children. The data can be used as a reference in the pediatric ophthalmology clinic to aid the identification of optic disc abnormalities.

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From the Department of Ophthalmology (Raffa), King Abdulaziz University Hospital, and from the Faculty of Medicine (Raffa, Basalem), King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia

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Address correspondence and reprint request to: Dr. Lina H. Raffa, Department of Ophthalmology, King Abdulaziz University Hospital, Jeddah, Kingdom of Saudi Arabia.
ORCID ID: https://orcid.org/0000-0001-8211-2353
Email: lraffa@kau.edu.sa

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Visual impairment is one of the most common disabilities affecting children worldwide and accounts for 19 million cases globally.[1] Four out of every 10,000 newborns with severe visual impairments or blindness receive a diagnosis before their first birthday, and 6 out of 10,000 receive one by the age of 16 years.[2] A cross-sectional study that involved 410 Saudi children reported that 10.2% of the children were visually impaired.[3] Congenital optic nerve abnormalities account for 15% of severe visual impairments or blindness.[4] Blindness significantly negatively affects a child's psychological, educational, and socioeconomic development.[5]

Numerous ophthalmic illnesses involve morphologic aspects of the optic nerve head.[6] Fundus photography is a highly useful tool for recording disease, monitoring treatment, and educating patients.[7] Ophthalmoscopy is a subjective method for assessing fundus anatomy. Currently, fundus images are assessed more objectively using a computerized image-processing system designed specifically to evaluate the retinal vessels in the peripapillary region and optic disc.[8]

Peripapillary structure characteristics and human optic disc morphology can be used as reference indicators to estimate eyeball development and as morphological indicators to detect the onset and progression of various fundus illnesses.[9] Several studies evaluated the optic disc parameters and characteristics for detecting abnormalities and followed patients with various ocular and systemic illnesses.[9,10] An analysis of the optic disc morphology and parameters in diabetic children and adults reported that hyperglycemia affected the papillary structure in adults prior to diabetic retinopathy and visual impairment development.[9] Despite the numerous studies that investigated optic morphology, most involved adults.[11-14]

One study investigated the optic disc parameters in 100 children aged 3–19 years and analyzed fundus photos using a computer-aided digital mapping tool. The study established normative values for Swedish children and reported that the median areas of the optic disc, cup, and neuroretinal rim were 2.67 mm^2, 0.41 mm^2, and 2.24 mm^2, respectively.[15] Several studies reported ethnic variations in the optic disc and cup properties.[13,16,17] Notably, individuals of white ethnicity tend to have smaller discs than those with African- American or Asian heritage.[13,16,17] Therefore, it is important to establish ethnicity-specific normative data on optic disc parameters in different populations.

There are few evaluation studies of the optic disc parameters of term and healthy children employing digital analysis of fundus photos.[15,17] We believe that no studies in the Middle East established a database of normative optic disc parameters in children. Our primary aim is to establish a database with normative data that describe the optic disc characteristics of healthy Saudi adolescents and children based on a simple objective tool, namely the Retinal Size Tool (RST) program, and use fundus photos to facilitate the detection of abnormal optic nerve structures. Our secondary objective is to examine how these optic disc parameters differ according to axial length, refraction, age, sex and birth parameters.

Methods.

Patient recruitment. This cross-sectional study involved all children who were cooperative and aged 3–17 years who visited the Department of Ophthalmology at King Abdulaziz University Hospital (KAUH), Jeddah, between 2018 and 2023. The children were recruited randomly from schools or were relatives of KAUH staff. The refractive error of the studied group was +4.00 to -5.00. The study included 85 participants [48 boys (56.5%) and 37 girls (43.5%)] who are Saudi nationals, born full-term (gestational age [GA] ≥37 weeks), healthy, had no retinal or optic disc abnormalities on examination, and aged <18 years. We excluded 20 children who had systemic or ocular illnesses, were born preterm, were aged >18 years, were uncooperative, or were of non-Saudi nationality.

Ocular examination. All participants underwent a complete eye examination. Visual acuity (VA) was examined using the Snellen E chart (school-aged children) or a picture chart (younger children). Refraction (KR 8900, auto kerato refractometer opcon, Tokyo, Japan) was recorded following the instillation of at least three rounds of eyedrops (1.0% cyclopentolate and 2.5% phenylephrine eyedrops) at 5–10-minute intervals. Ocular fundus photographs for both eyes were captured using a fundus camera (VISUCAM 500, Zeiss, Jena, Germany). Only sharply focused images with a well-centered optic disc were approved. The digitized fundus photographs were fed into the RST software.[8] The RST uses an algorithm designed for semi-automatic measurements of fundus images utilizing the elliptical approximation of the disc and cup shapes.[18] The optic disc area (ODA), cup area, and neuroretinal rim area were analyzed by manually drawing the cup, optic disc, and fovea contours, which produced the projected area results (**Figure 1**). The macula–disc distance, which is thought to be constant at 4.6 mm, was used to convert all recorded distances from length in pixels to millimeters.

Ethical consideration. This project was reviewed and approved by the KAU Institutional Review Board.

Information regarding the studies and examinations was made available to the parents or guardians of every child. The child's caregiver/parent signed an informed consent form for the child's participation. The study adhered to the Declaration of Helsinki principles, and was authorized by the KAU local ethics commission (Reference No. 472-22).

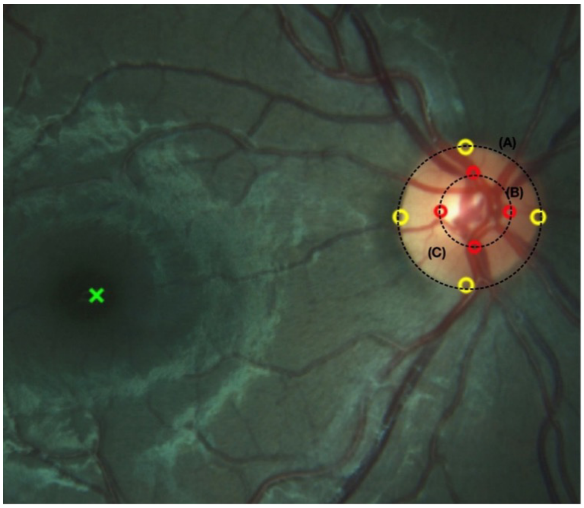

Figure 1 - Digital mapping of well-focused fundus photograph of the RE of a full-term, medically free 17-year-old female demonstrating a disc area of 2.32 mm^2 (**A**), cup area of 0.53 mm^2 (**B**), and rim area of 1.79 mm^2 (**C**).

Table 1 - Demographic data of 85 full-term children.

Demographics	n	(%)
Total	85	(100)
Gender		
Male	48	(56.5)
Female	37	(43.5)
Age		
3-7 years	27	(31.8)
8-12 years	34	(40.0)
13-17 years	24	(28.2)
Average GA		
37	2	(2.4)
38	1	(1.2)
39	81	(95.3)
40	1	(1.2)
Best VA		
20/20	65	(76.4)
20/25	9	(10.6)
20/30	5	(5.9)
20/40	5	(5.9)
20/60	1	(1.2)

VA- visual acuity, GA - gestational age

Statistical analysis. The data were analyzed using IBM SPSS version 27 (IBM Corp., Armonk, NY, USA). The variables were characterized using a basic descriptive statistic. Count and percentage values were used for categorical and nominal variables, while means and standard deviations were used for continuous variables. Variables that were both represented by means were correlated with Pearson's correlation coefficient. The means of 2 groups and >2 groups were compared using an independent t-test and one-way analysis of variance, respectively, with least significant difference (LSD) as a post hoc test. The tests were conducted based on the normal distribution hypothesis. Otherwise, the Games–Howell test for multiple groups and Welch's t-test for 2 group means were used as LSD alternatives. Binary outcomes were defined as dependent study variables. Lastly, the null hypothesis was rejected if the conventional p-value was <0.05.

Results. This study included 85 Saudi children. All participants were from full-term pregnancies and not known to have any chronic comorbidities. Each photograph could be assessed, meaning that the optic disc and macula were both visible. The participants were aged between 3 and 17 years and their VA was between 20/20 and 20/60. The mean best logMAR was 0.2±0.1. Forty-eight participants were male (56.5%). The mean birth weight was 2.97±0.8 kg and the median GA was 39 weeks (range, 37–40 weeks).

Table 2 - Optic disc parameters (ODA, neuro-retinal rim area and cup area) and cup/disc ratios of 85 full term Saudi children.

Variables	Min	Max	Mean±SD	Median	1st	5th	95th
Disk area							
Right eye	1.15	3.20	2.33± 0.4	2.33	1.15	1.76	2.95
Left eye	1.38	3.52	2.33±0.4	2.33	1.38	1.62	3.03
Cup area							
Right eye	0.18	0.93	0.51±0.2	0.48	0.18	0.28	0.82
Left eye	0.26	1.25	0.50±0.2	0.46	0.26	0.29	0.90
Rim area							
Right eye	0.84	2.83	1.83±0.3	1.80	0.84	1.35	2.36
Left eye	1.10	2.76	1.84±0.3	1.84	1.10	1.28	2.40
C/D ratio							
Right eye	0.10	0.35	0.22±0.1	0.21	0.10	0.13	0.33
Left eye	0.11	0.41	0.21±0.1	0.20	0.11	0.13	0.32
Rim/Disk Area							
Right eye	0.65	0.90	0.78±0.1	0.80	0.65	0.67	0.87
Left eye	0.59	0.89	0.79±0.1	0.80	0.59	0.68	0.87
Axial length							
Right eye	20.63	25.43	22.67±1.1	22.76	20.63	20.94	24.78
Left eye	20.48	25.59	22.65±1.1	22.69	20.48	21.06	24.54

1st percentile , 5th percentile, 95th percentile, C/D area cup/disc area Min - minimum, Max - Maximum, SD - standard deviation

Table 3 - Age specific distribution of optic nerve parameters, spherical equivalent and axial length.

Age	3-7 years	8-12 years	13-17 years	*P*-value
Spherical equivalent	1.26±1.2[A] 1.38(-1.3-3.8)	0.97±1.8[A] 0.75(-3.5-5.3)	0.07±2.0[B] 0.31(-5.0-4.0)	0.024[a,b]
Disk area	2.27±0.4 2.24(1.6-2.9)	2.38±0.3 2.46(1.4-2.8)	2.35±0.4 2.36(1.7-3.1)	0.472
Cup area	0.52±0.2 0.48(0.2-1.1)	0.50±0.1 0.49(0.3-0.8)	0.49±0.2 0.45(0.3-0.8)	0.729
Rim area	1.64±0.3[A] 1.57(1.2-2.8)	1.64±0.3[A] 1.65(1.1-2.2)	1.36±0.2[B] 1.36(1.1-1.7)	0.007[a,b]
C/D area	0.23±0.1 0.21(0.1-0.4)	0.21±0.0 0.20(0.1-0.3)	0.21±0.0 0.20(0.2-0.3)	0.304
Rim/Disk Area	0.77±0.1 0.79(0.6-0.9)	0.79±0.0 0.80(0.7-0.9)	0.79±0.0 0.81(0.7-0.9)	0.305
Axial length	22.11±0.7[A] 22.08(21.0-23.9)	22.70±1.2[B] 22.79(20.0-24.6)	23.89±1.0[C] 23.79(22.3-25.5)	<0.001[a,c]

[a]-significant using One-Way ANOVA Test at <0.05 level, [b]-Post-Hoc Test=LSD,[c]-Post-Hoc Test=Games Howell, *CAPITAL letters indicates Post-Hoc multiple pairing summary indicator. Having the same letter means the same measure statistically, C/D area=cup disc area

Table 4 - Sex- specific distribution of optic nerve parameters, spherical equivalent and axial length.

Variables	Male	Female	*P*-value
Spherical equivalent	0.99±1.3 0.88(-1.3-4.0)	0.80±2.1 0.75(-5.0-5.3)	0.589
Disk area	2.35±0.4 2.38(1.6-3.1)	2.32±0.3 2.36(1.4-2.9)	0.709
Cup area	0.51±0.2 0.48(0.3-1.0)	0.49±0.2 0.46(0.2-1.1)	0.577
Rim area	1.61±0.3 1.59(1.1-2.2)	1.59±0.3 1.55(1.1-2.8)	0.732
C/D area	0.22±0.1 0.21(0.1-0.3)	0.21±0.1 0.20(0.1-0.4)	0.545
Rim/Disk Area	0.78±0.1 0.80(0.7-0.9)	0.79±0.1 0.81(0.6-0.9)	0.531
Axial length	22.72±1.0 22.63(20.6-25.2)	22.19±1.2 21.91(19.3-25.5)	0.019[a]

[a]significant using Independent t-test at <0.05 level. [b]significant using Welch's t-test at <0.05 level. C/D area= cup/ disc area

Table 1 presents the participants' demographic data. **Table 2** describes the cup–disc (C/D) ratios and the optic disc metrics (ODA, cup area, neuroretinal rim area). The median areas were as follows: optic disc, 2.33 mm^2 (right eye [RE]) and 2.33 mm^2 (left eye [LE]); cup, 0.48 mm^2 (RE) and 0.46 mm^2 (LE); and neuroretinal rim, 1.80 mm^2 (RE) and 1.84 mm^2 (LE). None of the children had absence of cupping. The 5th and 95th centiles of the optic disc, cup, and neuroretinal rim areas were 1.76 mm^2 and 2.95 mm^2, 0.28 mm^2 and 0.82 mm^2, and 1.35 mm^2 and 2.36 mm^2, respectively in RE (**Table 2**). There was no difference between the optic disc, cup, or rim areas of the RE and LE. **Figure 2A–D** depicts the participants' optic disc reference values. All variables were of normal distribution.

Correlations. Age did not correlate significantly to the optic disc area, cup area, or C/D ratios. However, the rim area was weakly negatively correlated to age (r=-0.246, *p*=0.036). The GA was also weakly negatively correlated to cup area (r=-0.263, *p*=0.017). The older age group (13–17 years) had smaller neuroretinal areas (1.29±0.1 mm^2) compared to the younger age groups (1.54±0.2 mm^2 at 3–7 years and 1.66±0.3 mm^2 at 8–12 years) (**Table 3**). Axial length elongated as the age increased: that of the older group (13–17 years) was 23.89±1.0 mm compared to that of the younger participants (3–7 years), which was 22.11±0.7 mm (*p*<0.001) (**Table 3**). The variables demonstrated no apparent correlation to axial length, refraction, or birth parameters. Sex did not have any effect on optic disc parameters (**Table 4**). However, axial length was significantly longer in boys compared to girls (22.72±1.0 mm vs. 22.19±0.12 mm, *p*<0.019) (**Table 4**). There was a significant positive correlation between the ODA and cup area (r=0.659, *p*<0.001) and a negative correlation between the ODA and rim/disk area (r=-0.244, *p*=0.027).

Discussion.

This study aimed to establish normative optic disc parameters in Saudi children. Studies that examined ethnic disparities yielded numerous insights into ODA variability,[17,19] which explains the importance of establishing normative values for the Saudi population. Several researchers have documented optic geometry in both children,[15,17] and adults.[20,21] However, the children examined in those studies were of different races/ethnicities,[15,22] the

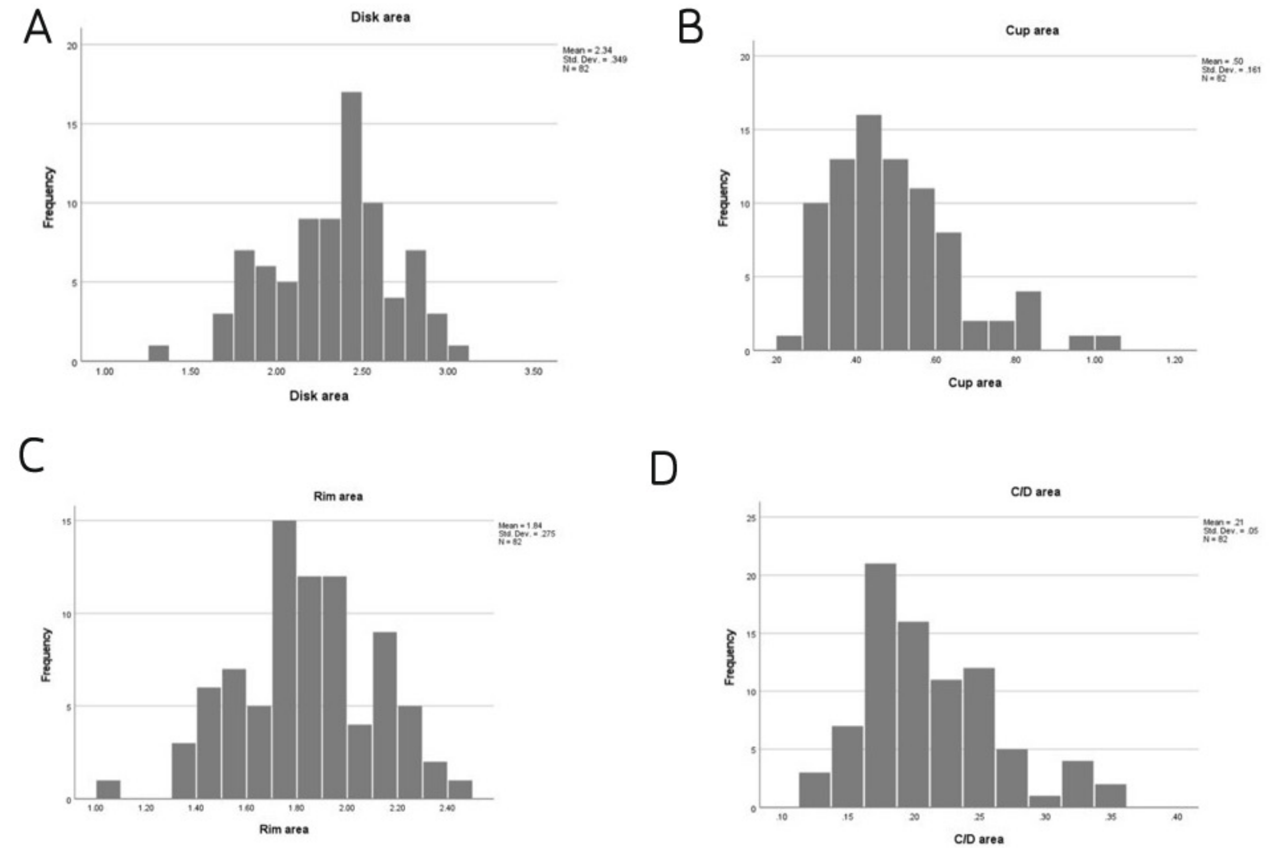

Figure 2 - Frequency distribution of (**A**) optic disc area, (**B**) cup area, (**C**) neuro-retinal rim area, and (**D**) cup-disc area

findings were based on alternative approaches such as optical coherence tomography (OCT),[23] or ocular diseases were investigated.[9,10,24]

Different optic disc sizes have been reported depending on the measurement technique used.[14,15,19,21] A study that included 100 healthy children aged 3–19 years reported an ODA of 2.67 mm^2, which was larger than the median ODA (RE: 2.33 mm^2, LE: 2.33 mm^2) we reported.[15] Our study included healthy Saudi children aged ≥3 years and detected no evidence of optic disc size growth with age. This finding was consistent with the majority of earlier investigations.[13,17,19,25,26] In fact, optic nerve growth is expected in children aged <3 years.[27] The present study found evidence of a negative correlation between rim area and age, which disagreed with another study that detected no evidence for decreasing rim area with increasing age.[15] In line with some previously published results, we detected no difference in the ocular fundus morphology between male and female participants.[19,26,28] Nonetheless, a few clinical publications[13,14,21] have reported that males have slightly larger optic discs.

No participant had absence of cupping, which differed from the reports of Bengtsson[29] and Snydacker,[28] who reported an absence of cupping in 9% and 13.5%, respectively. Our finding that cup size does not increase with age was consistent with the majority of previous investigations. Snydacker[28] demonstrated that the cup size did not increase as people aged. Tong et al[30] reported horizontal and vertical C/D ratios of 0.45 and 0.38, respectively, among 100 emmetropic East Asian children aged 8–13 years, but we detected a lower C/D ratio of 0.22.

Previous research on adults[13,14,26] and children[17] generally reported that the disc and neural rim areas had only a weak or nonsignificant correlation with refraction. In our study, we detected no correlation between optic disc parameters and spherical equivalent. Furthermore, the optic disc parameters did not correlate with axial length. This differed from the findings of Huynh et al,[31] who reported that the ODA increased as axial length grew, while the rim area decreased dramatically.[31] Our findings were consistent with studies that reported no relationship between axial length and ODA[32] and rim area.[33] In comparison to girls, boys had total axial lengths that were, on average, 0.7 mm longer ($p<0.0001$).[34] This was in agreement with our findings that boys had longer axial lengths by an average of 0.53 mm compared to girls.

This study involved healthy children from the general population, and any child exhibiting signs of ocular or systemic abnormalities was excluded. One strength of this prospective population-based study is the inclusion of a large sample of healthy children. Additionally, no prior research we know of has examined the optic nerve morphology of Saudi Arabian full-term children. One advantage was that all participants in our study are of Saudi nationality, as different ethnicities demonstrate differing optic nerve parameters.[31] Certain digital fundus imaging systems, such as VISUPAC (Carl Zeiss Meditec AG), necessitate the entry of axial length and account for the refractive error of the photographed eye, which was not essential for this study. Rather, the elliptical approximation of the disc and cup areas formed the basis for the algorithm we presented. This approach should be considered when comparing our findings to those of previous studies that used various reference points from other diagnostic techniques, including confocal scanning laser ophthalmoscopy, OCT, and scanning laser polarimetry. Another strength of the study is the fact that the macula–disc center distance was used as a reference to account for variations in camera magnification, which is an issue for other optic nerve measurement methods. We used a direct normalization technique predicated on the notion that the macula–disc center distance is sufficiently comparable between individuals to serve as a reference.[8,35] An important limitation was the exclusion of a significant number of fundus images with poor signal resulting in the inability to accurately identify fundus anatomical structures. Moreover, the inter- observer variability of this method has not been previously tested to explore the possible subjective variability in the measurements. This was not an issue in our study as only one observer analyzed all fundus images (E.B.). It is also important to note that the single point measurements obtained from our cross-sectional study are not ideal for evaluating longitudinal data and establishing optic nerve changes with age.

In conclusion, this study provided reasonably precise measurements of the optic disc characteristics in Saudi children aged between 3 and 17 years. The older age group had smaller neuroretinal areas compared to the younger age groups. The variables demonstrated no apparent correlation to axial length, refraction, or birth parameters. Our measurements matched those from most studies that involved other children. The reference intervals provided can be used in scientific research and routine pediatric ophthalmology to detect abnormal optic nerve morphology in children. Accordingly, the tested algorithm produced measurements might be helpful in a clinical setting and for population-based screening for pediatric glaucoma or congenital or acquired optic nerve abnormalities. However, longitudinal research is essential to examine how growth affects optic disc metrics and how those characteristics connect to other clinical factors.

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