NORMATIVE OCULAR METRICS IN HEALTHY INFANTS ATTENDING IMMUNIZATION CLINIC IN ILORIN, NIGERIA

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ABSTRACT

Background: **The management of different childhood ocular conditions requires measurement of ocular metrics, which changes continuously as the child grows and approaches adulthood. In childhood glaucoma, intraocular pressure, corneal diameter, and cup-to-disc ratio are measured and monitored. This study aimed to establish a normative value for intraocular pressure readings, corneal diameter, and cup-to-disc ratio among healthy infants.**

Methods: **This was a one-year descriptive cross-sectional study involving 1,198 eyes from 599 children, sampled from an age-stratified population attending the routine child immunization clinic of the tertiary hospital. All children had measurement of corneal diameter and intraocular pressure as well as the cup-to-disc ratio assessment. Frequency tables were generated for the demographic variables while comparisons of ocular metrics across the age groups were performed using the Kruskal–Wallis H test and post-hoc Dunn's test.**

Results: **The median intraocular pressure (IOP) increased slightly with age, from 9.0 mmHg in the 6–12 weeks group to 10.0 mmHg in the other age groups. Median corneal diameter rose progressively from 9.5 mm in the 6–12 weeks group to 10.0 mm in the 13–24 weeks group and 10.5 mm in both the 24–36 weeks and >36 weeks groups. The median cup-to-disc ratio (CDR) showed minimal variation, with values ranging between 0.30 and 0.35 in the age groups.**

Conclusion: **The study established normative values for intraocular pressure, corneal diameter, and cup-to-disc ratio among healthy infants providing a valuable reference for pediatric ocular assessments.**

Keywords: Ocular metrics, Corneal diameter, Intraocular pressure, Cup-disc ratio

INTRODUCTION

Pediatric glaucoma, especially Primary Congenital Glaucoma (PCG), is a leading cause of childhood blindness as documented by several studies from different parts of the world.[1–3] Globally, it accounts for 5% of all pediatric blindness, 18% of blindness among children in school for the blind, bilateral in 75% of cases, with an incidence of 1 in 10,000 to 18,000 live births and male preponderance.[4]

The diagnosis, treatment, and follow-up of children with glaucoma depend largely on the assessment and monitoring of cornea diameter (CD), intraocular pressure (IOP), and cup-disc ratio (CDR).[5] Unrecognized and undertreated elevation of intraocular pressure can lead to progressive structural damage to the eye, particularly in children under three years of age. The resulting changes may include enlargement of the globe with increased corneal diameter, stretching of the scleral coat, optic disc pallor with pathological cupping, and the development of corneal opacity. Collectively, these alterations can culminate in irreversible visual loss or blindness.[6]

Corneal diameter (CD), intraocular pressure (IOP), and cup-disc ratio (CDR) are essential parameters, and their normal range varies across the different age and sex groups.[7,8] These parameters have not been well documented in Africa and particularly among Nigerian children, as we currently rely on values obtained from Caucasian studies. This study sought to fill the knowledge gap and also expand the normative data on infants' eyes from 6 weeks to 1 year building on the previous work on neonates, in the same patient population by Olatunji *et al.*; who reported, a mean

vertical and horizontal corneal diameters were 9.62 ± 0.41 mm (range 8.75–10.75 mm) and 9.87 ± 0.04 mm (range 9.00–10.75 mm), respectively, while the mean IOP was 11.93 ± 1.80 mmHg (range 9.00–16.00 mmHg) in the right eye and 11.84 ± 1.77 mmHg (range 8.00–15.00 mmHg) in the left eye.[9,10]

METHODOLOGY

This descriptive cross-sectional study was conducted at the Immunization Unit of the University of Ilorin Teaching Hospital between April 2020 and March 2021. The minimum sample size was calculated using the formula for a descriptive cross-sectional study[11], based on a standard deviation of 3.15 mmHg for intraocular pressure reported by Wang *et al.*[12] This yielded a minimum sample size of 264 infants. However, a larger sample was targeted to improve the precision of the study estimates and ensure adequate representation across the four age strata. Accordingly, 599 infants were ultimately recruited for the study.

Apparently healthy infants aged 6 weeks to 1 year old with normal eyes, receiving routine immunization, were recruited into the study. Children with a history of ocular trauma or surgery, use of IOP-lowering medications, presence of ocular pathology, any sign of impaired vision, or a history of preterm birth were excluded from the study. Ethical approval was obtained from the hospital's Ethics and Research Committee (NHREC/02/2010), and informed consent was secured from the parents or guardians of the children. The study was conducted in accordance with the Declaration of Helsinki.

The infants were stratified into four age categories: 6–12 weeks, 13–24 weeks, 25–36 weeks, and >36 weeks. Proportionate allocation was used to determine the number of infants to be recruited from each age stratum based on the distribution of infants recorded in the immunization register in the preceding year. Systematic sampling was subsequently employed to select participants from each stratum. The immunization register served as the sampling frame.

Corneal diameter was measured using a standardized photographic technique. A facial image was obtained with an Android smartphone equipped with a rear camera of at least 8 megapixels, ensuring both eyes were in the primary gaze position. A meter rule was positioned across the child's forehead to provide a reference scale, as described by Lagreze *et al.*[13] The photographs were subsequently analyzed digitally. A vertical reference line was placed at the corneal limbus at the 3 o'clock position and another at the 9 o'clock position. The horizontal distance between the two reference lines was measured and recorded as the horizontal corneal diameter. IOP was measured while the child was calm in the upright position with the iCare tonometer. The average of 5 readings was recorded. All IOP measurements were done between 8 am and 2 pm daily during the period of study.

All subjects had pupillary dilatation with 0.5% Tropicamide drops and subsequently had fundoscopy and assessment of the cup-disc ratio using the direct ophthalmoscope in a dimly lit room. All children with abnormal ocular findings were referred to the pediatric ophthalmologist for further review.

Data were entered into Statistical Package for Social Sciences (SPSS) software version 23. The distribution of continuous variables was assessed and found to be non-normally distributed; therefore, non-parametric tests were applied. Categorical variables, including sociodemographic characteristics, were summarized using frequencies and percentages and presented in frequency tables. Comparisons of ocular metrics across the four age groups were performed using the Kruskal–Wallis H test, with post-hoc pairwise comparisons conducted using Dunn's test. A p-value of less than 0.05 was considered statistically significant.

RESULT

A total of 1198 eyes of 599 children were included in the analysis. The majority (213, 35.6%) of the subjects were between 13 and 24 weeks. Male subjects constituted 51.9% of the study population (Table 1). The overall mean age of the infants was 21.9 ± 11.3 weeks, with an age range of 6–52 weeks.

Cornea diameter

The distribution of corneal diameter demonstrated a bimodal pattern, with values ranging from approximately 8.0 mm to 12.0 mm. The majority of

Table 1: Demographic distribution of the subjects (n = 599)

Variables	Category	Frequency	Percentage (%)
Age group(weeks)	6 - 12	153	25.5
	13 - 24	213	35.6
	25 - 36	127	21.2
	>36	106	17.7
Sex	Male	311	51.9
	Female	288	48.1

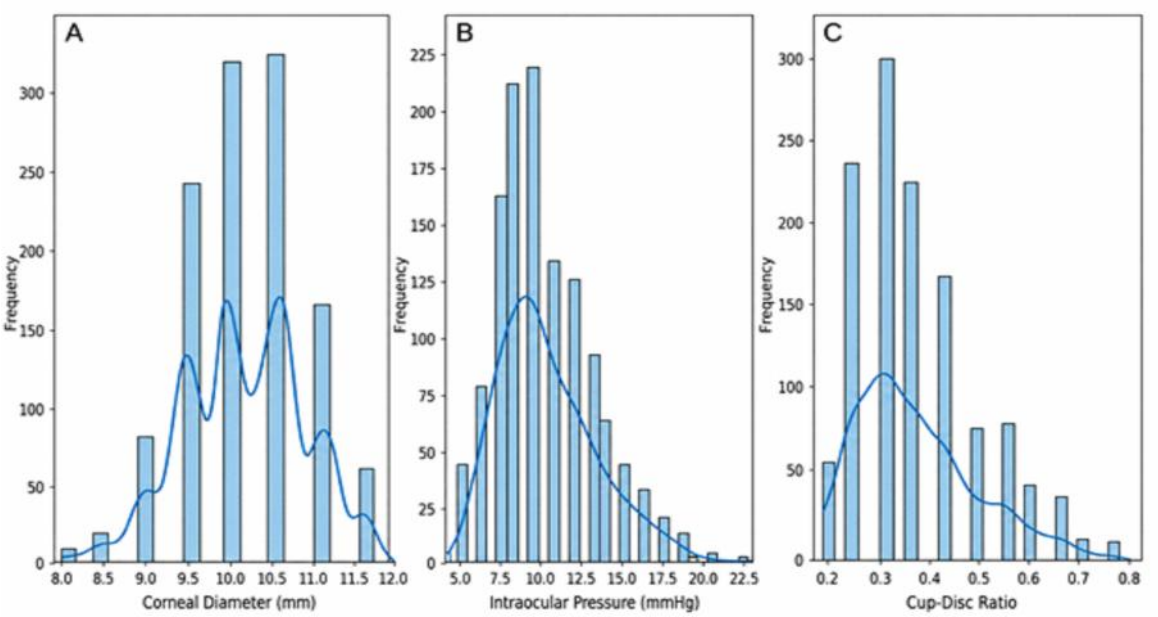


Figure 1: Distribution of ocular parameters among infants.
(A) Corneal diameter (mm) showing a broadly clustered distribution with multiple peaks.
(B) Intraocular pressure (mmHg) demonstrating a right-skewed distribution.
(C) Cup–disc ratio showing a positively skewed distribution with most values concentrated at lower ranges.

eyes, 1,064 (88.8%) had corneal diameters between 9.0 mm and 11.0 mm, while only 2 eyes (0.2%) exhibited a corneal diameter of 12.0 mm (Figure 1A). The corneal diameter increased progressively with age, as reflected in Figures 2A and 3A. The median (IQR) rose from 9.5 mm (9.5–10.0) in the 6–12 weeks age group to 10.0 mm (10.0–10.5) in 13–24 weeks, and further to 10.5 mm (10.0–11.0) in both the 25–36 weeks and >36 weeks groups, demonstrating a steady upward trend with advancing age. Pairwise comparisons demonstrated statistically significant differences between all age groups ($p < 0.05$ for all comparisons).

Intra-ocular pressure

Intraocular pressure (IOP) of <10 mmHg was recorded in 495 eyes (41.3%), while 631 eyes (52.7%) recorded IOP values between 10–15 mmHg.

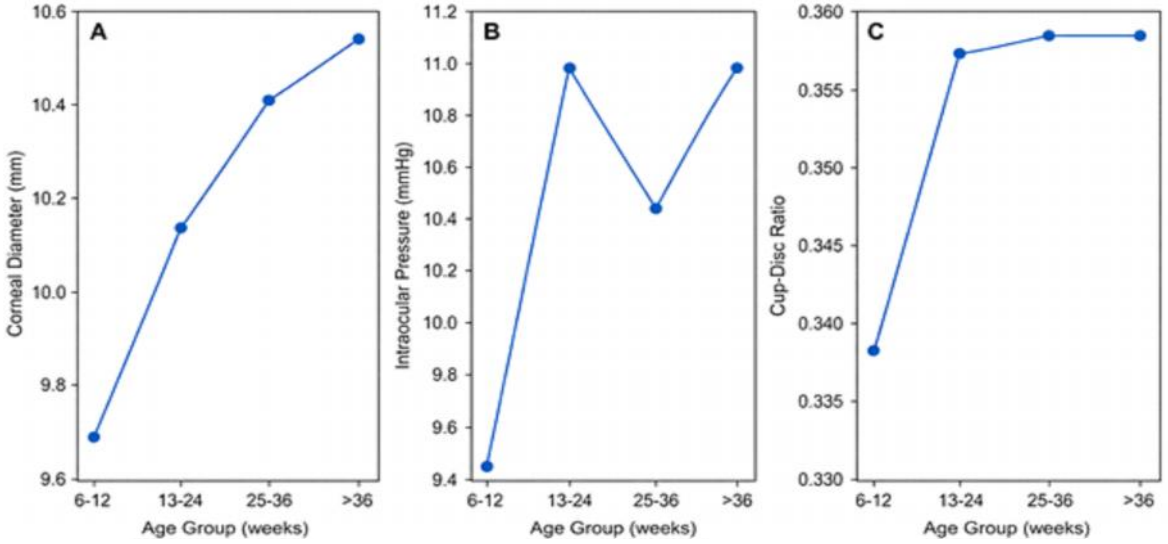


Figure 2: Age-related trends in ocular parameters among infants.
(A) Mean corneal diameter showing a progressive increase with age.
(B) Mean intraocular pressure demonstrating a variable pattern across age groups.
(C) Mean cup–disc ratio showing an increase up to 13-24 weeks followed by stabilization

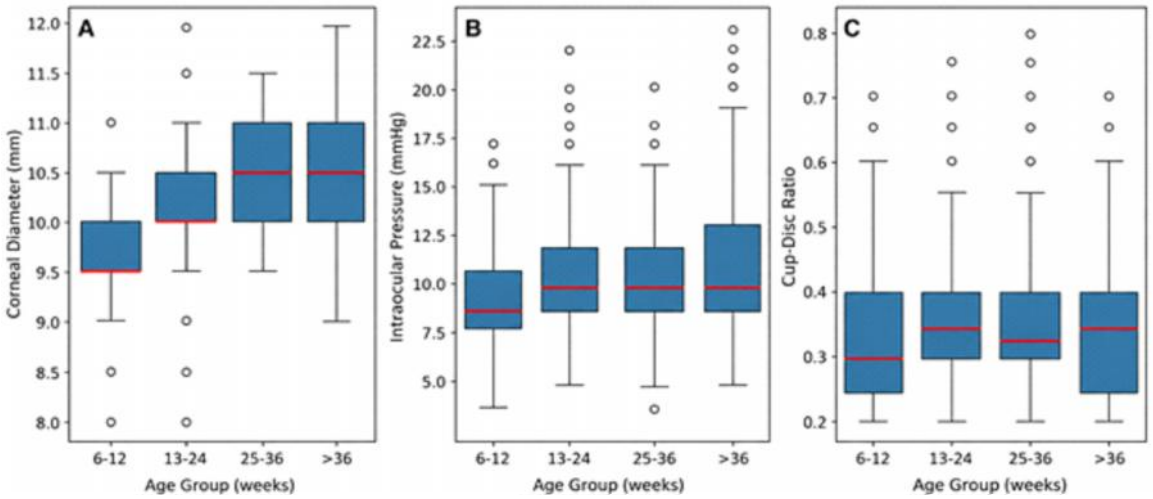


Figure 3: Boxplot distribution of ocular parameters across age groups among infants.
(A) Corneal diameter (mm) showing a progressive increase in median values with age.
(B) Intraocular pressure (mmHg) demonstrating variability across age groups
(C) Cup–disc ratio showing modest variation across age groups

Additionally, 68 eyes (5.7%) had IOP within the range of 16–21 mmHg, and only 4 eyes (0.3%) had IOP values >21 mmHg (Figure 1B). The mean intraocular pressure (IOP) shows a non-linear pattern across age groups (Figure 2B). The median IOP increases slightly from the youngest age group (6–12 weeks, 9 mmHg) to the older groups (~10 mmHg), where it remained stable. The interquartile ranges were broadly similar across the age groups, with values of 8.0–11.0 mmHg for 6–12 weeks, 9.0–12.0 mmHg for 13–24 weeks, 9.0–12.0 mmHg for 25–36 weeks, and 9.0–13.0 mmHg for >36 weeks; however, a slight increase in spread was observed in the >36 weeks group. Outliers are present in all groups, with some values exceeding 20 mmHg (Figure 3B). Significant IOP increase was observed between the 6–12 weeks age group and all older age groups ($p < 0.001$ for all comparisons). However, no statistically significant differences were found among the older age groups.

Cup-disc ratio

A total of 960 eyes (80.1%) had a vertical cup-to-disc ratio (CDR) of ≤0.4. The distribution demonstrated a peak density around 0.30–0.35. In contrast, only 12 eyes exhibited a CDR of ≥0.7 (Figure 1C). The most pronounced increase in cup-to-disc ratio (CDR) occurred between the 6–12 weeks and 13–24 weeks age groups, after which the values remain relatively stable across the older age groups (Figure 2C). The median CDR remained relatively stable across all age groups, ranging between 0.30 and 0.35. The interquartile range (IQR) was similar for the 6–12 weeks and >36 weeks groups, both showing a slightly wider spread (0.25–0.40; ≈ 0.15), compared to the 13–24 weeks and 25–36 weeks groups, which demonstrated a narrower and identical IQR (0.30–0.40; ≈ 0.10). All age groups exhibited upper-end outliers, with CDR values extending to approximately 0.8 (Figure 3C). A significant difference was observed only between the 6–12 weeks and 13–24 weeks groups ($p = 0.028$). No other pairwise comparisons were statistically significant.

DISCUSSION

Establishing normative values in children aged 6 weeks to 1 year provides an essential reference for differentiating normal ocular development from pathological changes and facilitates timely intervention. In this study, children aged 6–24 weeks constituted the majority of recruited participants. This distribution likely reflects the structure of routine immunization schedules, which require multiple clinic visits within the first six months of life. Caregivers are generally more adherent to immunization appointments during early infancy possibly due to increased health-seeking behavior during this period and heightened perceived vulnerability of younger infants by the parents.[14]

The present study reported an overall mean corneal diameter (CD) of 10.16 ± 0.65mm, alongside a positive correlation between increasing age and corneal diameter. This finding is consistent with established evidence indicating that corneal dimensions undergo progressive enlargement during early life and developmental stages. The observed mean corneal diameter is comparable to values reported by Ashaye *et al.*, who documented a mean CD of 10.26 ± 0.59mm.[15]

However, lower mean values have been reported in other populations. For instance, Sehrawat *et al.*[16] in India reported a mean CD of 9.5 ± 0.6 mm, while Wang *et al.*[12] in China found a mean CD of 9.78 ± 0.14 mm among neonates. The relatively smaller values observed in these studies may be partly explained by differences in study populations, as they were conducted exclusively in newborns. Corneal diameter is known to increase with age, particularly during infancy and early childhood, reflecting normal ocular growth and development. Consequently, the higher mean CD observed in the present study may be attributable to the inclusion of older age groups. Factors such as ethnic differences, genetic influences, and variations in measurement techniques may also contribute to the discrepancies observed.

The mean intraocular pressure (IOP) documented in this study demonstrated a variable trend across age groups, rising from approximately 9.4 mmHg in the 6–12 weeks group to 11.0 mmHg in the 13–24 weeks group, followed by a decline to 10.4 mmHg in the 25–36 weeks group, and a subsequent increase to about 11.0 mmHg in those older than 36 weeks. This is in contrast to findings in other studies.[12,17,18] Nanfack *et al.*[17] reported a gradual increase in mean IOP from 9.3 ± 3.7 mmHg in infants aged 1–5 months to 10.3 ± 3.7 mmHg in those aged 6–11 months, although this trend did not reach statistical significance. The observed differences may be attributed to the use of narrower, more segmented age categories in the present study, which could reveal fluctuations that are otherwise masked in broader groupings. Notwithstanding these variations, both studies consistently demonstrated lower IOP values in younger infants compared to older age groups.

A mean CDR of 0.35 was documented with a range of 0.2-0.8, with progressive increase with increasing age until 24 weeks, after which the values remain relatively stable across the older age groups. This pattern was different from that observed in a study by Patel *et al.*[19] who used a caliper on hand-held Optical Coherence Tomography (OCT) to measure optic nerve head parameters of children, whose ages ranged from birth to 13years, and reported that the mean CDR within the 1st week of life as 0.381 with a range of 0.212 to 0.549. The mean CDR remained unchanged for 12 to 18 months of age when it starts to slowly increase to 0.386 in the 13-year age group (0.216 to 0.556).[19] Also, a prospective study by Allingham *et al.*[20] in which the optic disc was evaluated using a handheld spectral domain optical coherence tomography (SD-OCT) device reported that the mean vertical cup disc ratio varies with individual racial groups. The study documented a mean vertical cup/disk ratio of 0.34 ± 0.10 in whites, 0.40 ± 0.17 in blacks, and 0.33 ± 0.20 in Hispanic newborns ($P = 0.07$ for white versus black). This shows that black newborns have a relatively larger CDR, which is in keeping with our findings. Zhou *et al.* reported that the CDR in newborns should not be more than 0.3 and the binocular difference should not be more than 0.2, otherwise could be regarded as one of the criteria for newborn glaucoma.[21]

Park *et al.*[22] on the other hand, reported that the rate of increase in size of the CDR from birth is influenced by both the birth weight and the gestational period of the child. The rate is higher in low-birth-weight babies and those born premature. Thus, CDR progression may not always be a sign of glaucoma in children.

Limitations

Photographic measurement of corneal diameter is a fast, non-contact, and practical technique; however, its accuracy may be affected by infant positioning, ocular alignment, camera angle, and distance.

CONCLUSION

This study establishes age group–specific normative values for intraocular pressure, corneal diameter, and cup–disc ratio among healthy infants. Corneal diameter demonstrated a consistent increase with advancing age. In contrast, intraocular pressure exhibited a more variable pattern across age groups, while cup–disc ratio showed an initial increase up to 13- 24 weeks before stabilizing. These findings provide clinically relevant reference ranges that may aid in the early detection, assessment, and monitoring of pediatric ocular disorders.

Conflict of interest

The investigators declare that they have no financial, professional, or personal conflicts of interest that could have influenced the design, conduct, analysis, or reporting of this study.

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Contribution of authors

All authors contributed to the conception and design of the study, data collection and analysis, interpretation of results, manuscript preparation, and approval of the final manuscript.

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