ORIGINAL ARTICLE

Optic Nerve Head Parameters Measured with Spectral-Domain Optical Coherence Tomography in Healthy Turkish Children: Normal Values, Repeatability, and Interocular Symmetry

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ABSTRACT

To determine normal values, repeatability, and interocular symmetry of optic nerve head measurements, three spectral-domain optical coherence tomography (SD-OCT) scans were obtained from 128 healthy Turkish children aged 5–17 years consecutively and prospectively. The mean disc area, rim area, cup volume, cup to disc area ratio, and vertical and horizontal cup to disc ratios were $2.30 \pm 0.42 \text{ mm}^2$, $1.84 \pm 0.45 \text{ mm}^2$, $0.09 \pm 0.10 \text{ mm}^3$, 0.20 ± 0.13 , 0.37 ± 0.17 , and 0.45 ± 0.20 , respectively. The intraclass correlation coefficients were >0.9 for repeatability and >0.75 for interocular correlation. Interocular differences were not statistically significant ($p > 0.05$). Normal paediatric SD-OCT measurements of the optic nerve head are presented, which showed excellent repeatability and no interocular difference.

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Introduction

The diagnosis of glaucoma and other optic neuropathies requires careful assessment of the optic nerve head with ophthalmoscopy. In addition to qualitative assessment, diagnostic tests such as visual fields, scanning laser ophthalmoscopy, and optical coherence tomography can be used to obtain quantitative functional and structural information about the optic nerve.

During the evaluation of childhood optic nerve diseases, it is usually difficult to perform a detailed ophthalmoscopic examination or visual field test due to poor cooperation. Spectral-domain optical coherence tomography (SD-OCT) is one of the latest technologies used in the assessment of optic nerve and retinal diseases and can be particularly helpful in children by providing accurate information quickly and non-invasively. However, to differentiate diseased optic nerves from healthy ones or to detect optic discs that carry risk of disease, the results of an individual should be compared with normal values. There are few studies that have provided paediatric normal values of optic nerve head parameters.^{1–5} Additionally, for evaluating paediatric SD-OCT

data accurately in clinical practice, the repeatability and interocular difference of the measurements in children must be taken into consideration. A limited number of previous studies have provided such information.^{6–10}

We recently have studied normative SD-OCT values of retinal nerve fibre layer and macular thickness in a sample of 5–17-year-old children.¹¹ In the present study, we aimed to determine the normal values of optic nerve head parameters in a subgroup of the same cohort and to analyse the repeatability and interocular symmetry of the measurements.

Materials and methods

Healthy children aged 5–17 years were recruited prospectively and consecutively. The study protocol was approved by the local ethics committee and adhered to the tenets of the Declaration of Helsinki. An informed consent was obtained from parents or legal guardians of each child before participation.

All subjects underwent comprehensive ophthalmological examination, including best-corrected

Snellen visual acuity (BCVA), motility assessment, non-contact tonometry, biomicroscopy, and indirect funduscopy. Cycloplegic refraction was measured with an autorefractometer (ARK 510A; Nidek, Aichi, Japan) 20 minutes after instillation of two drops of tropicamide 1% and recorded as spherical equivalent refraction (SER).

Children who had BCVA $\geq 20/25$ in both eyes with normal findings on biomicroscopic and fundoscopic examination were included in the study. Children with preterm birth, metabolic or neurologic systemic diseases, and family history of glaucoma and those who had prior ocular surgery, trauma, strabismus, anisometropia, media opacities, retinal pathologies, optic nerve head abnormalities, glaucoma, and high refractive errors (spherical error exceeding ± 6.00 dioptres [D] or cylindrical error more than 2.50 D) were excluded.

Optic disc parameters were measured with iVue 100 SD-OCT (version 3.1; Optovue Inc., Fremont, CA, USA) through dilated pupils by the same experienced technician. Data obtained with the nerve fibre optic nerve head scan of the device were collected. iVue 100 SD-OCT uses a scanning laser diode to emit a scan beam with a mean wavelength of 840 ± 10 nm to provide images of ocular microstructures. The scan speed is 26,000 A-scans per second and the axial length resolution is 5 μm . A 6×6 mm raster scan centred on the optic disc consisting of 128 B-scans each composed of 512 A-scans (acquisition time, 2.2 seconds) provides a three-dimensional (3D) image of the optic disc and surrounding area. The analysis points are derived from a 3.45 mm diameter area. The optic cup is defined automatically by the iVue software as the intersection points of the nerve head inner boundary and a parallel line that is 150 μm above the connecting line of the retinal pigment epithelium (RPE) tips. Nerve head parameters provided automatically by the iVue software are cup area, rim area, cup volume, cup to disc area ratio, cup to disc horizontal ratio, and cup to disc vertical ratio.

Three consecutive measurements were performed on both eyes. The position and focus of the child were randomly disrupted between scans. The image quality was determined by the scan quality index (SQI) of the device. According to the manufacturer's guidelines, SQI ≥ 27 for a

nerve fibre optic nerve head scan indicates adequate quality. Children who were unable to cooperate with SD-OCT scans and those who had SD-OCT scans with inadequate quality or motion artefacts were excluded from the study.

The average values of three consecutive measurements obtained from right eyes were used to provide normal values for each optic nerve head parameter. Repeatability (the concordance of repeated measurements) was calculated using the three consecutive measurements obtained from the right eyes. Interocular symmetry was analysed by comparing the average of three consecutive measurements obtained from right and left eyes.

Statistical analysis was performed using NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA). Descriptive statistics were reported as mean, standard deviation, median, and minimum–maximum. The data for all variables were examined for normality with the Shapiro-Wilk test. Independent-samples *t* test was used to analyse the effect of gender on measured parameters. Repeatability and correlation between right and left eyes were expressed as intraclass correlation coefficients (ICCs). An ICC between 0.75 and 1.00 is regarded as excellent. Interocular difference was analysed with paired-samples *t* test. *p* values less than 0.05 were considered statistically significant.

Results

Among children who attended our outpatient clinic between September 2014 and September 2015, 217 children who fulfilled the inclusion and exclusion criteria were initially enrolled in the study. Fifteen of these children either could not cooperate with SD-OCT measurements or had unreliable scans with inadequate quality or motion artefacts in both eyes. Among the remaining 202 subjects, 128 children (59% of the total subject pool) with three adequate quality scans obtained from both eyes were finally included in the study. There were 68 males and 60 females in the study group, with a mean age of 10.87 ± 3.50 years (median: 10.32, range: 5.29–17.88). Age distribution of the study group is shown in [Figure 1](#) The mean SER of the right eyes were -0.10 ± 2.03 D (median: 0.25 D, range: -6.00 – 5.88 D).

Figure 1. Bar graph showing age distribution of the study group.

Table 1 presents normal values of optic nerve head parameters and comparison between boys and girls. There were no statistically significant differences ($p > 0.05$) between genders in any of the optic nerve head parameters.

The repeatability of the measurements is given in Table 2. The ICCs were greater than 0.90 for all the parameters. The interocular symmetry analysis is shown in Table 3. The differences between right and left eyes were not statistically significant ($p > 0.05$) and interocular correlation expressed as ICCs were greater than 0.75 for all the parameters.

Table 1. Normal values of optic nerve head parameters with SD-OCT in children ($N = 128$).

Parameter	Total ($N = 128$)			Boys ($n = 60$) Mean $\pm$ SD	Girls ($n = 68$) Mean $\pm$ SD	p
	Mean $\pm$ SD	Median	Range			
C/D area ratio	0.20 ± 0.13	0.17	0–0.52	0.21 ± 0.12	0.19 ± 0.13	0.508
C/D vertical ratio	0.37 ± 0.17	0.36	0–0.73	0.39 ± 0.16	0.36 ± 0.17	0.337
C/D horizontal ratio	0.45 ± 0.20	0.43	0–0.83	0.46 ± 0.19	0.43 ± 0.20	0.442
Rim area (mm^2)	1.84 ± 0.45	1.80	0.75–3.11	1.86 ± 0.41	1.83 ± 0.49	0.741
Disc area (mm^2)	2.30 ± 0.42	2.26	0.96–3.26	2.34 ± 0.39	2.25 ± 0.44	0.219
Cup volume (mm^3)	0.09 ± 0.10	0.05	0–0.54	0.09 ± 0.09	0.08 ± 0.11	0.765

Note. C/D = cup to disk.

Table 2. Repeatability of optic nerve head measurements with SD-OCT in children ($N = 128$).

Parameter	Repeated measurements (mean $\pm$ SD)			ICC
	1. measurement	2. measurement	3. measurement	
C/D area ratio	0.20 ± 0.14	0.20 ± 0.13	0.20 ± 0.13	0.951*
C/D vertical ratio	0.37 ± 0.19	0.38 ± 0.18	0.37 ± 0.18	0.908*
C/D horizontal ratio	0.44 ± 0.22	0.45 ± 0.21	0.44 ± 0.21	0.912*
Rim area (mm^2)	1.85 ± 0.48	1.84 ± 0.45	1.84 ± 0.45	0.983*
Disc area (mm^2)	2.29 ± 0.42	2.29 ± 0.41	2.30 ± 0.42	0.999*
Cup volume (mm^3)	0.09 ± 0.11	0.08 ± 0.11	0.09 ± 0.11	0.950*

Note. C/D = cup to disk; ICC = intraclass correlation coefficient.

* $p < 0.001$.

Table 3. Interocular symmetry analysis of optic nerve parameters with SD-OCT in children ($N = 128$).

Parameter	Right eyes ($N = 128$) Mean $\pm$ SD	Left eyes ($N = 128$) Mean $\pm$ SD	Difference Mean (95% CI)	ICC	p
C/D area ratio	0.20 ± 0.13	0.20 ± 0.13	$-0.002 (-0.015-0.012)$	0.906*	0.813
C/D vertical ratio	0.37 ± 0.17	0.37 ± 0.19	$0.004 (-0.018-0.026)$	0.855*	0.732
C/D horizontal ratio	0.45 ± 0.20	0.44 ± 0.21	$0.006 (-0.018-0.031)$	0.868*	0.611
Rim area (mm^2)	1.84 ± 0.45	1.84 ± 0.47	$-0.002 (-0.066-0.062)$	0.811*	0.951
Disc area (mm^2)	2.30 ± 0.42	2.29 ± 0.42	$0.004 (-0.061-0.070)$	0.751*	0.896
Cup volume (mm^3)	0.09 ± 0.10	0.08 ± 0.09	$0.010 (-0.001-0.020)$	0.895*	0.072

Note. C/D = cup to disk; ICC = intraclass correlation coefficient.

* $p < 0.001$.

Discussion

In this study, we present normal values, repeatability, and interocular symmetry of optic nerve head parameters measured with SD-OCT in a cohort of paediatric subjects. Several previous studies have reported optic nerve head parameters in children using different methods and devices. A summary of selected studies in comparison with the current study is shown in Table 4. Earliest studies evaluated fundus photographs. Mansour¹² made manual measurements of fundus stereophotographs of 66 children in 1992 and reported optic disc sizes ranging from 2.66 to 3.08 mm. Hellström and Svensson¹³ analysed fundus photographs of 100 healthy children utilising a computer-assisted digital mapping system in 1998. They found similar results to Mansour. In another photographic study, Samarawickrama et al.¹⁴ documented planimetric measures of normal optic nerve head parameters in a population-based study of 6-year-old children and reported smaller optic disc sizes. This discrepancy may be due to the different image analysis techniques. Compared with the photographic studies, the mean disc area found in the current study was in accordance with Samarawickrama et al.'s findings. He et al.,¹⁵ Pang et al.,¹⁶ and Larsson et al.¹⁷ assessed paediatric optic nerve head parameters with Heidelberg retina tomography (HRT) among children of similar age groups from different racial backgrounds. Among their cohort of European children, Larsson et al. found smaller cup area and cup to disc area ratio compared with the other two studies reporting results of African American (Pang et al.¹⁶) and Chinese (He et al.¹⁵) children. Similar ethnic differences have been found by other authors.^{1,3,18} In comparison with the HRT studies, we have found slightly larger disc and rim areas with SD-OCT, concurrent with previous studies that compared the two imaging modalities.^{19,20}

Optic nerve head parameters in children have also been assessed with time-domain OCT (TD-OCT). For example, Huynh et al.^{1,5} studied large population-based cohorts of 6-year-old and adolescent children in two separate studies with Stratus OCT. Our results were comparable to both those studies. El-Dairi et al.³ reported optic

nerve head parameters in normal children aged 3–17 years with Stratus OCT in a hospital-based sample and found similar results to ours. In our study, we used the latest version of OCT imaging technology, SD-OCT, which can provide high-resolution images in a small amount of time. This makes this technology especially convenient for children. Few studies have reported normal paediatric optic nerve head parameters with SD-OCT. In a community-based study among 6–13 years old European Caucasian children, Elía et al.² used SD-OCT; however, it was a different device (Cirrus) than the one used in the present study (iVue 100). They reported a more than twice larger cup to disc area ratio than ours. The difference between our findings and Elía et al.'s may have been resulted from the different scanning patterns of the devices. In another study by Bueno-Gimeno et al.²¹ with Cirrus SD-OCT among a hospital-based cohort of European Caucasian children, the results were similar to Elía et al.'s.² Bhoiwala et al.⁴ reported optic nerve morphology in a sample of 5-year-old North American children with RTVue 100 Avanti, which is an equivalent device to the one used in the present study. The mean values and ranges of disc areas and vertical and horizontal cup to disc ratios reported in their study were comparable to our results.

In comparison with the adult database of the device we utilised, we observed larger mean disc and rim areas and a smaller mean vertical cup to disc ratio in our study group of children.²² Regarding difference between children and adults, similar findings were reported in Larsson et al.'s¹⁷ study with HRT and Bhoiwala et al.'s⁴ study with RTVue SD-OCT. However, the ranges of optic disc area both in our group (0.96–3.26 mm²) and in the adult database (0.9–3.7 mm²) were large and overlapping. Because of this large interindividual variability, the differences in mean values may not be of major importance clinically.

In the present study, there was no difference in optic nerve head parameters between boys and girls. This is consistent with some of the previously published reports.^{2,13,17,18} In their study with 6-year-old children, Huynh et al.¹ reported that there were generally no gender differences in disc or cup parameters, except for horizontal and vertical average nerve widths, which were slightly

Table 4. Previous studies presenting data on optic nerve head parameters of children.

Studies, year	Subjects	N	Age (years)	ONH parameters, mean $\pm$ SD				
				Disc area (mm ²)	Rim area (mm ²)	Cup area (mm ²)	Cup volume (mm ³)	C/D area
Photographic studies								
Mansour ¹² , 1992	Healthy volunteers	66	2–10	2.93 /2.81*	2.50 /2.54*			
Hellström ¹³ , 1998	Healthy volunteers	100	3–20	2.69 $\pm$ 0.44	2.24	0.44 $\pm$ 0.32		
Samarawickrama ¹⁴ , 2012	Population based	1225	6	2.29		0.48		0.40
HRT studies								
He ¹⁵ , 2008	Population based	557	7–15	1.98 $\pm$ 0.15		0.51 $\pm$ 0.31		0.24 $\pm$ 0.12
Pang ¹⁶ , 2009	Hospital based	146	6–17	2.18 $\pm$ 0.57	1.63 $\pm$ 0.40	0.52 $\pm$ 0.37		0.22 $\pm$ 0.11
Larsson ¹⁷ , 2011	Population based	54	5–16	2.16 $\pm$ 0.47	1.75 $\pm$ 0.39	0.41 $\pm$ 0.33	0.09 $\pm$ 0.12	0.18 $\pm$ 0.12
TD-OCT studies (Stratus OCT)								
El-Dairi ⁴ , 2009	Hospital based	286	3–17	2.42	1.96	0.47		0.2
Huynh ² , 2006	Population based	1309	6–7	2.20 $\pm$ 0.39	1.76 $\pm$ 0.44	0.48 $\pm$ 0.32	0.06 $\pm$ 0.07	0.22 $\pm$ 0.13
Huynh ⁶ , 2008	Population based	2054	11–14	2.34 $\pm$ 0.41	1.93 $\pm$ 0.42	0.46 $\pm$ 0.32		0.21 $\pm$ 0.14
SD-OCT studies								
Elia ³ , 2012, Cirrus	Community based	358	6–13	2.05	1.59			0.43
Bueno-Gimeno ²¹ , 2014, Cirrus	Hospital based	199	6–17	2.09 $\pm$ 0.44**	1.67 $\pm$ 0.34**			0.36 $\pm$ 0.17**
				1.85 $\pm$ 0.34***	1.58 $\pm$ 0.28***			0.32 $\pm$ 0.19***
Bhoiwala ⁵ , 2015, RTVue	Community based	77	5	2.01 $\pm$ 0.40		0.36 $\pm$ 0.34		0.32 $\pm$ 0.22
Present study, 2015, Optovue	Hospital based	128	5–17	2.30 $\pm$ 0.42	1.84 $\pm$ 0.45		0.09 $\pm$ 0.10	0.37 $\pm$ 0.17
								0.45 $\pm$ 0.20

Note. C/D = cup to disc ratio; ONH = optic nerve head; V = vertical; H = horizontal.

*Boys /girls.

**Emmetropic.

***Myopic.

larger in boys. In another report by Huynh et al.⁵ among adolescent children, the optic disc diameter, optic disc area, and neural rim area were significantly greater in girls than in boys, whereas the cup to disc ratios were significantly greater in boys. These differences, however, were marginal. Similar to this finding, Pang et al.¹⁶ reported that optic nerve head measurements among African American children were not related to gender with the exception of the cup to disc area ratio and linear cup to disc ratio, which were greater in boys than in girls. He et al.¹⁵ found also found that cup to disc area ratio was 0.03 units smaller in the girls (adjusted for age). We may conclude from these data that minor differences may exist between genders; however, the clinical importance of this difference is debatable.

Repeatability of an instrument is crucial, as it reflects the concordance of the repeated measurements. It is particularly important in the assessment of children whose cooperation is limited. The repeatability of optic nerve head measurements in children has been reported in a few studies previously.^{6,7,17} Larsson et al.¹⁷ reported high ICCs that ranged between 0.9 and 1.0 for optic nerve head parameters measured with HRT in children and stated that the rim area had the best repeatability. Wang et al.⁶ studied the reproducibility of TD-OCT measurements in children and found no significant difference between two sessions on the same day. They reported that the least reproducible parameters were disc diameters and the most reproducible measure was cup to disc ratio. Altemir et al.⁷ also reported good intraobserver reproducibility with Cirrus SD-OCT among children for rim area, disc area, and cup to disc area ratio; the most reproducible parameter was cup to disc area ratio among these three parameters, consistent with findings by Wang et al.⁶ In the present study, the repeatability of the measurements was excellent for all optic nerve head parameters, with high ICCs ranging from 0.91 to 0.99. The ICCs found in our study and in Larsson et al.'s¹⁷ study were mostly higher than those reported by Wang et al.⁶ and Altemir et al.,⁷ probably because of the smaller age range of their samples.

It is important to know the physiological interocular difference of the optic nerve head

measurements during the assessment of monocular or asymmetric binocular diseases. Interocular difference exceeding normal limits may be an indication for further investigations. Among year 1 primary school students with Stratus OCT, Huynh et al.¹⁰ found that mean interocular differences were ≤ 0.02 mm for optic disc and cup diameters and ≤ 0.04 mm² for optic disc, cup, and neural rim areas. The most symmetric parameter was cup to disc ratio, with minimal mean differences. The authors stated that this result was consistent with those of adults, which showed that only 6% have cup to disc asymmetry of 0.2 or more. Huynh et al. also pointed out that large degree of asymmetry existed among individual children. Altemir et al.⁹ evaluated retinal asymmetry in children with SD-OCT and found the least difference between right and left eyes in parameters related to optic disc. They reported that the interocular correlations for rim area, disc area, and cup to disc area ratio expressed as ICCs ranged from 0.63 to 0.85, with the highest correlation in cup to disc area ratio. In accordance with these two studies, we did not find any significant differences between measurements of the right and left eyes. Additionally, the correlation between right and left eyes expressed as ICCs ranged from 0.75 to 0.90, with the lowest correlation in disc area and the highest in cup to disc area ratio. In contrast, Larsson et al.¹⁷ found significant differences between right and left eyes in cup to disc and rim to disc area ratios and smallest interocular differences in disc and rim areas. This discrepancy might be related to the measurement technique as Larsson et al.¹⁷ used HRT whereas Huynh et al.,¹⁰ Altemir et al.,⁹ and the present study used OCT.

Limitations of the present study are its small sample size and hospital-based design, which may limit the generalizability of the reported data. Another weakness is that the data are presented without adjustment for scan magnification effect, which is a measurement artefact that can produce abnormal results in eyes with extreme axial length (AL) or refraction. However, our data may apply to clinical situations, as most clinicians use raw data of the SD-OCT.

In conclusion, SD-OCT measurements of optic nerve head parameters in healthy children are presented in this study. The repeatability was

excellent, and the measurements of right and left eyes were found to be highly symmetric. High degrees of repeatability may indicate that optic nerve head measurements obtained with SD-OCT in children are reliable. Cup to disc area ratio may be a helpful parameter for detection of optic nerve head diseases in children, as it is the most symmetric parameter with high repeatability.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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