ASSESSING THE DISTRIBUTION OF INTRAOCULAR PRESSURE AMONG SCHOOL-AGED CHILDREN

BY

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FACULTY OF OPTOMETRY

UNIVERSITY OF BENIN

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CERTIFICATE OF APPROVAL

This is to certify that this research project titled: **ASSESSING THE DISTRIBUTION OF INTRAOCULAR PRESSURE AMONG SCHOOL AGED CHILDREN** was carried out by **EGWU INNOCENT OGBONNIA** in the Faculty of Optometry, University of Benin in partial fulfillment of the requirement for the DOCTOR OF OPTOMETRY (OD) degree in the 2024/2025 Academic Session.

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DEDICATION

This work is dedicated to the WORD, the Lord God Almighty for the wisdom, knowledge, love, care, and protection over me.

Also to my wonderful parents for their love, care, support, advice, and words of encouragement thus far in my sojourn in the university.

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I want to also say a very big thank you to all my kingdom fellowship pastors; PST Jerry and PST Jane, and to all my brethren, sister Susan, brother Chinenye, etc., for their spiritual guidance and biblical teachings that kept me in the faith to date.

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ABSTRACT

Background: Intraocular pressure (IOP) is a key physiological parameter that maintains the structural integrity of the eye and plays a critical role in the pathogenesis of glaucoma. Although normal IOP values are well established in adults, there remains limited data regarding its distribution and influencing factors among children in Nigeria. This study aimed to assess the distribution of intraocular pressure among school-aged children in Benin City, Nigeria, and to evaluate variations in relation to age, gender, and body mass index (BMI). **Data Analysis**: A cross-sectional design was adopted, involving 568 children aged 6–14 years selected from public and private schools in Benin City through stratified random sampling. Ethical approval and informed consent were obtained prior to participation. Data were collected using a structured form and IOP was measured with a non-contact tonometer. Anthropometric parameters were recorded to calculate BMI. Statistical analyses, including descriptive statistics, Spearman's rank correlation, and the Mann–Whitney U test, were conducted using SPSS version 26, with significance set at $p < 0.05$. **Results**: results showed a mean IOP of 17 ± 2 mmHg, with values ranging between 14 and 21 mmHg. A strong positive correlation was observed between IOP and age (Spearman's rho = 0.827, $p < 0.001$), while a moderate positive correlation was found between IOP and BMI (Spearman's rho = 0.633, $p < 0.001$). There was also a statistically significant difference in IOP between male and female participants ($p = 0.027$). **Conclusion**: The study concludes that Nigerian children demonstrate IOP distributions consistent with international findings, but population-specific reference values are required for accurate clinical assessment.

Keywords: intraocular pressure, school-aged children, ocular health, glaucoma screening, pediatric eye care.

CHAPTER ONE

1.0 INTRODUCTION

Each eyeball is a cystic structure that remains distended due to the pressure within it. Although commonly referred to as a "globe," the eyeball is not perfectly spherical but rather an oblate spheroid, formed by the fusion of two modified spheres. The cornea constitutes part of the smaller anterior sphere with a radius of 7.8 mm, while the sclera forms part of the larger posterior sphere with a radius of about 12 mm (Khurana and Khurana, 2017).

Intraocular pressure (IOP) refers to the pressure exerted by the internal contents of the eye on its outer coats. It is maintained through a dynamic balance among aqueous humour production, aqueous outflow, and episcleral venous pressure. This pressure is evenly distributed throughout the eye, ensuring that the posterior vitreous and the aqueous humour experience the same pressure. The maintenance of normal IOP is crucial for preserving the eyeball's shape and optical integrity (Khurana and Khurana, 2017).

The aqueous humour supplies essential nutrients—chiefly oxygen and glucose—to the avascular structures of the cornea and lens. It is produced by the pars plicata of the ciliary body and secreted into the posterior chamber through the epithelium covering the ciliary processes. From there, it flows between the iris and lens and enters the anterior chamber via the pupil (Remington, 2012).

Aqueous formation, which generates intraocular pressure, involves two components: a hydrostatic component derived from arterial blood pressure and ciliary body tissue pressure, and an osmotic component resulting from active ion secretion (notably sodium) by the ciliary epithelium. The normal range of IOP is approximately 10.5–20.5 mmHg, with an average of 15.5 ± 2.57 mmHg (Khurana and Khurana, 2017).

Aqueous humour exits the anterior chamber through two pathways. The first is the unconventional or uveoscleral route, which accounts for about 5–35% of total outflow. In this pathway, fluid passes through the uveal meshwork into the connective tissue spaces around the ciliary muscle, moves into the suprachoroidal space, and is absorbed through the sclera or into the anterior ciliary and vortex veins. Recently identified suprachoroidal collector channels and possible lymphatic routes in the ciliary stroma may also facilitate this flow. The remaining aqueous follows the conventional pathway, passing through the corneoscleral meshwork and juxtacanalicular tissue before entering Schlemm's canal (Remington, 2012).

In general, glaucoma can be regarded as a relatively straightforward condition, though certain cases may present challenges—often due to poor patient compliance. Essentially, the management of glaucoma centers on regulating ocular fluid dynamics: reducing aqueous production and/or enhancing aqueous outflow (Thomas and Melton, 2014).

1.1 BACKGROUND OF STUDY

Intraocular pressure (IOP) refers to the fluid pressure within the eye, primarily regulated by the balance between the production and outflow of aqueous humor. It is a vital physiological parameter that maintains the structural stability of the eye and ensures normal visual function. IOP is recognized as one of the most critical factors in the development of glaucoma. The term "normal" IOP describes a pressure level that does not cause glaucomatous damage to the optic nerve head. Although individual eyes may respond differently to the same pressure, an approximate safe range for IOP can be established by analyzing its distribution across the general population (Suh and Kee, 2012).

Glaucoma is an optic neuropathy characterized by optic disc cupping and compromised blood supply, often resulting from elevated intraocular pressure. It accounts for approximately 12.3% of global blindness and visual impairment (Park *et al*., 2010). Elevated IOP is a major risk factor for glaucoma, whereas abnormally low IOP can be associated with ocular conditions such as retinal detachment and uveitis.

While glaucoma is more commonly seen in adults, certain types—such as congenital glaucoma and juvenile open-angle glaucoma—can occur in children and may go undiagnosed for years due to their asymptomatic progression. In such cases, increased IOP is often the earliest detectable indicator. Early identification of abnormal IOP levels in children is crucial to preventing irreversible vision loss. Elevated IOP in pediatric cases can cause corneal enlargement, tears in Descemet's membrane, and corneal edema.

In the management of glaucoma, the percentage reduction in IOP serves as an important measure for assessing treatment effectiveness. Consequently, mechanisms controlling IOP have been extensively studied. Research has revealed that various systemic, ocular, and biometric factors are associated with IOP. Among these, central corneal thickness (CCT) is particularly significant, as it can affect IOP measurement accuracy, leading to variations across different populations. Additionally, systemic parameters such as systolic blood pressure, as well as demographic and lifestyle factors including age, sex, alcohol consumption, smoking, and family history, have been shown to influence IOP distribution (Hashemi *et al*., 2016).

1.1.1 CLASSIFICATION OF GLAUCOMA

Glaucoma in adults is generally categorized based on the anatomy of the anterior chamber angle—as open-angle or angle-closure—and by origin, as primary or secondary. In contrast, pediatric glaucoma is typically classified as either primary or secondary. Pediatric or childhood glaucomas represent a diverse group of conditions characterized by elevated intraocular pressure (IOP), which can result in optic nerve and visual field damage, as well as corneal and anterior segment changes, particularly in children under the age of four. These glaucomas are relatively rare and exhibit varied clinical presentations and underlying causes (Tanna *et al*., 2020).

Although pediatric glaucomas share several similarities with adult-onset forms, their management poses distinct challenges specific to infants, children, and adolescents (Tanna *et al*., 2020).

1.1.1.1 PRIMARY PEDIATRIC GLAUCOMA

Primary pediatric glaucomas involve isolated abnormalities of the anterior chamber angle. In primary congenital glaucoma (PCG), developmental anomalies of the angle (angle dysgenesis) cause increased resistance to aqueous outflow and elevated IOP. This results in the hallmark features of PCG: enlarged or cloudy corneas, Haab’s striae, and an enlarged globe (buphthalmos). Another form, juvenile open-angle glaucoma (JOAG), also involves isolated angle abnormalities but manifests later in childhood—typically after age four—or during early adulthood (Tanna *et al*., 2020).

Primary pediatric glaucoma can be further subclassified as follows:

a. Primary congenital glaucoma (PCG)
    i. Neonatal or newborn onset (0–1 month)

    ii. Infantile onset (1–24 months)
    iii. Late onset or late-recognized (≥24 months)
b. Juvenile open-angle glaucoma (JOAG) — generally manifests up to age 40

1.1.1.2 SECONDARY PEDIATRIC GLAUCOMA

Secondary glaucomas in children occur in association with other ocular or systemic abnormalities and can either be nonacquired (present at birth) or acquired (developing later). Nonacquired glaucomas are classified according to whether the associated abnormalities are primarily ocular or systemic.

The subtypes of secondary pediatric glaucoma include:

a. Glaucoma associated with non-acquired ocular anomalies
b. Glaucoma associated with nonacquired systemic diseases
c. Glaucoma associated with acquired conditions
d. Glaucoma following cataract surgery

Notably, glaucoma that develops after congenital cataract extraction forms a distinct category separate from the nonacquired group (Tanna *et al*., 2020).

1.1.2 FACTORS AFFECTING INTRAOCULAR PRESSURE

1.1.2.1 AQUEOUS HUMOR AND MAINTENANCE OF INTRAOCULAR PRESSURE (IOP)

The aqueous humor serves a vital function by supplying nutrients to the cornea and lens—both of which are avascular—and by removing metabolic waste products. Maintaining a constant volume of aqueous humor is crucial for keeping intraocular pressure (IOP) within normal limits. IOP must remain stable at a level that does not harm ocular tissues, and this is achieved through a delicate equilibrium between the rate of aqueous production and drainage. Under normal circumstances, homeostatic mechanisms maintain this balance; however, even small disruptions in either process can result in significant fluctuations in IOP. Since aqueous production is generally steady, most cases of elevated IOP arise from reduced aqueous outflow (Remington, 2012).

1.1.2.2 AQUEOUS OUTFLOW PATHWAYS

Obstruction to aqueous outflow can occur at several points along its drainage route. The unconventional (uveoscleral) outflow pathway involves the movement of aqueous humor from the anterior chamber into the ciliary body through the uveoscleral meshwork or directly into the ciliary tissues. Because the ciliary body lacks a continuous epithelial lining where it meets the anterior chamber, resistance to aqueous passage is minimal. Uveoscleral outflow is considered relatively constant and largely independent of IOP (Remington, 2012).

In contrast, the conventional outflow pathway exhibits greater variability and plays a major role in determining total aqueous outflow resistance. Normally, aqueous passes freely through the trabecular meshwork unless pigment or debris accumulates within its pores. When Schlemm’s canal and the associated collector channels are open, resistance remains minimal. The area offering the greatest resistance to aqueous flow appears to be the juxtacanalicular tissue (JCT) and, in some cases, the inner wall endothelium of Schlemm’s canal. Deposits of plaque-like material in the extracellular matrix of the JCT can increase resistance and, consequently, IOP. Cells within the trabecular meshwork and JCT are thought to possess some degree of self-regulation, adjusting resistance as needed; however, persistent obstruction in this region can lead to sustained IOP elevation (Remington, 2012).

1.1.3 FACTORS INFLUENCING INTRAOCULAR PRESSURE

Factors affecting IOP are generally grouped into two categories:

a. Long-term influences, and
b. Short-term influences.

Long-term factors (Khurana and Khurana, 2017):

i. Heredity: Individuals with a family history of primary open-angle glaucoma tend to exhibit higher IOP, suggesting a multifactorial genetic influence.
ii. Age: After age 40, both mean IOP and its variability slightly increase each decade, likely due to a decline in aqueous outflow despite reduced aqueous production.
iii. Sex: Between ages 20–40, IOP is similar in males and females, but after 40, females tend to show a greater age-related increase.
iv. Race: Ethnic variations in IOP exist; for instance, full-blooded Native Americans from a New Mexican tribe were found to have significantly lower IOP compared to other populations.
v. Refractive Error: Individuals with myopia tend to have slightly higher IOP than emmetropic individuals.

1.1.3.1 SHORT-TERM FACTORS

IOP can fluctuate due to physiological and external factors, including circadian rhythm, heartbeat, respiration, physical activity, posture, fluid intake, and medication use(Tanna *et al.*, 2020).

Body position also significantly influences IOP—measurements are lowest when sitting upright with the neck in a neutral position and higher when lying down, primarily due to increased episcleral venous pressure (EVP). Some individuals experience an exaggerated rise in IOP when recumbent, which may contribute to certain forms of glaucoma. Alcohol and cannabis temporarily lower IOP, though cannabis is not clinically practical due to its short action and adverse effects. Caffeine generally has little effect on IOP. Among healthy individuals, IOP remains relatively stable across different ages (Tanna *et al*., 2020).

1.1.3.2 CIRCADIAN VARIATION

In healthy individuals, IOP fluctuates by approximately 2–6 mmHg over a 24-hour cycle due to changes in aqueous humor production, outflow facility, and uveoscleral drainage. Higher mean IOP is typically associated with wider fluctuations. Peak IOP usually occurs during sleep or early morning, corresponding with reduced aqueous production and outflow. In many cases, another smaller peak occurs shortly after awakening. Continuous or out-of-office IOP monitoring can be beneficial for detecting unexplained optic nerve damage in patients with apparently controlled pressure (Tanna *et al*., 2020).

1.1.3.3 DRUGS AFFECTING INTRAOCULAR PRESSURE

The pharmacological management of glaucoma aims to reduce IOP by either decreasing aqueous humor production or enhancing its outflow. Cholinergic agonists (e.g., pilocarpine) act by contracting the iris sphincter and ciliary muscle, thereby widening the trabecular meshwork and facilitating outflow. However, side effects such as miosis and ciliary spasm often limit compliance.

Beta-blockers and alpha-adrenergic agonists decrease aqueous production by acting on the ciliary epithelium, possibly by interfering with neural control or ion transport mechanisms(Remington, 2012).

Carbonic anhydrase inhibitors reduce aqueous formation by inhibiting enzymes essential for ionic transport, though they may cause systemic side effects. Prostaglandin analogues are currently the most effective and well-tolerated glaucoma medications. They primarily enhance uveoscleral outflow, likely by remodeling the extracellular matrix within the ciliary muscle and increasing tissue permeability. Some may also facilitate trabecular outflow (Remington, 2012)

1.1.4 MEASUREMENT OF INTRAOCULAR PRESSURE (TONOMETRY)

Tonometry refers to the measurement of IOP and is essential in glaucoma diagnosis and management. All tonometers function by applying force to deform a specific corneal area—either flattening (applanation tonometry) or indenting (indentation tonometry) it (Bhattacharyya, 2009).

1.1.4.1 APPLANATION TONOMETRY

This widely used method is based on the Imbert-Fick principle, which states that the pressure inside a thin-walled sphere equals the applied force divided by the flattened area ($P = F/A$). By flattening the cornea and measuring the applied force, IOP can be accurately determined (Tanna *et al*., 2020).

1.1.4.1.1 GOLDMANN APPLANATION TONOMETER (GAT)

Introduced in 1954, the Goldmann Applanation Tonometer (GAT) is considered the gold standard for IOP measurement. It measures the force required to flatten a 3.06 mm area of the cornea, where corneal rigidity is balanced by tear film surface tension. The measured force (in grams) multiplied by 10 gives IOP in mmHg. Using a split-image prism, the examiner aligns fluorescein-stained semicircles (mires) to determine the correct endpoint—when their inner edges just touch—ensuring precise readings(Samples and Schacknow, 2014).

The Perkins tonometer, a portable version of the GAT, uses the same split-image prism principle and can be employed with patients in either upright or supine positions (Tanna *et al*., 2020).

Applanation tonometry is safe, simple, and provides consistent results. Because it displaces only about 0.5 µL of aqueous humor, it causes minimal changes in IOP during measurement, making it more accurate than indentation techniques (Tanna *et al*., 2020).

1.1.4.2 INDENTATION TONOMETRY

1.1.4.2.1 SCHIÖTZ TONOMETER

The Schiötz tonometer, introduced in 1905, is the classic example of an indentation tonometer and remains in use in some clinical settings today. It operates based on the principle of measuring the degree of corneal indentation produced by a known weight. Although it is a displacement tonometer, the Schiötz tonometer is less accurate compared to applanation methods, as its readings can be influenced by factors such as corneal curvature, central corneal thickness, and ocular rigidity. Despite these limitations, it remains valuable due to its small, handheld, fully metal design, which makes it easily sterilizable and independent of electrical power. Consequently, it is often used in operating rooms or as a backup instrument in cases where more advanced tonometers are unavailable (Samples and Schacknow, 2014).

Fig. 1.1: Parts of a Schiötz Tonometer. 1 = Handle, 2 = Footplate, 3 = 5.5 gm weight, 4 = 7.5 gm and 10 gm weight, 5 = Plunger, 6 = Bent lever, 7 = Pointer, 8 = Scale and 9 = Test block (dummy cornea). Source:(Bhattacharyya, 2009)

Fig. 1.2: Goldmann applanation tonometer. Source :(Bhattacharyya, 2009)

1.1.4.3 INTRAOCULAR PRESSURE MEASUREMENT AND CORNEAL PACHYMETRY

When practical, it is recommended to obtain three to four intraocular pressure (IOP) readings prior to initiating treatment in order to establish a more comprehensive IOP profile. Understanding a patient’s IOP pattern, including identifying the peak IOP, can be clinically useful in diagnosis and management planning(Thomas and Melton, 2014).

Corneal pachymetry plays a vital role in accurately interpreting IOP measurements. Intraocular pressure values, when considered in isolation, may be misleading if the central corneal thickness (CCT) is not accounted for. A thinner cornea can lead to underestimation of true IOP, while a thicker cornea may result in overestimation. Beyond this correction factor, a physiologically thin cornea is also recognized as an independent risk factor for the development and progression of glaucoma(Thomas and Melton, 2014).

Pachymeters, which are relatively inexpensive, are essential tools for optometrists (ODs) in assessing glaucoma risk. For practitioners who refer glaucoma suspects, incorporating pachymetry into clinical assessment can significantly improve the sensitivity and specificity of referrals, ensuring that patients at genuine risk receive timely specialist care(Thomas and Melton, 2014).

1.2 STATEMENT OF PROBLEM

The developing eye in children possesses unique features that differ from those of the adult eye, making adult intraocular pressure (IOP) reference ranges unsuitable for pediatric use (Masoumpour *et al.*, 2020). Establishing standard IOP values in children requires data from large, diverse populations of healthy children across different countries and ethnic backgrounds. Currently, there is limited data available regarding IOP in children, including its distribution with respect to age and ocular growth, factors influencing IOP readings, and clear thresholds for identifying abnormally high or low IOP levels.

1.3 AIM AND OBJECTIVES OF THE STUDY

1.3.1 **AIM**

The aim of this study is to assess the distribution of intraocular pressure among school-aged children in Benin City, Nigeria.

1.3.2 OBJECTIVES

1. To determine the mean intraocular pressure among school-aged children in the study area.
2. To examine the variation of IOP based on age.
3. To examine the variation of IOP based on sex

4. To examine the variation of IOP based on body mass index (BMI).

1.4 HYPOTHESES

1. **$H0_1$**: There is no significant difference between the mean intraocular pressure of school-aged children and established reference values.
2. **$H0_2$**: There is no significant variation in intraocular pressure among school-aged children based on age and sex.
3. **$H0_3$**: There is no significant relationship between intraocular pressure and body mass index (BMI) among school-aged children.

1.5 SIGNIFICANCE OF THE STUDY

This study is expected to provide locally relevant reference data on IOP in Nigerian children. It will assist eye care professionals in identifying abnormal pressure readings and contribute to early diagnosis of childhood ocular diseases, like ocular hypertension and glaucoma. Furthermore, the findings will raise awareness about the importance of routine eye examinations for children and may influence policy decisions regarding school-based vision screening programs.

1.6 DEFINITION OF TERMS

1. **Intraocular Pressure (IOP):**

   Intraocular pressure refers to the fluid pressure within the eye, maintained primarily by the balance between the production and drainage of aqueous humor. It is a vital physiological parameter that helps maintain the structural integrity of the eye and supports normal visual function. “Normal” IOP is defined as the pressure level that does not cause glaucomatous damage to the optic nerve head (Suh and Kee, 2012).

2. **Glaucoma:**

   Glaucoma is an optic nerve disease characterised by optic disc cupping and a disturbance of blood supply caused by elevated intraocular pressure. It is one of the leading causes of blindness and visual loss globally, accounting for about 12.3% of cases (Park *et al*., 2010).

3. **Pediatric Glaucoma:**

   Certain forms of glaucoma, such as juvenile open-angle glaucoma and congenital glaucoma, affect children and may remain undetected due to their asymptomatic presentation. Elevated IOP in children can cause corneal enlargement, Descemet's membrane tears, and corneal oedema (Park *et al*., 2010).

4. **Risk Factors for Elevated IOP:**

   Several systemic, ocular, and biometric factors influence IOP. Central corneal thickness (CCT), systolic blood pressure, age, sex, alcohol consumption, smoking, and family history have all been identified as determinants of IOP distribution (Hashemi *et al*., 2016).

5. **Body Mass Index (BMI):**

   BMI is a measure of body composition that has been associated with variations in IOP. Evidence suggests that higher BMI levels are correlated with elevated intraocular pressure among children (Jiang *et al*., 2014).

6. **Sample Size Determination:**

   Sample size in medical research refers to the minimum number of participants required to achieve statistical validity. It is commonly calculated using established statistical formulas (Charan and Biswas, 2013). In this study, reference values were adapted from Briggs (2023).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 IOP DISTRIBUTION IN CHILDREN

The distribution of intraocular pressure in pediatric population has also been studied by a few authors. Jiang *et al*.,(2014) studied the distribution of intraocular pressure (IOP) and its associated factors in children. Using a random cluster sampling from kindergartens, primary schools, and junior and senior high schools from rural Guanxian County and the city of Weihai, the school-based cross-sectional Shandong Children Eye Study included children aged 4 to 18 years. All participants underwent an ocular examination, including ocular biometry, cycloplegic refractometry, and noncontact tonometry. At the end of the study it was discovered that the mean IOP was 17.6 ± 6 2.7 mmHg (range, 10–28 mmHg). The IOP increased up to an age of 10 years and subsequently decreased with older age. In multivariate regression analysis, higher IOP was associated with female sex ($P < 0.001$; standardized correlation coefficient b, 0.06; regression coefficient b, 0.34; 95% confidence interval [CI], 0.18, 0.50), higher body mass index ($P < 0.001$; correlation coefficient b, 0.09; regression coefficient b, 0.07; 95% CI, 0.04,0.09), younger age ($P < 0.001$; correlation coefficient b, 0.15; regression coefficient b, 0.13; 95% CI, 0.17, 0.10), maternal myopia ($P < 0.001$; correlation coefficient b, 0.05; regression coefficient b, 0.34; 95% CI, 0.15,0.53), and more time spent indoors with reading/ writing ($P = 0.002$; correlation coefficient b, 0.05; regression coefficient b, 0.07; 95% CI, 0.03,0.11), and with the ocular parameters of longer axial length ($P < 0.001$; correlation coefficient b, 0.14; regression coefficient b, 0.29; 95% CI, 0.21,0.37) and smaller corneal horizontal diameter ($P < 0.001$; correlation coefficient b, 0.06; regression coefficient b, 0.31; 95% CI, 0.46,–0.15).

Masoumpour *et al*.,(2020) did a study to describe the mean and normal range of intraocular pressure (IOP) and its associations in healthy Iranian school children using the noncontact tonometer. Basic demographics and socioeconomic status of households, past medical history, drug history, and eye health history were collected for each eligible student. Of 2,001 eligible children, only 1,901 (95.0%; 3,802 eyes) participated in the study. Children underwent complete ophthalmic examination. Axial length, corneal curvature, and anterior chamber depth were measured using the IOL-Master 500. Upon analysis of the data the mean spherical equivalent refraction was 0.5 ± 1.3 D for the right eye and 0.6 ± 1.2 D for the left eye. Mean IOP in the right eye was 15.1 ± 2.5 mmHg (median, 15.0; range, 8.0–27.0 mmHg); in the left eye, 15.2 ± 2.5 mmHg (median, 15.0; range, 9.0–28.0 mmHg). Multiple regression was used to analyze and it was discovered that, the mean IOP was significantly lower among asthmatic children compared to normal participants (P = 0.007). The measured IOP was significantly higher in myopic participants than hyperopic patients (P = 0.003).

2.2 IOP IN PEDIATRIC GLAUCOMA AND POST-SURGICAL OUTCOMES

Yoo *et al*.,(2023) conducted a prospective observational study to assess corneal biomechanics, endothelial cell health, and retinal vasculature using noninvasive imaging modalities in pediatric patients diagnosed with glaucoma, glaucoma suspects, and healthy controls. The study enrolled 141 children between the ages of 6 and 18 years who were evaluated using the Ocular Response Analyzer (ORA), specular microscopy, and optical coherence tomography angiography (OCT-A). The authors reported that children with glaucoma had significantly greater central corneal thickness (CCT) and reduced corneal hysteresis (CH) compared to controls, indicating altered corneal biomechanics that may impact the accuracy of intraocular pressure (IOP) measurements and reflect increased optic nerve susceptibility. Additionally, endothelial cell density was significantly lower and average cell area significantly larger in glaucoma patients, suggesting compromised endothelial integrity potentially linked to the number of prior intraocular surgeries. In contrast, OCT-A findings revealed no statistically significant differences in superficial or deep retinal vessel density among glaucoma patients, suspects, and controls. The study underscores the relevance of corneal metrics in pediatric glaucoma assessment, while also highlighting the limited discriminative value of OCT-A in this population and calling for further research with larger and more stratified cohorts.

Eksioglu *et al*.,(2017) conducted a retrospective chart review to evaluate the short- to long-term outcomes of Ahmed glaucoma valve (AGV) implantation for the management of elevated intraocular pressure (IOP) in pediatric patients with uveitis. The study involved 16 eyes from 11 children who had undergone AGV surgery due to uncontrolled IOP despite maximal tolerated medical therapy. Uveitis in these patients was most commonly due to pars planitis, followed by Behçet’s disease and idiopathic anterior uveitis. The average age at AGV implantation was 14.2 years, and the mean follow-up period extended to over five years (64.5 months), offering a rare long-term view of outcomes in this patient population.

The findings demonstrated a significant reduction in IOP from a preoperative mean of 33.5 mmHg to 12.7 mmHg at the last follow-up, confirming the efficacy of AGV in achieving IOP control. However, while some patients achieved complete success—defined as IOP control without medication—many required continued use of antiglaucoma medications, with the complete success rate declining progressively over time (35.2% at 84 months). Qualified success, which included those controlled with medications, was more common.

Complications were not infrequent and increased with time. Early postoperative complications occurred in 25% of eyes, including transient hypotony and hyphema. Cataract progression was the most frequent late complication, seen in 50% of phakic eyes, necessitating surgical intervention. Notably, tube exposure—a serious concern due to the associated risk of endophthalmitis—was observed in three eyes, and one patient developed endophthalmitis, which was initially misdiagnosed as a uveitis relapse, underscoring the importance of differential diagnosis in postoperative care.

The study concludes that AGV implantation is a viable and effective surgical option for pediatric uveitic glaucoma, especially when conventional glaucoma surgeries fail. However, long-term follow-up is critical due to the risk of complications such as tube exposure and cataract progression. While the results highlight the usefulness of AGV, they also point to the ongoing need for adjunctive medical therapy and careful postoperative monitoring. The authors call for further comparative studies to establish the optimal surgical approach for this complex patient population.

2.3 IOP DISTRIBUTION AND ASSOCIATED FACTORS

Hashemi *et al*.,(2005) did a study to provide data on the distribution of intraocular pressure (IOP) in an Iranian population. The study involved 3834 participants aged 10 years and older. All participants received a standardized protocol including applanation tonometry, fundus examination, demographic data, and an interview. IOP measurement was used to evaluate its distribution by age, sex, and some eye parameters. Analysis of data collected during the study revealed the mean (SD) IOP to be 14.5 (2.6) mmHg in the total population, 14.4 (2.7) in men, and 14.5 (2.5) in women. Mean (SD) IOP in people >40 years was 15.1 (2.9) mmHg. IOP increased significantly with age and cup: disc ratio except for a fall in old age. This relation was also observed when individuals without diabetes or hypertension history were analyzed. IOP increased with darker eye pigmentation except for blue/grey eyes. There was a non-linear increase in IOP from emmetropic to high myopic eyes. In 2016 Hashemi *et al*., in their study " *distribution of intraocular pressure and its determinants in an Iranian adult population"* examined 5190 persons. All participants had optometry and ophthalmic exams. IOP was determined using the Goldmann tonometry method and biometric components were measured. The results of the study revealed the mean IOP of the participants to be 12.87 ± 2.27 mmHg. In this study 0.3% of the participants had an IOP higher than 21 mmHg. The multiple linear regression model revealed that sex (*b*=-0.30; 95% CI: -0.43 to -0.17), diabetes (*b* = 0.43; 95% CI: 0.19 to 0.67), high systolic blood pressure (*b*=0.02; 95% CI: 0.01 to 0.02), high body mass index (BMI) (*b* =0.03; 95% CI: 0.01 to 0.04), higher education (*b*=0.02, 95% CI: 0.01 to 0.04), thicker central corneal thickness (*b*=0.01; 95% CI: 0.01 to 0.02), and myopic shift in spherical equivalent (***b***=-0.14; 95% CI: -0.18 to -0.10) significantly correlated with high IOP.

In 2018 Hashemi *et al*., did another study in which the distribution of intraocular pressure (IOP) in a young population was evaluated using a non-contact air-puff tonometer, aiming to establish normative IOP values and explore associated ocular and demographic parameters. The cross-sectional study involved 1044 students aged 20–34 from Mashhad University of Medical Sciences, making it one of the few large-scale investigations focusing on younger adults. The authors measured IOP alongside variables such as age, gender, central corneal thickness (CCT), spherical equivalent (SE), corneal diameter, and keratoconus status.

The mean IOP was reported as 16.38 mmHg, with women showing slightly higher values than men, although the difference was not clinically significant. IOP values showed a statistically significant increase with age within this young cohort. Importantly, CCT and SE were found to be the strongest predictors of IOP, with thicker corneas and more myopic refractive errors associated with higher pressures. Individuals with keratoconus had significantly lower IOP values, likely due to reduced corneal biomechanical resistance.

The study also revealed that myopic eyes had higher IOP compared to emmetropic and hyperopic eyes, supporting existing theories about the anatomical and genetic links between myopia and elevated IOP. While gender was initially associated with IOP, multivariate analysis suggested this relationship may be confounded by other variables. The study concluded that air-puff tonometry, despite its tendency to overestimate IOP relative to Goldmann applanation tonometry (GAT), can provide reliable IOP estimates in large-scale screenings, particularly in younger populations.

Pakravan *et al.*,(2017) did a study to determine the distribution of intraocular pressure (IOP), central corneal thickness (CCT) and vertical cup-to-disc ratio (VCDR) in the healthy Iranian population. The study involved adults aged 40-80 years and were selected by cluster random sampling. Each participant underwent an interview and ophthalmologic examination including slit lamp examination, Goldmann applanation tonometry, binocular optic disc evaluation, stereoscopic fundus photography, ultrasonic pachymetry and visual field testing. Of 2320 eligible individuals, 2098 subjects (response rate of 90.4%) participated in the study. One eye from 1159 subjects (total of 2262 normal eyes) were randomly selected for the purpose of the study. Statistical analysis of the data from the study revealed that the mean IOP, CCT and VCDR were 14.2 ± 2.5 mmHg, 543 ± 37 um and 0.32 ± 0.14, respectively. Multiple regression analysis showed a significant correlation between IOP and age (regression coefficient = 0.02 per year, p = 0.015), CCT (regression coefficient = 0.02 per micron, p < 0.001), Spherical equivalent (regression coefficient = - 0.15 per dioptre, p = 0.0.024) and smoking (regression coefficient = 0.89 higher for smokers, p = 0.009); it also showed a significant correlation between CCT with spherical equivalent (regression coefficient = 3.6 per dioptre, $p = 0.002$) and IOP (regression coefficient = 3.6 per mmHg, $p < 0.001$). There was no significant correlation with VCDR.

In a study done by Kim *et al*.,(2014) the distribution of intraocular pressure (IOP) and its associated factors was being examined. The study 13,431 adult subjects who were required to complete a comprehensive questionnaire and underwent an ocular examination including measurement of IOP by Goldmann applanation tonometry, as well as a systemic evaluation including blood pressure measurements, anthropometry and blood tests. Upon analysis the results of the study it was discovered that the mean IOP in the right eye was 13.99 ± 2.75 mmHg, and in the left eye, 13.99 ± 2.75 mmHg, representing no significant bilateral difference. There was, however, a significant difference between males (14.19 ± 2.78 mmHg) and females (13.79 ± 2.70 mmHg) ($p < 0.001$). Multiple regression analysis revealed that higher IOP was significantly correlated with male sex, higher myopic refractive error, higher body mass index, higher systolic blood pressure, higher fasting plasma glucose and higher total cholesterol (all $p < 0.05$). On the other hand, age, histories of smoking or migraine or cold hands/feet were not significantly correlated with IOP (all $p > 0.05$).

In 2013 Hoehn *et al*., did a study to describe the distribution of intraocular pressure (IOP) and its association with ocular features and cardiovascular risk factors in adults. This analysis was based on a Gutenberg Health Study (GHS) cohort that included 4335 eligible enrollees from among 5000 subjects who participated in the survey from 2007 through 2008. The age range was 35 to 74 years at enrollment. Participants underwent a standardized protocol with a comprehensive questionnaire; ophthalmic examination including slit-lamp biomicroscopy, noncontact tonometry, fundus photography, central corneal thickness measurement, and visual field testing; and a thorough general examination focused on cardiovascular parameters, psychological evaluation, and laboratory tests, including genetic analysis. The data of the study was analyzed and it was discovered that the mean SD ± IOP in men(n=2216)and in women(n=2119) was 14.1 ± 2.7 mmHg and 13.9 ± 2.5 mmHg with an intersex difference (P 0.009). Positive univariate associations with higher IOP were detected for brown iris color, central corneal thickness, hypertension, diabetes, smoking, obesity, dyslipidemia, body mass index, weight, hip size (women only), waist circumference, and waist-to-hip ratio. Multivariate testing revealed male gender, central corneal thickness, brown iris color, hypertension, smoking, and waist-to-hip ratio to be correlated with higher IOP. In women, age correlated negatively with IOP in the multivariate analysis.

Park *et al*.,(2010) studied the distribution of intraocular pressure (IOP) and its association with metabolic syndrome (MS). IOP and MS components from 446 adults, age 20 or more years old, who reside in a community in Kyunggi Province, South Korea was measured. They compared the level of IOP according to the number of metabolic abnormalities and between normal and abnormal metabolic components. They discovered that there was no significant difference in IOP (mean ± SE) was found between men (12.24 ± 2.42) and women (12.55 ± 2.41 mmHg, $p > 0.1$), while IOP of men tended to decrease as age increased (p for trend< 0.05). Female subjects with MS showed significantly higher IOP than those without MS. Participants with more metabolic disturbances tended to have a greater IOP elevation with a linear trend after adjusting for age and sex. In the univariate regression analysis, age and waist circumference were significantly associated with IOP in men, but systolic and diastolic blood pressure were associated with IOP in women. In final multiple regression model, age, systolic blood pressure, and triglyceride were associated with IOP in women, and age in men.

2.4 GEOGRAPHIC AND ETHNIC VARIATIONS IN IOP

Intraocular pressure (IOP) varies between individuals, and a range of associations have been documented in various races. Suh and Kee (2012) did a cross-sectional, epidemiologic study on the distribution of intraocular pressure in urban and in rural populations. A total of 3191 subjects residing in urban and rural areas of South Korea were recruited. All participants underwent interview and the following ocular examinations: visual acuity measurement, autorefraction, pachymetry, anterior segment evaluation, slit-lamp examination, Goldmann applanation tonometry, binocular optic disc evaluation, fundus photography, and visual field test. Patients with ocular diseases other than mild senile cataract or with history of ocular surgery were excluded. At the end of the study, it was discovered that the mean IOP of patients from the urban area was significantly higher than that of those from the rural area (14.45 ± 2.67 mmHg vs 13.53 ± 2.76 mmHg, $P < .05$). There was regional difference of mean IOP, even after controlling for different demographic factors in the 2 areas ($P < .05$).

In another study by Giuffrè *et al*.,(1995) 1062 middle-aged and elderly subjects of a small Sicilian town to examine the prevalence of glaucoma and distribution of intraocular pressure in the population. The mean IOP subjects was 15.1 ± 3.7 mmHg without interocular or sex differences. A small but significant age-dependent increase of IOP was found. Circadian and seasonal influences were recorded: IOP was higher in the morning and in winter. The prevalence of chronic open-angle glaucoma was 1.2%, but it grew to 3.6 if only subjects aged 70 years or more were considered. IOP of 24 mmHg or more was found in 2.7%, while 4.3% of subjects showed IOP of 21 mmHg or more.

In central Australia Landers *et al*.,(2011) did a study on the distribution and associations of intraocular pressure. The study involved 1060 individuals aged 20 years or over. Participants underwent IOP measurement using either a Perkins tonometer (Haag-Streit, Koeniz, Switzerland) or an ICare tonometer (Tiolat Oy, Helsinki, Finland) depending on the availability of equipment. Central corneal thickness (CCT) was also measured using ultrasound pachymetry. Mean IOP discovered to be 12.8 mmHg (SD 3.2 mmHg) and CCT was 512 mm (SD 36 mm). IOP was also discovered to be strongly associated with CCT ($r^2 = 0.14$, $t = 3.87$; $P < 0.0001$), showing an increase of 0.4 mmHg with every 10 mm increase in CCT. Furthermore, IOP was strongly associated with age, decreasing by 1.9 mmHg for every decade increase in age, but only for eyes with a CCT above the mean. Indicating the IOP of indigenous Australians is lower than any other racial group previously published. This may relate to the low CCT readings found among this population.

Leske *et al*.,(1997) did a study to provide data on the distribution of intraocular pressure (IOP) in a predominantly black population, which has a high prevalence of open-angle glaucoma. The study involved 4601 participants aged 40-84 years who had undergone applanation tonometry measurements in the Barbados Eye Study. The race of the subjects was 93% black,4% mixed (black and white), and 3% white or others. The results of the study revealed that the IOP was highest in the population of African origin. The mean IOP values for black, mixed, and white participants were 18.7 ± 5.2,18.2 ± 3.8,and 16.5 ± 3.0mmHg, respectively. An IOP greater than 21mmHg was present in 18.4%, 13.6%, and 4.6%of the black, mixed, and white participants, respectively.

Bonomi *et al*.,(1998) examined the prevalence of various types of glaucoma and to determine the intraocular pressure (lOP) distribution in a defined population in an Italian rural community. All subjects residing in the Egna-Neumarkt area of Alto Adige region (Northern Italy) and over 40 years of age were invited to undergo an ophthalmologic examination. Each subject was examined according to a standard protocol, including computerized perimetry, applanation tonometry, evaluation of anterior chamber depth and optic disc, and a medical history interview. The diagnosis of glaucoma was based on the presence of at least two of the following criteria: lOP greater than or equal to 22 mmHg, glaucomatous optic disc abnormalities, and glaucomatous visual field defects. Ocular hypertension was defined as lOP greater than or equal to 22 mmHg without visual field or glaucomatous optic disc abnormalities. Of a total of 5816, 4297 subjects were examined (73.9% overall participation rate). At the end of the study it was discovered that the distribution of intraocular pressure was skewed to the right, mean lOP increased with age, and was slightly higher in men (15.14 mmHg) than in women (14.94 mmHg). The overall prevalences of ocular hypertension, primary open-angle glaucoma, primary angle-closure glaucoma, and normal-tension glaucoma were 2.1%, 1.4%, 0.6%, and 0.6%, respectively. Only 28 of 210 patients with glaucoma or ocular hypertension had been diagnosed prior to the screening.

2.5 INTRAOCULAR PRESSURE (IOP) MEASUREMENT TECHNIQUES AND DEVICE COMPARISONS

In a study by Paredes *et al.*,(2020) , the reliability of rebound tonometry using re-sterilised tips was evaluated in comparison to the Goldmann applanation tonometer (GAT), which is widely regarded as the gold standard for intraocular pressure (IOP) measurement. Conducted among pediatric patients in Guatemala, the study addressed a practical concern in low-resource settings where the cost of single-use TRB tips often necessitates their re-sterilisation. The authors assessed IOP measurements in 25 healthy children aged 8 to 12 years using three methods: rebound tonometry with new tips (TRB), rebound tonometry with re-sterilised tips (TRB-RE), and GAT. Their findings revealed a statistically significant correlation between GAT and TRB (p

= 0.0011), but no correlation was found between GAT and TRB-RE, nor between TRB and TRB-RE. Moreover, TRB consistently overestimated IOP compared to GAT, though the values remained within normal ranges. The study also found that central corneal thickness (CCT) influenced IOP readings with GAT and TRB, but not with TRB-RE. Based on these findings, the authors concluded that while TRB can be a useful tool for IOP screening in children, particularly due to its non-invasive nature and ease of use, re-sterilised tips should be avoided due to their lack of measurement reliability.

In their 2015 study, McKee *et al*.,(2015) investigated the comparative performance of the Icare PRO rebound tonometer and the Tono-Pen XL in measuring intraocular pressure (IOP) in anesthetized children. Given the difficulty of using traditional Goldmann applanation tonometry (GAT) in pediatric patients due to issues of cooperation and positioning, the study aimed to evaluate these two handheld devices under controlled conditions in the operating room, where children were supine and under general anesthesia.

The study included 50 children (100 eyes) undergoing ophthalmic procedures, encompassing a range of ocular conditions including normal eyes, glaucoma, corneal edema, and other corneal abnormalities. IOP measurements were taken using both devices in random order, immediately following anesthesia induction. The mean IOP measured by the Tono-Pen XL (18.9 mmHg) was found to be significantly higher than that measured by the Icare PRO (16.7 mmHg), with an average difference of 2.2 mmHg. This difference was more pronounced in eyes with corneal edema, where the Tono-Pen readings exceeded Icare PRO measurements by an average of 8.4 mmHg.

The study found a strong correlation between the two devices overall (r = 0.88), and for most eyes—especially those without corneal pathology—the IOP measurements between the two devices were within 3 mmHg of each other. However, in cases of corneal edema, Icare PRO tended to significantly underestimate IOP compared to both the Tono-Pen and pneumatonometry, the latter of which was used as a confirmatory method in some eyes.

The findings highlight the Icare PRO as a practical and reasonably accurate tool for IOP measurement in supine, anesthetized children, particularly in eyes without significant corneal pathology. However, the authors emphasize caution when interpreting IOP readings from Icare PRO in the presence of corneal edema, recommending confirmation with another method due to the risk of underestimation. This study is the first to identify the underestimation of IOP by rebound tonometry in the context of corneal edema in pediatric patients, offering important clinical guidance for managing young children with glaucoma or corneal disease.

Perez-Garcia *et al*.,(2020) conducted an observational study to assess the agreement between intraocular pressure (IOP) measurements obtained using the newly developed Icare 200™ (IC200) rebound tonometer and the Perkins™ handheld applanation tonometer (a portable Goldmann equivalent) in both healthy individuals and patients with primary congenital glaucoma (PCG). Given the difficulty of obtaining reliable IOP measurements in children due to poor cooperation, this study aimed to evaluate whether IC200 could serve as a clinically valid and efficient alternative in such cases.

The study enrolled 82 eyes in total, divided into two groups: 42 eyes from healthy subjects and 40 eyes from patients diagnosed with PCG. IOP measurements were performed sequentially in the same visit, first with IC200 and then with the Perkins tonometer. The authors also recorded other clinical data, including central corneal thickness (CCT), best corrected visual acuity (BCVA), and details of prior glaucoma surgeries and topical treatments in the PCG group.

The results revealed that IC200 consistently recorded slightly higher IOP values than Perkins, but these differences were not statistically significant. Specifically, in the healthy group, the mean difference between IC200 and Perkins was 0.84 mmHg, and in the PCG group, it was 0.98 mmHg. Importantly, intraclass correlation coefficients (ICCs) indicated excellent agreement between the two devices in both groups, with ICC values of 0.875 for healthy subjects and 0.924 for PCG patients.

The study further explored whether CCT influenced the differences in IOP readings. A significant correlation between CCT and IOP measurement differences was observed in the healthy group, but not in the PCG group. This suggests that while corneal thickness may affect IOP readings in general, its impact may be less pronounced in eyes affected by congenital glaucoma, possibly due to additional anatomical or biomechanical changes.

The authors concluded that the IC200 is a reliable and efficient tool for measuring IOP in both healthy children and those with PCG. Its advantages—such as not requiring topical anesthesia, ease of use in supine position, and speed—make it particularly valuable in pediatric practice where patient cooperation is limited. However, they acknowledged limitations including potential sample bias due to the tertiary care setting and the older age of participants, and recommended further research, particularly in younger age groups and across a broader range of IOP values.

CHAPTER THREE

3.0 METHODOLOGY

3.1 STUDY AREA

This study was conducted in Benin City, Edo State.

3.2 STUDY DESIGN

The study adopted a cross-sectional design.

3.3 SAMPLING TECHNIQUE

A multistage sampling technique was used. Firstly, schools in Benin City were stratified into public and private categories. Then, a random selection of schools was made from each stratum. Within each selected school, systematic random sampling was used to recruit eligible participants from class registers.

3.4 STUDY POPULATION

The study population comprised school-aged children between 6 and 14 years enrolled in selected primary and secondary schools in Benin City.

3.5 SAMPLE SIZE

Using formula below:

$$n = \frac{Z^2 \times SD^2}{d^2}$$ (Charan and Biswas, 2013)

Where;

n = Minimum Sample Size

Z = Standard Normal Variate (at 5% type 1 error ($P < 0.05$) it is 1.96)

SD = Standard deviation of variable taken from a previously done study or through pilot study= 3.1 (Briggs, 2023)

d = Absolute error or precision. An absolute error of 0.64 was used

$$n = \frac{1.96^2 \times 3.1^2}{0.64^2} = \frac{3.8416 \times 9.61}{0.4096} = 90.13 \approx 90$$

Considering a 10% non-participation rate (attrition rate)

0.1 x 90 = 9

Final sample size = 90 + 9 = 99

Using convenience sampling technique a total of 568 subjects was used for this study.

3.6 RESEARCH INSTRUMENTS AND MATERIALS

3.6.1 INSTRUMENT OF STUDY: Direct ocular examination

3.6.2 MATERIALS OF STUDY

- A structured data collection form to record demographic and ocular information
- Air puff tonometer for IOP measurement
- Alcohol swabs and disposable gloves
- Visual acuity charts (Snellen or LogMAR)
- Pen torch and direct ophthalmoscope for basic ocular screening
- Consent and assent forms.

- Weight scale
- Metre rule

3.7 INCLUSION CRITERIA

- Children aged 6 to 14 years
- Children enrolled in selected schools within Benin City
- Children whose parents or guardians provide informed consent and who provide assent

3.8 EXCLUSION CRITERIA

- Children with known ocular pathology or systemic illness affecting intraocular pressure
- Children currently on medications known to affect IOP (e.g., steroids)
- Children who decline to participate or show signs of distress during the examination

3.9 ETHICAL CONSIDERATION

Ethical approval to conduct this study was obtained from the Research and Ethics Committee of the Department of Optometry, University of Benin. A written consent was obtained from the parent(s) of each child also a verbal consent from the children participating in the study before participation. All participants were given comprehensive information regarding the study and told of their rights to withdraw at any time. To maintain anonymity, personal identifying information such as name, was not be collected. Data was used strictly for this study. The study adhered to the other tenets of the Helsinki Declaration.

3.10 PROCEDURE

The study was carried out over a period of three months. On the days for screening, participants were gathered in a quiet, well-lit room within the school premises. Basic demographic data such as age, sex, and class were recorded. A preliminary ocular screening was done to rule out visible abnormalities. IOP was measured using a calibrated non-contact tonometer. The right eye was measured at least twice, and the average reading was recorded. Children found with abnormal IOP readings or other ocular issues were referred to a tertiary eye care facility for further evaluation.

3.11 DATA ANALYSIS

Collected data was entered into a spreadsheet and later imported into a statistical software (SPSS v26) for analysis. Intraocular pressure readings were categorized by age group, sex, school type. Descriptive statistics (mean, standard deviation, frequency distribution) was used to present the IOP values, and comparative analyses (e.g., t-tests or ANOVA) was employed to assess significant differences among groups.

CHAPTER FOUR

4.0 RESULTS AND DATA ANALYSIS

A total of 568 students participated in the study, comprising 296 females (52.1%) and 272 males (47.9%). This study was conducted to assess the distribution of intraocular pressure among school-aged children in Benin City, Nigeria.

TABLE 4.1: SOCIO-DEMOGRAPHIC DATA OF PARTICIPANTS

				Age(Years)			
				Mean	**S.D**	**Minimum**	**Maximum**
		N	**N (%)**				
Gender	Female	296	52.1%	10	2	6	14
	Male	272	47.9%	10	3	6	14
	Total	568	100.0%				
Class	Primary 1	64	11.30%	7	0	7	7
	Primary 2	70	12.30%	8	0	8	8
	Primary 3	64	11.30%	9	0	9	9
	Primary 4	59	10.40%	10	0	10	10
	Primary 5	70	12.30%	11	0	11	11
	Primary 6	67	11.80%	12	2	8	14
	Junior Secondary School 1	67	11.80%	13	0	13	13
	Junior Secondary School 2	63	11.10%	14	0	13	14
	Junior Secondary School 3	44	7.70%	6	0	6	6
	Total	568	100.0%				
BMI Classification	Normal	200	35.2%	12	2	8	14
	Underweight	368	64.8%	9	2	6	13
	Total	568	100.0%				

Table 4.1 presents the demographic characteristics of the respondents. The sample showed a near-even gender distribution, with slightly more females (52.1%) than males (47.9%). The

overall mean age was 10 ± 2 years. Class distribution ranged from Primary 1 to Junior Secondary School 3, with most pupils in Primary 2 and Primary 5 (12.3%), while Junior Secondary School 3 had the least representation (7.7%).

TABLE 4.2: FREQUENCY DISTRIBUTION OF PARTICIPANTS BY AGE

Age (Years)	**Frequency**	**Percent**
6	64	11.3
7	70	12.3
8	64	11.3
9	59	10.4
10	70	12.3
11	67	11.8
12	67	11.8
13	70	12.3
14	37	6.5
Total	568	100.0

The age groups 7, 10, and 13 years were the most represented, each accounting for 12.3% of the sample, while the age group 14 years had the lowest frequency (6.5%).

TABLE 4.3: DESCRIPTIVE STATISTICS FOR WEIGHT, HEIGHT, BODY MASS INDEX, AND INTRAOCULAR PRESSURE (IOP)

	Mean	**Std. Deviation**	**Minimum**	**Maximum**
Weight(KG)	35	5	28	46
Height(M)	1.42	.13	1.29	1.87
Body Mass Index(BMI)	17.58	1.98	10.00	19.39
IOP(mmHg)	17	2	14	21

The mean weight of participants was 35 ± 5 kg, the mean height was 1.42 ± 0.13 m, and the mean BMI was 17.58 ± 1.98, with values ranging from 10.00 to 19.39. The mean intraocular pressure (IOP) recorded was 17 ± 2 mmHg, ranging from 14 to 21 mmHg. These findings suggest that the majority of students were within normal anthropometric and ocular parameters.

TABLE 4.4: CORRELATION BETWEEN AGE AND INTRAOCULAR PRESSURE

					Age (Years)	IOP(mmHg)
Spearman's rho	Age	Correlation Coefficient			1.000	.827**
		Sig. (2-tailed)			.	< .001
		N			568	568
		Bootstrap	Bias		.000	.000
			Std. Error		.000	.020
			95% Confidence Interval	Lower	1.000	.786
				Upper	1.000	.866
	IOP(mmHg)	Correlation Coefficient			.827**	1.000
		Sig. (2-tailed)			< .001	.
		N			568	568
		Bootstrap	Bias		.000	.000
			Std. Error		.020	.000
			95% Confidence Interval	Lower	.786	1.000
				Upper	.866	1.000

Table 4.4 shows that there was a strong, positive, and statistically significant correlation between age and IOP (Spearman's rho = 0.827, $p < 0.001$). This indicates that as age increased, IOP also tended to increase. The 95% confidence interval ranged between 0.786 and 0.866, affirming the strength of the relationship.

TABLE 4.5: CORRELATION BETWEEN BMI AND INTRAOCULAR PRESSURE

					IOP(mmHg)	Body Mass Index(BMI)
Spearman's rho	IOP(mmHg)	Correlation Coefficient			1.000	.633**
		Sig. (2-tailed)			.	< .001
		N			568	568
		Bootstrap[b]	Bias		.000	.000
			Std. Error		.000	.027
			95% Confidence Interval	Lower	1.000	.577
				Upper	1.000	.682
	Body Mass Index(BMI)	Correlation Coefficient			.633**	1.000
		Sig. (2-tailed)			< .001	.
		N			568	568
		Bootstrap[b]	Bias		.000	.000
			Std. Error		.027	.000
			95% Confidence Interval	Lower	.577	1.000
				Upper	.682	1.000

A moderate positive correlation was observed between BMI and IOP (Spearman’s rho = 0.633, p < 0.001). The 95% confidence interval (0.577–0.682) suggests a consistent relationship, implying that students with higher BMI tended to have higher IOP.

TABLE 4.6: COMPARISON OF IOP ACROSS GENDER USING MANN-WHITNEY U TEST

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of IOP(mmHg) is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.027	Reject the null hypothesis.

The Mann–Whitney U test revealed a statistically significant difference in IOP between male and female students (U = 36,002.50, p = 0.027).

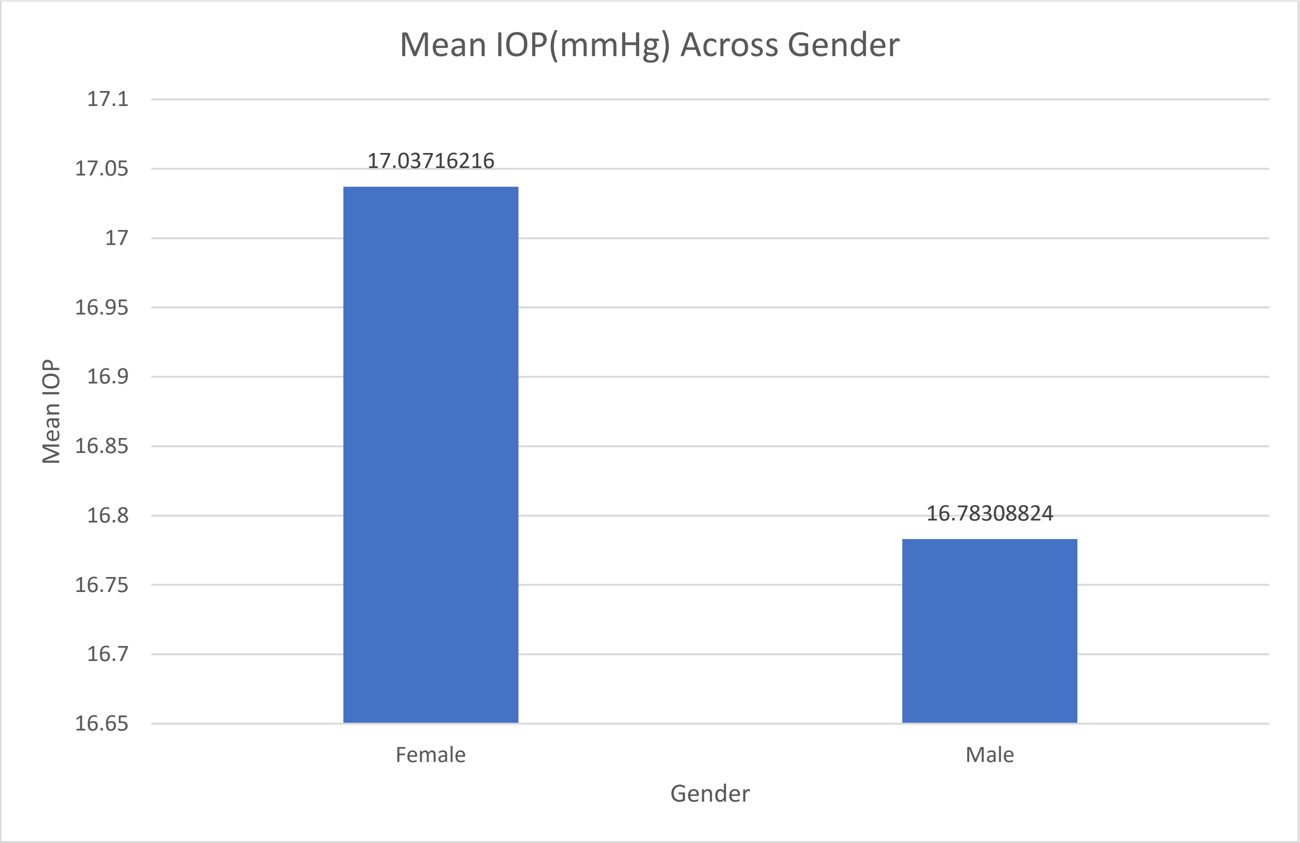

Figure 1: Mean IOP Across Gender

Figure 1 illustrates mean IOP across gender, showing that one gender group recorded a slightly higher mean IOP than the other.

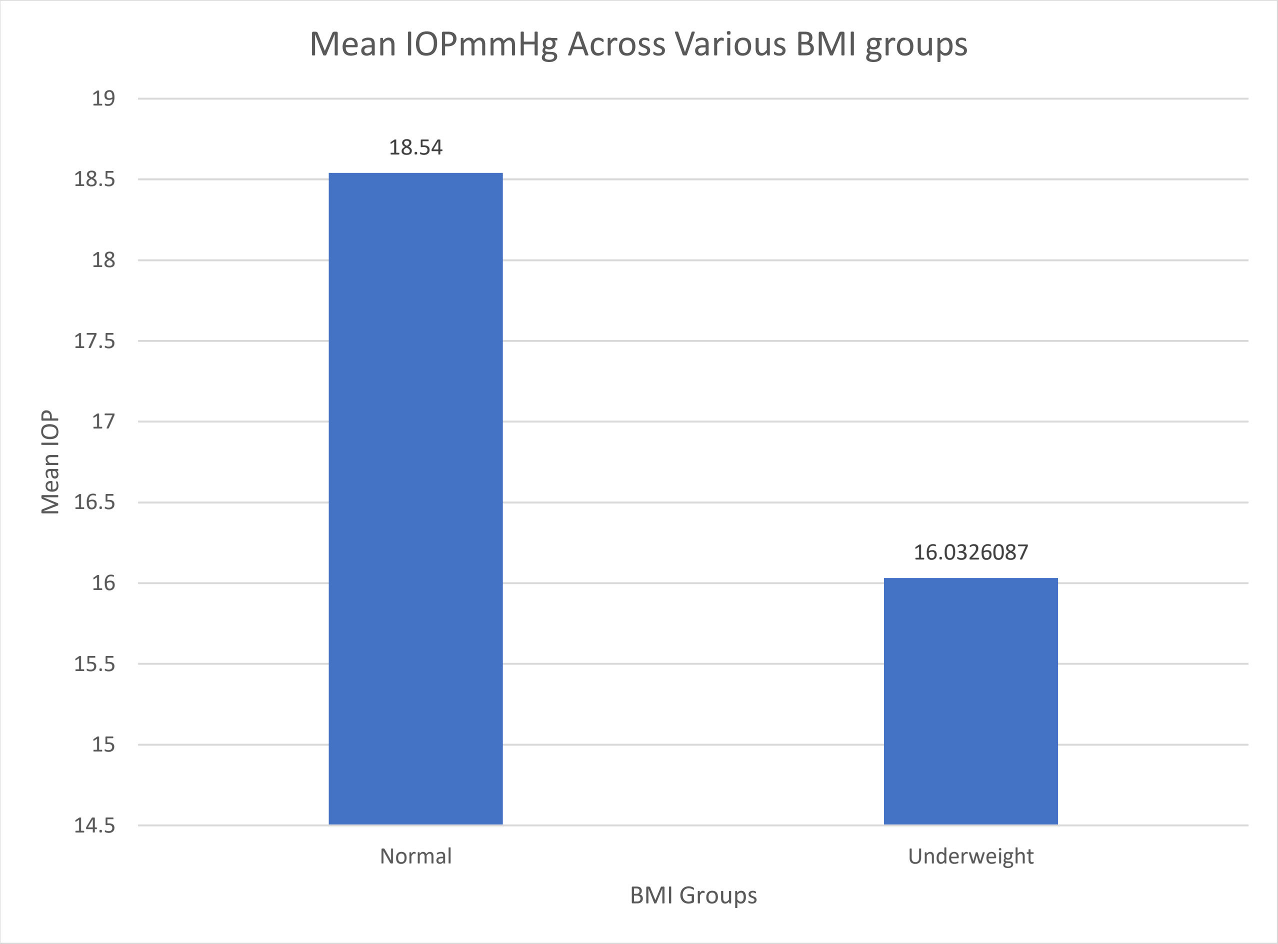

Figure 2: Mean IOP across BMI Classifications

Mean IOP was higher among students with normal BMI (18.54 mmHg) compared to those who were underweight (16.03 mmHg)

TABLE 4.7: COMPARISON OF BMI ACROSS GENDER USING MANN-WHITNEY U TEST

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Body Mass Index(BMI) is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.360	Retain the null hypothesis.

The Mann–Whitney U test showed no significant difference in BMI between genders (U = 42,041.00, p = 0.360).

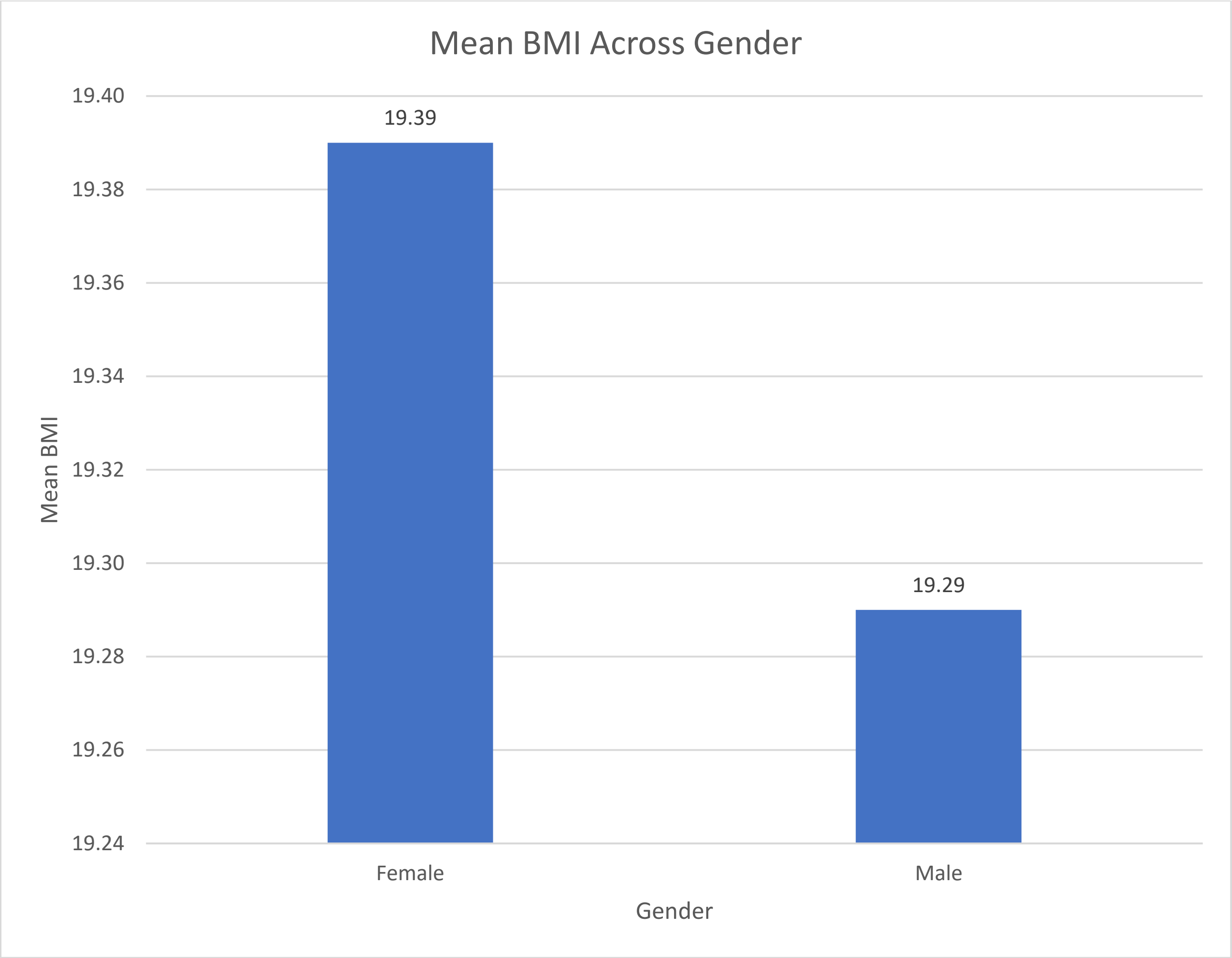

Figure 3: Mean BMI Across Gender

Female students had a mean BMI of 19.39, while male students had a slightly lower mean of 19.29.

CHAPTER FIVE

5.0 DISCUSSION

5.1 OVERVIEW OF FINDINGS

This study investigated the distribution of intraocular pressure (IOP) among school-aged children in Benin City, Nigeria, with specific attention to variations by age, gender, and body mass index (BMI). The study recorded a mean IOP of 17 ± 2 mmHg, which aligns with previously established normative ranges in paediatric populations (Jiang *et al*., 2014; Masoumpour *et al*., 2020). The analysis demonstrated a statistically significant increase in IOP with age and BMI, as well as a modest but notable difference between genders. These findings provide relevant local data for Nigerian children and contribute to the global understanding of paediatric ocular physiology.

5.2 INTRAOCULAR PRESSURE DISTRIBUTION AMONG SCHOOL-AGED CHILDREN

The mean IOP observed in this study (17 ± 2 mmHg) is comparable to the findings of Jiang *et al.*(2014), who reported a mean IOP of 17.6 ± 2.7 mmHg among Chinese children aged 4–18 years, and Masoumpour *et al.,*(2020), who documented a mean IOP of 15.1 ± 2.5 mmHg among Iranian children. The slight variation in mean IOP across studies may be attributed to differences in ethnicity, geography, and measurement techniques, as highlighted by Suh and Kee (2012) in their Korean population-based study.

Geographic and ethnic variations in IOP distribution have been well-documented. Cristina Leske *et al.,*(1997) reported that individuals of African origin exhibited higher mean IOP values compared to Caucasians, while Landers *et al.,*(2011) found lower mean IOP levels among

Indigenous Australians. Thus, the relatively higher mean IOP in this Nigerian paediatric sample may reflect inherent ethnic differences in ocular structure or physiological response, particularly in central corneal thickness and aqueous humour dynamics (Hashemi *et al*., 2016).

These findings further support the notion that IOP norms established for adults or non-African populations may not be directly applicable to African children. Establishing population-specific reference ranges is therefore crucial for accurate glaucoma risk assessment and screening in children (Bonomi *et al*., 1998).

5.3 RELATIONSHIP BETWEEN AGE AND INTRAOCULAR PRESSURE

The study revealed a strong positive and statistically significant correlation between age and IOP (Spearman's rho = 0.827, $p < 0.001$). This suggests that IOP tends to increase as children grow older, consistent with earlier studies by Jiang *et al.*,(2014) and Hashemi *et al.*,(2018). These authors observed that IOP rises during childhood and early adolescence, likely due to ocular maturation, increases in axial length, and changes in corneal biomechanics.

Hashemi *et al.,*(2005) and Pakravan *et al.,*(2017) similarly found that IOP increased with age in both adult and younger populations, though it tends to stabilise or decline in older adults. The present finding aligns with this trend, as the participants were primarily between ages 6 and 14, representing the period of ocular growth and biometric development.

Physiologically, this increase in IOP may be related to the thickening of the cornea and increased resistance in aqueous humour outflow pathways during growth (Masoumpour *et al*., 2020). It also underscores the importance of considering age-related changes when evaluating IOP in paediatric patients to avoid misclassification of normal developmental changes as pathology.

5.4 GENDER VARIATION IN INTRAOCULAR PRESSURE

The Mann–Whitney U test revealed a significant difference in IOP between male and female participants (p = 0.027), indicating that gender may influence IOP levels in children. Similar findings were reported by Jiang *c* (2014), who noted higher mean IOP in female children compared to males. Kim *et al.*,(2014) and Hoehn *et al.*,(2013) also documented gender-related differences, though these were more pronounced in adults.

Potential explanations for these differences include hormonal influences and variations in corneal or ocular rigidity between sexes (Park *et al*., 2010). However, the degree of variation remains relatively small and within the normal physiological range. It is worth noting that Hashemi *et al.*,(2018) found gender differences to lose significance in multivariate analyses, suggesting that other covariates such as BMI, corneal thickness, and refraction may confound this relationship.

Given these mixed results, the gender-related differences in IOP observed in this study should be interpreted with caution. Nonetheless, the finding supports the inclusion of gender as a variable in paediatric ocular screening and research, especially in diverse populations.

5.5 ASSOCIATION BETWEEN BODY MASS INDEX (BMI) AND INTRAOCULAR PRESSURE

The study demonstrated a moderate, positive, and statistically significant correlation between BMI and IOP (Spearman's rho = 0.633, p < 0.001). Students with higher BMI exhibited higher mean IOP values, which aligns with previous studies by Hashemi *et al.*,(2016), Kim *et al.*,(2014), and Park *et al.*,(2010), all of which established BMI as an independent determinant of IOP.

Increased BMI may influence IOP through several mechanisms, including elevated episcleral venous pressure, increased orbital adiposity, and changes in autonomic regulation of aqueous humour dynamics. Park *et al.*,(2010) further associated elevated IOP with metabolic abnormalities, suggesting a link between systemic physiology and ocular pressure regulation.

While the present findings indicate that higher BMI correlates with increased IOP in children, the implications for long-term ocular health remain to be fully understood. It may, however, serve as a warning that overweight or obese children should receive regular ocular monitoring due to potential predisposition to ocular hypertension and glaucoma later in life (Hashemi *et al*., 2016).

5.6 IMPLICATIONS OF FINDINGS

This study's results reinforce the idea that IOP is influenced by multiple demographic, physiological, and biometric factors even within the paediatric population. The consistency of findings with international studies (Hashemi *et al*., 2016; Jiang *et al*., 2014; Masoumpour *et al*., 2020) underscores the biological universality of these relationships, despite regional variations.

Moreover, the observed increase in IOP with age and BMI and its difference across genders highlight the need for paediatric-specific diagnostic thresholds, rather than extrapolating adult standards. These data contribute to the baseline understanding of ocular physiology in Nigerian children and provide a foundation for establishing normative IOP ranges that reflect local population characteristics.

Finally, since elevated IOP is a key risk factor for glaucoma, these findings may inform school-based ocular screening programs aimed at early detection of children at risk of ocular hypertension. Given the silent nature of paediatric glaucoma and the potential for irreversible visual loss, routine IOP screening among school-aged children should be encouraged.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This study examined the distribution of intraocular pressure (IOP) among school-aged children in Benin City, Nigeria, and explored its relationship with age, gender, and body mass index (BMI). The findings revealed that the mean IOP among the participants was 17 ± 2 mmHg, which falls within the normal range reported in previous paediatric studies. A strong positive correlation was found between IOP and age, indicating that intraocular pressure tends to increase as children grow older. Similarly, a moderate positive correlation was observed between BMI and IOP, showing that children with higher body mass indices exhibited higher intraocular pressures. In addition, a statistically significant difference in IOP was noted between male and female participants, suggesting a possible influence of gender-related physiological differences on IOP regulation.

These findings confirm that demographic and biometric factors such as age, gender, and BMI play important roles in determining intraocular pressure even among apparently healthy children. The results are consistent with global literature, highlighting the universality of these associations across populations while also emphasizing the need for region-specific reference values. The study provides essential baseline data for the Nigerian paediatric population, which can serve as a guide for clinicians in evaluating ocular health and detecting abnormalities early.

Overall, the research underscores the importance of routine IOP assessment as part of paediatric eye care and school health programs. Establishing population-specific normative data is necessary to improve diagnostic accuracy, particularly for conditions like ocular hypertension and childhood glaucoma, which can lead to irreversible visual impairment if undetected. This study therefore contributes meaningfully to the understanding of ocular physiology among Nigerian children and supports the integration of comprehensive ocular evaluation into public health strategies aimed at preventing vision loss from elevated intraocular pressure.

6.2 RECOMMENDATIONS

Based on the findings and conclusions of this study, the following recommendations are proposed:

6.2.1 FOR CLINICAL PRACTICE

1. **Establishment of Local Reference Ranges:** Eye care practitioners should adopt IOP reference ranges that are tailored to the Nigerian paediatric population, as extrapolating adult or non-African norms may result in misclassification of normal readings.

2. **Routine IOP Screening:** Regular IOP measurements should be incorporated into school health programs and paediatric eye care routines to facilitate early detection of ocular hypertension and glaucoma.

3. **Comprehensive Ocular Evaluation:** Children with elevated IOP, especially those with higher BMI or rapid growth rates, should undergo detailed ocular assessments to rule out early glaucomatous changes.

6.2.2 FOR PUBLIC HEALTH AND EDUCATION

1. **Implementation of School-based Vision Programs:** The government, in collaboration with optometric associations and ministries of health and education, should promote vision screening programs within schools, focusing on early ocular disease detection.

2. **Awareness Campaigns:** Parents and teachers should be educated about the importance of routine eye examinations in children to prevent avoidable visual impairment.

6.2.3 FOR FUTURE RESEARCH

1. **Longitudinal Studies:** Further longitudinal studies should be undertaken to monitor IOP changes over time in children and to establish developmental trends in ocular physiology.

2. **Expanded Geographic Scope:** Future research should include participants from different regions of Nigeria to evaluate potential geographical and ethnic variations in IOP, as reported by Suh and Kee (2012) and Leske *et al.*(1997).

3. **Advanced Biometric Correlates:** Studies examining the relationship between IOP and corneal thickness, axial length, and refractive status are recommended, given their known influence on IOP readings (Hashemi *et al*., 2018; Pakravan *et al*., 2017).

6.3 CONTRIBUTION TO KNOWLEDGE

This study provides baseline data on intraocular pressure distribution among Nigerian school-aged children, which was previously scarce in the literature. It also reinforces the influence of age, gender, and BMI on IOP variations in paediatric populations. The findings thus serve as a valuable reference for clinicians, educators, and researchers seeking to understand and manage paediatric ocular health within the Nigerian context.

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APPENDIX

IOP(mmHg) across Gender

Independent-Samples Mann-Whitney U Test Summary

Total N	568
Mann-Whitney U	36002.500

Wilcoxon W	73130.500
Test Statistic	36002.500
Standard Error	1917.585
Standardized Test Statistic	-2.218
Asymptotic Sig.(2-sided test)	.027

Body Mass Index(BMI) across Gender

Independent-Samples Mann-Whitney U Test Summary	
Total N	568
Mann-Whitney U	42041.000
Wilcoxon W	79169.000
Test Statistic	42041.000
Standard Error	1951.405
Standardized Test Statistic	.915
Asymptotic Sig.(2-sided test)	.360

TESTS OF NORMALITY FOR BMI AND INTRAOCULAR PRESSURE

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Body Mass Index(BMI)	.280	568	< .001	.682	568	< .001
IOP(mmHg)	.174	568	< .001	.928	568	< .001

Kolmogorov–Smirnov and Shapiro–Wilk tests confirmed that BMI and IOP were not normally distributed ($p < .001$ for both), indicating the use of non-parametric tests was appropriate.