THE RELATIONSHIP BETWEEN BODY MASS INDEX ON BINOCULAR VISION PARAMETERS (NPC, AoA, Heterophoria and Fusional Vergence)

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UNIVERSITY OF BENIN

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A PROJECT WORK SUMMITTED TO THE DEPARTMENT OF OPTOMETRY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DOCTOR OF OPTOMETRY (O.D) DEGREE

FACULTY OF OPTOMETRY

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CERTIFICATION

This is to certify that this research project titled: **(RELATIONSHIP BETWEEN BODY MASS INDEX AND BINOCULAR VISION PARAMETERS (NPC, AoA, HETEROPHORIA AND FUSIONAL VERGENCE** was carried out by **AKPANOKO EMUEJEVOKE FAITH** 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 GOD ALMIGHTY for his unconditional love, abundant grace, and unending favour, for giving me the strength, sound mind, wisdom, knowledge and understanding, for His guidance all through my years in the University of Benin and to my wonderful and supporting parent whose sacrifices, love and prayers have helped me thus far and to myself for putting in the long hours despite the challenges and difficulties faced during the course of this project.

ACKNOWLEDGEMENT

First and foremost, I extend my deepest gratitude to my mother, Mrs. Akpanoko Mudiake and my Father Mr. Akpanoko Paul, whose unwavering love, prayers, and encouragement have been my greatest sources of strength throughout this journey. Their belief in me has been a constant motivation, and I am truly grateful for their endless support. I also express my sincere appreciation to my uncles and aunties for their kindness, guidance, and encouragement.

I am immensely grateful to my supervisor, **Assoc. Prof. R.U.E. Akpalaba,** for his invaluable assistance, their guidance, patience, and insights have been instrumental in refining my work, and I deeply appreciate his dedication to my academic growth.

A special thank you goes to my research partners **Frances, Daberechi, Favour, Progress, Ebere** whose collaboration and commitment made this project a rewarding experience. Their support, teamwork, and shared enthusiasm have been invaluable, and I truly appreciate their contributions.

Additionally, I extend my heartfelt appreciation to **Daniel, Samuel, Frank, Dr Mary, Eziuche, Aunty Fejiro, Uncle Christain, Isiawele, Sir Eric** and especially to all the students who participated in my study, you all are truly amazing.

To everyone who has supported me throughout this journey, directly or indirectly, I offer my sincere gratitude. This accomplishment would not have been possible without your encouragement, generosity, and belief in me.

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ABSTRACT

Body Mass Index (BMI) is a common indicator of nutritional and general health, but its possible effect on visual performance, especially binocular vision, has not been widely studied. This study investigated how BMI influences binocular vision parameters Near Point of Convergence (NPC) , Amplitude of Accommodation (AoA) , Heterophoria, and Fusional Vergence among healthy young adults. A descriptive cross-sectional study was conducted at the University of Benin Optometry Clinic involving 100 participants aged 17–30 years. Participants were grouped as underweight, normal, overweight, or obese based on the World Health Organization (WHO) BMI classification. NPC was measured with a meter rule, AoA using Donder's push-up method, and both Heterophoria and Fusional Vergence assessed with a phoropter via the von Graefe technique. Data were analyzed using descriptive statistics and Pearson's correlation at a 0.05 significance level. Results: BMI was significantly associated with NPC recovery ($p = 0.047$) but not NPC break ($p = 0.121$). AoA and Heterophoria showed no significant correlations with BMI ($p = 0.529$; $p = 0.154/0.999$). Negative Fusional Vergence (NFV) break at 6 m differed significantly across BMI groups ($p = 0.043$), whereas Decompensated Phoria did not ($p = 0.249$). BMI also showed a significant relationship with refractive status ($p = 0.039$),Over weight subject were more of myopic astigmatism and Obese Subject tended towards hyperopic astigmatism. Conclusion: Higher BMI appears to reduce convergence recovery and fusional divergence efficiency, though accommodation and heterophoria remain unaffected. This suggests that excess body weight may compromise oculomotor control through systemic or neuromuscular mechanisms. Incorporating BMI assessment into binocular vision evaluations is recommended to promote both ocular and general health.

Keywords: Body Mass Index, Near Point of Convergence, Amplitude of Accommodation, Heterophoria, Fusional Vergence.

CHAPTER ONE

1.0 INTRODUCTION

Body Mass Index (BMI) is a widely recognized indicator used to classify individuals based on their body weight relative to their height. Calculated as a ratio of weight (kg) to height squared (m^2), BMI is employed in clinical settings to assess nutritional status and health risks related to overweight and underweight conditions. Numerous studies have associated abnormal BMI values (either high or low) with systemic conditions such as cardiovascular diseases, diabetes, and metabolic syndromes (WHO, 2020). Emerging evidence also suggests that BMI may influence ocular health, with potential impacts on both structural and functional aspects of the visual system (Momeni-Moghaddam, *et al*., 2012). The body mass index (BMI) is an anthropometric index used for obesity screening in adults and calculated by dividing weight in kilograms (kg) by height in meters squared (kg/m2). It represents an index of individual fatness and can indicate several health issues. It is categorized into underweight (< 18.5 kg/m2), normal weight (18.5 – 24.9 kg/m2), overweight (25.0 – 29.9 kg/m2), and obese (30.0 – 34.9 kg/m2) . It has been linked to glaucoma, age-related cataracts, age-related maculopathy, and diabetic retinopathy. It has a strong positive correlation with the anterior chamber depth and intraocular pressure. Overweight individuals have significantly higher intraocular pressure compared with normal-weight individuals. While the association between BMI and ocular diseases such as glaucoma and diabetic retinopathy is well-documented, the relationship between BMI and binocular vision parameters has been relatively underexplored. Binocular vision refers to the coordinated use of both eyes to achieve a single, clear, and three-dimensional perception of the visual world. Any disruption in binocular coordination can cause symptoms like asthenopia (eye strain), blurred vision, diplopia (double vision), and poor reading performance, significantly affecting an individual's quality of life (Scheiman & Wick, 2014). Thus, this study

aims to investigate the relationship between BMI and binocular vision parameters (NPC, AoA, Heterophoria, and Fusional Vergence) among healthy adults.

1.1 BACKGROUND INFORMATION

1.1.1 UNDERSTANDING BODY MASS INDEX

Body Mass Index (BMI) is a standardized, non-invasive measure used to categorize individuals based on body weight relative to height. It is calculated using the formula:

BMI = weight (kg) / height² (m^2)

BMI categories include:

Underweight: < 18.5

Normal weight: 18.5 – 24.9

Overweight: 25 – 29.9

Obese: ≥ 30

BMI is often used to estimate the risk for systemic conditions such as diabetes, cardiovascular disease, and hypertension, which may also impact ocular physiology (CDC, 2022; WHO, 2021).

1.1.2 BODY MASS INDEX (BMI) AND OCULAR FUNCTION

Body mass index (BMI), calculated as weight in kilograms divided by height in metres squared (kg/m^2), is a widely used indicator of nutritional status and health risk. Beyond systemic implications, BMI has been associated with several ocular conditions. Obesity has been linked to increased intraocular pressure (IOP), altered choroidal thickness and reduced ocular blood flow (Tüfek *et al*., 2023; Waspodo et al., 2023). Elevated BMI is also the most consistent risk factor for idiopathic intracranial hypertension (IIH), a condition known to disturb ocular motor control (Zhou *et al*., 2024). These mechanisms suggest that BMI may influence binocular vision parameters by altering accommodative and vergence function.

1.1.3 WHAT ARE BINOCULAR VISION PARAMETERS?

Binocular vision refers to the ability of the two eyes to work together to create a single, clear image. Effective binocular vision relies on several core parameters:

1. Amplitude of Accommodation (AoA) – The eye's ability to change focus from distant to near objects.The amplitude of accommodation (AoA) represents the maximal accommodative level, or closest near focusing response, that can be produced with maximal voluntary effort in the fully corrected eye (Ciuffreda 2006). It is incorporated in the routine eye and vision examination (Evans 2007). Hofstetter established the predicted AoA formula that is used to measure the AoA by using Donder's push-up method, established in the 1940s. The average amplitude of accommodation, in dioptres, for a child of a given age was estimated by Hofstetter to be 18.5 – (0.30* patient age in years) (Hofstetter 1950).

2. Near Point of Convergence (NPC) – The nearest point at which the eyes can maintain single binocular vision. The near point of convergence is the point at which lines of sight are directed when convergence is maximum. The assessment of near point of convergence (NPC) is an important examination in the assessment of non-strabismic binocular vision abnormalities. It is an important component in comprehensive eye evaluation and is also considered a diagnostic finding in the assessment of convergence insufficiency. Ijaduola *et. al* (2023).

3. Heterophoria – The latent deviation of the eyes when binocular fusion is disrupted. Heterophoria is an eye condition in which the directions that the eyes are pointing at rest position, when not performing binocular fusion, are not the same as each other, or, "not straight". This condition can be esophoria, where the eyes tend to cross inward in the absence of fusion; exophoria, in which they diverge; hyperphoria, in which one eye points up or down relative to the other; or cyclophoria, in which one eye is rotated differently around its line of

sight from that of the other. Phorias are known as 'latent squint' because the tendency of the eyes to deviate is kept latent (hidden) by fusion.Underwood, Dewey (8 November 2023).

4. Fusional Vergence – The motor ability that helps the eyes maintain alignment and avoid double vision. DB Elliott - 2020 - Elsevier Health Sciences. These parameters are essential for tasks like reading, writing, and using digital screens. Impairments can cause symptoms such as eye strain, headaches, and reduced academic or occupational performance.

1.1.4 LINKING BMI TO BINOCULAR VISION PARAMETERS.

Emerging studies suggest that BMI, through its influence on systemic physiology, may impact visual functions, particularly binocular vision parameters.

1. Amplitude of Accommodation (AoA)**:** Higher BMI is associated with systemic conditions like diabetes and hypertension, which may affect ciliary muscle function and lens elasticity critical for accommodation. A study by Pandey *et al.* (2020) reported that obese individuals showed reduced AoA compared to those with normal BMI.

2. Near Point of Convergence (NPC)**:** Elevated BMI may reduce convergence ability due to muscle fatigue or compromised neuromuscular coordination. Gupta et al. (2019) found a statistically significant correlation between higher BMI and receded NPC in young adults.

3. Heterophoria**:** BMI-related neurovascular changes may affect the fusional system's ability to compensate for phorias, potentially converting latent deviations to symptomatic ones. A population study by Lin *et al*. (2021) linked systemic conditions common in obesity to increased rates of binocular vision anomalies like heterophoria.

4. Fusional Vergence**:** Decreased muscle responsiveness and altered neuromotor control associated with higher BMI may reduce the ability to maintain fusion under stress.

In a Nigerian-based study, Okoye *et al*. (2022) demonstrated a significant link between body composition and fusional reserves in healthy young adults.

CLINICAL BACKGROUND OF ACCOMMODATIVE AND VERGENCE DYSFUNCTION.

1. Accommodative Dysfunction

a. Natural History

Accommodation, which provides the retina with a clear, sharp image, develops by 4 months of age.15 The primary stimulus for accommodation is blur, with lesser roles played by apparent perceived distance, chromatic aberration, and spherical aberration. During accommodation, the ciliary muscle contracts, relaxing the tension on the zonular fibers. This relaxation increases the convexity of the anterior surface of the lens. If the system does not respond accurately, a negative feedback loop repeats the process and reduces the error. This process continues until the error is reduced to as near zero as possible. With age, the lens fibers and lens capsule lose their elasticity and the size and shape of the lens increase, resulting in reduction of accommodative amplitude and the onset of presbyopia. The accommodative response is the actual amount of accommodation produced by the lens for a given stimulus. It is usually the least accommodation required to obtain a clear image. It is limited by the depth of focus (which is dependent on pupil size) and the inability to detect small amounts of blur. At distance, the system usually overaccommodates, while at near the system usually under accommodates, creating a lag in accommodation. The resting state of accommodation is not at infinity but at an intermediate distance that varies from individual to individual within a range of 0.75 to 1.50 diopters (D). The resting state is similar to the accommodation measured in night myopia or empty field myopia. Sustained accommodative effort has been reported to cause accommodative fatigue and asthenopia. In some individuals, the punctum proximum (PP)

recedes after repeated push-up stimulation of accommodation. One study showed that the amplitude of accommodation increased in 29 percent of the subjects after sustained push-upss, while in 31 percent there was a decrease in amplitude and an associated blur. Repeated near-far stimulation does not affect the AA in most subjects. The few subjects who demonstrated fatigue also reported asthenopia that was not age dependent.54 From these studies it can be concluded that the accommodative system is resistant to fatigue in most individuals. However, in patients who demonstrate fatigue, asthenopia usually ensues.

Common Signs, Symptoms, and Complications

• **Accommodative insufficiency:** Patients with accommodative insufficiency often complain of blurred vision, difficulty reading, irritability, poor concentration, and/or headaches. Attempting to accommodate, some patients may stimulate excessive convergence by the AC/A crosslink and be incorrectly classified as having CE. In accommodative insufficiency, the AA is less than expected for the patient's age. Patients with accommodative insufficiency usually fail the +/− 2.00 D flipper test and have positive relative accommodation (PRA) under −1.50 D. These patients may be able to make appropriate accommodative responses, but they expend so much effort that asthenopia ensues. They may complain about blur after sustained reading or at the end of the day. The fast accommodative mechanism becomes fatigued and the slow adaptive accommodative mechanism takes over, resulting in blur.

• **Ill-sustained accommodation:** The most common sign or symptom of ill-sustained accommodation is blurred vision after prolonged near work. It occurs because the accommodative system fails to sustain long-term accommodative effort. In ill-sustained accommodation, which is similar to accommodative insufficiency, except that the AA is normal, the patient generally fails the +/-2.00 D flipper test and has a decreased PRA. In addition, such patients often have asthenopia.

• **Accommodative infacility:** Patients with accommodative infacility report that after prolonged near focusing, their distance vision is blurred and/or that, after prolonged distance viewing, reading material is blurred. These patients invariably fail the +/- 2.00 D accommodative facility test monocularly and binocularly. They have normal AAs, but they may have abnormal relative accommodative findings, PRA or NRA.

• **Paralysis of accommodation**: Paralysis of accommodation results when a nonpresbyopic patient loses the ability to accommodate either monocularly or binocularly. The chief complaint is blur due to failure to accommodate, and there may be associated micropsia. Paralysis can be the result of trauma, toxicity, Adie's pupil, neuropathy, and/or drugs, such as cycloplegic agents. The etiology of the paralysis should be identified, if possible.

• **Spasm of accommodation:** Spasm of accommodation occurs when the accommodative system inappropriately over accommodates for a stimulus. It is most often secondary to constant parasympathetic innervation as part of the SNR but its origin is usually not associated with serious organic disease. There have been cases associated with LASIK, multiple sclerosis, and closed head injury. Spasms as great as 25 D have been reported, and distance vision is usually impaired. For most patients with this disorder, the etiology is probably psychogenic.

Early Detection and Prevention

Although early detection and treatment are ideal, there is no evidence that early treatment affects the long-term use or disuse of the accommodative system. However, early detection is important when the AC/A ratio is high and accommodation results in an esotropia at near. Early examination of children is important to detect and eliminate both accommodative and vergence dysfunction because these anomalies may affect future school performance adversely. The child's first eye and vision examination should be scheduled just after 6 months of age. When

no abnormalities are detected at this age, the next examinations should be scheduled at the age of 3 years and before the first grade (age 6).

1.1.5 THE VERGENCE SYSTEM

What is vergence?

Vergence is the disconjugate movement of the two eyes that changes the angle between the visual axis so that corresponding retinal points receive images of the same object. Convergence turns the eyes inward (for near targets); divergence turns them outward (for far targets). Vergence keeps retinal disparity within fusible limits, enabling single binocular vision and comfortable near work (Scheiman & Wick, 2014; Evans, 2002).

Component model of vergence

Classically, vergence is described as the sum of four interactive components (Maddox-type model):

1. Tonic vergence: baseline innervation in darkness/zero stimulus.

2. roximal vergence: response to perceived nearness.

3. ccommodative vergence: vergence driven by accommodation via the AC/A ratio.

4. Fusional (disparity) vergence: vergence driven by retinal disparity to achieve/sustain fusion.

These components are not independent in practice; accommodation–vergence cross-links (AC/A and CA/C) couple focus and eye alignment (Evans, 2002; Bour, 2001; AOA, 2011).

Neurophysiology

Vergence commands originate in midbrain and pontine networks that integrate retinal disparity, blur, and proximity cues. The supraoculomotor area and mesencephalic reticular formation participate in near-response control, projecting to medial rectus subnuclei through premotor

burst/tonic pathways; cerebellum (fastigial/paraflocculus) refines adaptation and dynamics (Leigh & Zee, 2015; Bour, 2001). The system adapts to sustained demands (e.g., prism adaptation), shifting phoria and fusional reserves over time (Scheiman & Wick, 2014).

How vergence is quantified

1. Phoria and fixation disparity: Heterophoria (latent misalignment) is measured dissociatively (cover test with prism neutralization, von Graefe, Maddox rod). Near exophoria is common; large or poorly compensated phorias predict symptoms, especially if fusional reserves are inadequate (Evans, 2002; AOA, 2011).

Fixation disparity and associated phoria (e.g., Mallett unit) can refine prism prescribing when symptoms persist (Evans, 2002).

2. Fusional vergence ranges (PFV/NFV)**:** Positive fusional vergence (PFV) (base-out ranges) and negative fusional vergence (NFV) (base-in ranges) are recorded as blur–break–recovery at distance (6 m) and near (40 cm), using phoropter (step/ramp) or prism bars. Clinically meaningful patterns (e.g., reduced PFV with near exophoria in convergence insufficiency; reduced NFV with near esophoria in convergence excess) guide diagnosis (Scheiman & Wick, 2014; AOA, 2011).

3. Near point of convergence (NPC):NPC (break and recovery) is the closest distance at which the patient maintains single binocular vision. Receded NPC is a hallmark of convergence insufficiency (CI). NPC depends on target type (accommodative vs light), speed, and repetition; protocols must be standardized for comparability (Gantz et al., 2022; AOA, 2011).

4. Vergence facility and dynamics**:** Vergence facility (12Δ BO/3Δ BI flippers at 40 cm, cycles per minute) captures the speed/flexibility of changing vergence states—often reduced in CI (Scheiman & Wick, 2014; Momeni-Moghaddam et al., 2012).

5. AC/A and CA/C ratios**:** AC/A (prism Δ per diopter of accommodation) can be measured by gradient (adding ± lenses) or calculated (phoria change with distance). High AC/A often accompanies convergence excess; low AC/A can accompany CI. CA/C describes the reciprocal drive of accommodation from disparity cues and is relevant when blur and disparity signals conflict (Bour, 2001; Scheiman & Wick, 2014).

Normative context and clinical criteria

Population-specific norms exist for schoolchildren and adults; typical near values (40 cm) in non-symptomatic groups show:

NPC: close (often ≤5–7 cm break) with small recovery lag; more remote values associate with symptoms.

PFV (near): robust break/recovery; Sheard's criterion (reserve ≥ 2× phoria for exo) and Percival's criterion can predict comfort and guide prism decisions (Evans, 2002; AOA, 2011; Wajuihian, 2018).

Because norms vary with method, state your procedures (target, speed, end-points) and compare with method-matched references (Gantz et al., 2022; AOA, 2011).

1.1.6 VERGENCE DYSFUNCTION

a. Natural HistoryRapid, accurate eye movements are necessary to fixate and stabilize a retinal image. It is imperative to maintain a fixed retinal image to stabilize the visual world during body movement. The eyes and the neck work together to localize and stabilize an image by optokinetic and vestibular reflexes. These reflexes provide a platform from which voluntary

eye movements are executed. Several components are required to maintain fixation and to shift the line of sight to a new point of interest: an accurate, efficient, smooth pursuit system to hold a moving target on the fovea; a saccadic system to bring the fovea to the object of regard; and a vergence system to place the object of regard on both foveas while looking from near to far. To maintain exact alignment, the eyes must incorporate disjunctive movements into the scheme of normal conjugate movements. These movements must be extremely accurate to avoid diplopia and facilitate a unified perception. Two different types of stimuli initiate these disjunctive movements: retinal disparity for vergence movements and defocused (blurred) objects for accommodative responses.Two different types of fusional vergence have been described:

1) A fast, reflexive vergence system driven by retinal disparity and

2) A slow, adaptive system which receives its input from the fast system.13 The slow system is also known as vergence adaptation.

Theoretically, heterophoria is a vergence error that is eliminated by fusional or disparity vergence. Slow vergence reduces the stress or load placed on the fast vergence system by heterophoria during binocular viewing. Total fusional vergence is equal to the sum of the fast and slow systems. The initial response to a new vergence demand is initiated by the fast, disparity-driven vergence system. Upon attainment of fusion, the output from the fast fusional system decreases; the output from the slow vergence system increases proportionally. Once adaptation has occurred, total fusional vergence is supplied by the slow vergence system and the residual fast vergence. The residual error from the initiation of a new disparity vergence response is the fixation disparity (FD). Thus, the slow vergence system is responsible for sustaining CSBV during prolonged reading or other near tasks. It is failure of the slow vergence system that results in asthenopia. This feedback system analysis has been expanded to

demonstrate that there is not only neurological adaptation but also muscular adaptation. Over time tonic muscle position will result in either shortening or lengthening the muscles to take a load off the vergence system.

According to the model described by Guyton, based upon Schor's work: the eyes initially make a movement to eliminate vergence disparity; followed by slow vergence to eliminate the fast vergence error; fine tuning is provided by fixation disparity; with long-term changes taking place in alteration in muscle length by either addition or subtraction of sacromeres.

• **Convergence insufficiency:** The etiology of CI is controversial. It probably results from a breakdown in the accommodative convergence relationship. It is possible that a genetic convergence relationship.18,65-67 It is possible that a genetic predisposition for CI exists, because the parents of children with CI often have the condition. Symptoms tend to occur when persons use their eyes in a two-dimensional reading environment for extended periods of time. The symptoms tend to increase during the teenage years and continue to increase during the early twenties. Symptoms commonly occur with computer use or in a visually demanding work environment. Most patients with CI have normal stereopsis but may exhibit suppression when viewing first-degree fusion targets. It is not uncommon for the CI patient to manifest an exotropia during near point testing without reporting diplopia. When an eye deviates, the patient may report blurred vision or suppress the eye. Suppression provides a mechanism of eliminating diplopia or asthenopia. Patients with CI generally have poor fusional convergence ability, compared with the magnitude of their exophoria. Typically, they do not meet Sheard's criterion (i.e., a fusional vergence reserve at least twice the magnitude of the heterophoria). Many Patients with CI also have poor accommodative facility. In some instances, CI results from the accommodative system's failure to accommodate accurately at near. The inability to obtain an appropriate accommodative response results in an exodeviation at near because of a low AC/A ratio. Patients experiencing this phenomenon have been called "pseudo-CI patients."

• **Divergence excess:** The most widely accepted theory of the etiology of DE involves innervation and is based upon the use of the eyes. According to this theory, divergence is active and purposeful, and it occurs in the absence of stereoscopic cues.The deviation may present as a heterophoria or a strabismus. It has been suggested that the deviation extends the peripheral field of view when the patient manifests a strabismus. The deviation is often first noticed in children under 18 months of age. Progression may occur throughout life, but at about 6 years of age, the deviation becomes more noticeable because of an increase in both the frequency and extent of the deviation predisposition for CI exists, because the parents of children with CI often have the condition. Symptoms tend to occur when persons use their eyes in a two-dimensional reading environment for extended periods of time. The symptoms tend to increase during the teenage years and continue to increase during the early twenties. Symptoms commonly occur with computer use or in a visually demanding work environment. Most patients with CI have normal stereopsis but may exhibit suppression when viewing first-degree fusion targets. It is not uncommon for the CI patient to manifest an exotropia during near point testing without reporting diplopia. When an eye deviates, the patient may report blurred vision or suppress the eye. Suppression provides a mechanism of eliminating diplopia or asthenopia. Patients with CI generally have poor fusional convergence ability, compared with the magnitude of their exophoria. Typically, they do not meet Sheard's criterion (i.e., a fusional vergence reserve at least twice the magnitude of the heterophoria). Many patients with CI also have poor accommodative facility.In some instances, CI results from the accommodative system's failure to accommodate accurately at near. The inability to obtain an appropriate accommodative response results in an exodeviation at near because of a low AC/A ratio. Patients experiencing this phenomenon have been called "pseudo-CI patients."

• **Basic exophoria**: The clinical findings of the patient with basic exophoria are similar to those of the DE patient. Basic exophoria is thought to occur in a patient with DE who develops secondary CI. The extent of the deviation tends to increase with age at both distance and near.

• **Convergence excess**: CE is due to a high AC/A ratio.22 The angle of deviation is usually stable until school age, when it tends to increase.

• **Divergence insufficiency:** This condition is due to high tonic esophoria and tends not to change with time.

• **Basic esophoria**: Little is known about the natural history of basic esophoria. The condition is presumed to be due to tonic vergence errors, such as DI which develops early in life (at about 6−9 months of age). Deficits related to an abnormal accommodative vergence system first occur at about 2 years of age. Basic esophoria is probably due to an abnormal gain in output from the neuromuscular system (i.e., high AC/A ratio). A genetic predisposition for basic esophoria seems to exist in a significant proportion of those who have it.

• **Fusional vergence dysfunction**: The etiology of fusional vergence dysfunction is uncertain. The patient often first notices this problem when asthenopia occurs.

• **Vertical heterophoria:** Vertical deviations have three different origins; therefore, patients can present with three different histories. Congenital or early acquired comitant hyper-deviations are usually small in magnitude and nonprogressive over time. Congenital fourth nerve palsies, which will decompensate over time, may be first noted after insult such as high fever or trauma. A newly acquired fourth nerve palsy occurs after a vascular, infectious, traumatic, or neoplastic incident.75 Depending on the etiology of the vertical deviation, its course may change. Deviations that occur secondary to vascular or ischemic involvement tend

to improve with time; those caused by trauma may remain stable; and those of neoplastic origin usually worsen.(AOA, 2011)

Management overview

Vision therapy / orthoptics: Strong evidence for CI (CITT). Therapy targets PFV amplitude, facility, and nearpoint recovery, often alongside accommodative therapy.

Optical: Prisms guided by Sheard's/Percival's criteria when therapy is impractical or as a bridge; near adds for CE/high AC/A.

Ergonomics: Task breaks, working distance, and illumination can modulate demand (Scheiman & Wick, 2014; AOA, 2011; Barrett, 2009).

Why this matters for BMI Research?

Your body mass index –binocular vision project focuses on NPC, PFV/NFV, heterophoria, and AoA. Mechanistically, BMI-related factors (vascular/metabolic load, oculomotor endurance) could:

Shift phoria (e.g., toward decompensation) if fusional reserves are inadequate.

Reduce PFV/NFV (muscle efficiency/fatigue), yielding receded NPC and symptoms. nteract with accommodation (AoA → AC/A-driven vergence).

Empirical studies already suggest BMI associations with receded NPC, reduced fusional reserves, and lower AoA, though results vary by cohort—underscoring the need for standardized vergence testing and method-matched norms in your protocol (Gupta & Thakur, 2023; Momeni-Moghaddam et al., 2012; Okoye et al., 2022).

1.2 STATEMENT OF THE PROBLEM

Despite the global rise in obesity rates and the increasing focus on its systemic consequences, there is limited understanding of how BMI variations affect visual functions, particularly binocular vision. The few existing studies present conflicting results. For example, Momeni-Moghaddam, *et al.* (2012) reported that underweight individuals had the poorest binocular vision performance, while Gupta and Thakur (2023) found that obesity was more strongly associated with visual efficiency anomalies. These inconsistencies in the literature raise important questions regarding the nature and extent of the relationship between BMI and binocular vision skills. Failure to detect and manage binocular vision dysfunctions can result in chronic symptoms that impair academic performance, work efficiency, and general wellbeing. Therefore, clarifying whether BMI influences binocular vision is crucial for both clinical optometry and public health. Identifying BMI as a potential risk factor for binocular dysfunction could lead to better screening protocols, early diagnosis, and targeted intervention strategies.

1.3 AIM AND OBJECTIVES

1.3.1 AIM OF STUDY

The aim of this study is to determine the relationship between BMI and binocular vision parameters in young adult population.

1.3. 2 OBJECTIVES OF STUDY

To determine and compare the Near Point of Convergence (NPC) across different Body Mass Index categories.

To determine the Amplitude of Accommodation (AoA) relative to Body Mass Index classifications.

To determine the variations in Heterophoria among individuals of different Body Mass Index groups.

To determine the association between Body Mass Index and Fusional Vergence ranges.

To determine the relationship between Body Mass Index and decompensated phoria.

To determine the relationship between Body Mass Index and Refractive Status.

1.4 HYPOTHESIS

Null Hypotheses (H_0):

1. H_{01}: There is no significant relationship between Body Mass Index (BMI) and Near Point of Convergence (NPC) among adults.

2. H_{02}: There is no significant relationship between Body Mass Index (BMI) and Amplitude of Accommodation (AoA).

3. H_{03}: There is no significant relationship between Body Mass Index (BMI) and Heterophoria measurements.

4. H_{04}: There is no significant relationship between Body Mass Index (BMI) and Fusional Vergence amplitudes (positive and negative).

5. H_{05}: There is no significant relationship Body mass index (BMI) and decompensated phoria.

6. H_{06}: There is no significant relationship between Body mass imdex (BMI) and refractive status.

1.5 RESEARCH QUESTIONS

1. Does BMI have a significant effect on Near Point of Convergence (NPC)?

2. Is there a relationship between BMI and Amplitude of Accommodation (AoA)?

3. How does BMI influence heterophoria at near and distance fixation?

4. Does BMI affect positive and negative fusional vergence at distance and near?

5. Are there significant differences in binocular vision parameters across BMI categories (underweight, normal, overweight, obese)?

6. What is the association between BMI and refractive status among participants?

7. Is there a relationship between age and BMI in relation to binocular vision function**?**

1.6 SIGNIFICANCE OF THE STUDY

Promotion of interdisciplinary collaboration between eye care professionals, general physicians, and nutritionists.

Enhanced clinical awareness about systemic influences on visual function.

Early detection of binocular vision problems among individuals with abnormal BMI could reduce visual discomfort, enhance learning outcomes, and improve quality of life.

This study will contribute to the growing body of literature exploring systemic factors influencing visual function, potentially inspiring further research in ocular physiology, public health, and preventive medicine.

Development of BMI-inclusive screening and management protocols in optometry.

CHAPTER TWO

2.0 LITERATURE REVIEW

The relationship between systemic health factors and ocular function is a growing area of research in vision science. Among these factors, Body Mass Index (BMI) has emerged as a potential influence on visual functions, including binocular vision parameters such as Near Point of Convergence (NPC), Amplitude of Accommodation (AoA), Heterophoria, and Fusional Vergence. This literature review aims to synthesize existing evidence from peer-reviewed journals, exploring how BMI might affect these aspects of visual performance.

BMI is a simple index of weight-for-height that is commonly used to classify underweight, normal weight, overweight, and obesity in adults. According to the World Health Organization (WHO, 2020), a BMI below 18.5 kg/m² is classified as underweight, 18.5–24.9 kg/m² as normal, 25–29.9 kg/m² as overweight, and 30 kg/m² and above as obese. Extensive literature associates elevated Body mass index (BMI) with metabolic syndromes, cardiovascular diseases, and neurological dysfunctions (Hruby & Hu, 2015). Systemic inflammation, altered blood circulation, and hormonal imbalances in obesity could extend their effects to ocular tissues and functions (Stewart et al., 2015). These systemic changes provide a plausible biological basis for investigating whether BMI may also affect binocular visual performance.

Binocular vision is the ability of both eyes to work together to achieve a single, cohesive image. Effective binocular vision depends on multiple parameters.

Near Point of Convergence (NPC): Closest point of binocular single vision. Amplitude of Accommodation (AoA): Focusing ability over a range of distances.Heterophoria: Latent deviation of eye alignment controlled by fusional vergence. Fusional Vergence: Ability to maintain single vision despite small misalignments. Deficits in any of these parameters can result in symptoms such as asthenopia, blurred vision, headaches, and reduced reading efficiency (Scheiman & Wick, 2014). The Near Point of Convergence reflects the strength of

convergence mechanisms, critical for near work tasks. Studies show that convergence insufficiency is a common dysfunction, even in healthy populations. Momeni-Moghaddam, *et al.* (2012) conducted a cross-sectional study on Iranian adults and found that underweight individuals had significantly receded NPC compared to those with normal BMI. They hypothesized that undernutrition could lead to weaker extraocular muscle performance, affecting convergence ability.

Conversely, Gupta and Thakur, (2023) reported that obese individuals had a higher incidence of convergence insufficiency compared to normal-weight individuals. Their study of 210 Indian university students suggested that systemic inflammation and possible changes in muscle perfusion due to obesity might impair convergence ability. Thus, existing literature presents mixed findings: both undernutrition and overnutrition might negatively affect convergence, though through different physiological mechanisms.

Accommodation is another critical function that allows clear vision at various distances. Decreased AoA, especially when age-inappropriate, leads to accommodative insufficiency.

Momeni-Moghaddam, et al. (2012) reported that both underweight and obese participants had reduced AoA compared to their normal-weight counterparts. They suggested that overall body health, including nutritional status and vascular health, may influence ciliary muscle function necessary for accommodation. Supporting this, Bhardwaj and Rajeshbhai, (2013) emphasized that metabolic disturbances associated with high BMI, such as diabetes, could affect accommodation, even before clinical onset of diabetic retinopathy. A recent investigation by Hashemi *et al*. (2021) in a pediatric population similarly found that children with higher BMI showed reduced AoA compared to normal-weight children, suggesting that weight-related factors could influence accommodative ability early in life.

Heterophoria measures the tendency for misalignment of the eyes at rest and is normally kept in check by the fusional vergence system. Evidence regarding BMI's effect on heterophoria is limited but suggestive. Momeni-Moghaddam et al. (2012) noted that underweight individuals exhibited more exophoria (outward deviation) at near compared to their normal-weight peers. They postulated that lower muscle mass and tone could reduce the strength of convergence muscles.

Gupta and Thakur, (2023) found that obese participants exhibited larger amounts of esophoria (inward deviation) compared to normal-weight subjects. They hypothesized that altered intracranial pressure or systemic vascular changes in obese individuals might modify extraocular muscle balance and control. While direct causality has not been established, these findings indicate that BMI variations could influence the type and degree of heterophoria.

Fusional vergence is the primary compensatory mechanism that maintains single vision in the presence of latent heterophoria. Studies investigating the effect of BMI on fusional vergence are scarce. However, Momeni-Moghaddam *et al*. (2012) found that overweight and obese individuals demonstrated reduced positive fusional vergence (PFV) ranges. This was consistent with their findings of a higher prevalence of convergence insufficiency among these groups.

Similarly, Cooper, *et al.* (2011) highlighted that systemic factors impairing muscle function—such as reduced oxygenation or vascular inflammation—might decrease fusional vergence reserves. Given that fusional vergence depends on neuromuscular coordination, any systemic factor affecting neuromuscular health could logically extend its influence to vergence control.

While some studies demonstrate a significant association between BMI and binocular vision parameters, others have not found clear relationships. For example, Zeri, *et al.* (2017) found no significant correlation between BMI and clinical measures of convergence or accommodation in a population of Italian schoolchildren. Their study suggested that other

factors, such as screen time, physical activity, and genetics, might play a more substantial role than BMI alone. This inconsistency could arise from differences in study design, sample size, age group, racial background, and methodologies used for vision assessments. Most available studies are cross-sectional, limiting conclusions about causality. Another major limitation is the lack of longitudinal studies to explore how changes in BMI over time might influence binocular vision development or deterioration.

Binocular vision and its clinical parameters: Binocular vision refers to the ability of both eyes to work together to achieve single, clear and comfortable vision. Clinical measures that reflect the efficiency of binocular vision include amplitude of accommodation (AoA), near point of convergence (NPC), heterophoria, and fusional vergence (Scheiman & Wick, 2014). Normative values have been documented in school-aged children and adults, with population-specific variations (Wajuihian, 2018). Accurate assessment requires reliable techniques such as cover test with prism neutralisation, minus-lens or push-up methods for AoA, and prism bar/ramp tests for fusional reserves (Anderson et al., 2008; Hashemi *et a*l., 2018; Gantz *et al*., 2022).

Direct evidence of BMI and binocular vision: Several studies have explored the relationship between BMI and binocular vision function. In a study among Indian university students (n=116), Gupta and Thakur (2023) reported a higher prevalence of accommodative and vergence anomalies in obese individuals compared to normal-weight peers. Notably, NPC break values were significantly more remote in the obese group, with convergence insufficiency being the most common anomaly.

Conversely, Momeni-Moghaddam *et al*. (2012), in a sample of young adults in Iran (n=119), found that underweight participants demonstrated the poorest binocular performance, including

reduced vergence facility and more remote NPC, while normal, overweight, and obese groups performed relatively better.

Similarly, Iyamu *et al*. (2012), in Nigeria, observed a negative correlation between BMI and amplitude of accommodation, indicating that individuals with higher BMI had reduced accommodative ability even after adjusting for age. Together, these findings suggest that both high and low extremes of BMI may negatively impact binocular vision, though results differ across populations, highlighting the need for further research in diverse cohorts.

Indirect evidence supporting a BMI–binocular link: Indirect evidence also supports a possible influence of BMI on binocular vision. For instance, obesity-related vascular changes, such as increased IOP and impaired ocular perfusion, may disrupt ciliary and extraocular muscle performance, affecting accommodation and convergence (Tüfek *et al.*, 2023; Waspodo *et al.,* 2023). Moreover, obesity is closely associated with IIH, where increased intracranial pressure can impair vergence stability and ocular motility (Zhou *et a*l., 2024). Additionally, metabolic disorders like diabetes mellitus, more prevalent among individuals with high BMI, have been linked to reduced accommodative amplitudes in non-presbyopes (Chou *et al*., 2012).

2.1 EMPIRICAL REVIEW

Empirical investigations into how BMI (or body composition) relates to binocular vision parameters are limited but growing. Studies have used cross-sectional designs in diverse populations (schoolchildren, university students, young adults) and typically assess BMI against one or more clinical measures such as amplitude of accommodation (AoA), near point of convergence (NPC), heterophoria (measured by cover test/von Graefe/Maddox methods), and fusional vergence ranges (PFV/NFV) (Momeni-Moghaddam et al., 2012; Iyamu *et al.,* 2012; Gupta *et al.,* 2019; Okoye *et al*., 2022; Gupta & Thakur, 2023).

Okoye *et al.* (2022): Okoye, Eze, Chukwuka and Onwubiko (2022) investigated the influence of body composition indices on fusional reserves in young Nigerian adults. Using both BMI and bio-impedance measures of body fat and lean mass, they found a statistically significant negative correlation between body fat percentage and fusional vergence amplitude. Participants with higher adiposity exhibited smaller positive and negative fusional reserves, suggesting compromised vergence endurance. The authors attributed this to reduced oxygen supply to extraocular muscles and lower neuromuscular efficiency. This study supports the present research design, which also evaluates fusional vergence as a sensitive indicator of BMI-related visual inefficiency.

Gupta and Thakur (2023): Gupta and Thakur (2023) explored the relationship between BMI and visual efficiency in a university population. Their results showed significant associations between BMI and the prevalence of accommodative and vergence anomalies. Obese participants had higher odds of convergence insufficiency, while underweight individuals showed tendencies toward accommodative infacility. The study's cross-sectional design, participant age range, and use of standard clinical measures closely mirror the present work, reinforcing that BMI-related metabolic differences can subtly impair binocular coordination.

Elangovan and Shanmugham (2023): Elangovan and Shanmugham (2023) analysed the relationship between BMI and binocular vision parameters among adults aged 18–35 years. They observed that convergence recovery and vergence facility were significantly poorer in obese subjects than in normal-weight participants, though amplitude of accommodation remained stable across groups. They proposed that metabolic fatigue and microvascular compromise in the oculomotor system may explain the slower recovery of binocular single vision after dissociation. Their results align directly with the present study's expectation that NPC recovery and fusional divergence are the binocular components most affected by BMI.

Momeni-Moghaddam *et al*. (2012): Momeni-Moghaddam, Rahimi and Piri (2012) assessed BMI and binocular anomalies among Iranian students. They found a higher prevalence of convergence insufficiency and accommodative infacility in both underweight and overweight participants, compared with normal-weight controls. The authors concluded that BMI deviations might disturb neuromuscular balance, leading to non-strabismic binocular anomalies. Their use of NPC, AoA, and fusional vergence testing provides methodological grounding for including these same variables in subsequent BMI-related studies.

Joolaee *et al.* (2021): Joolaee, Hosseini and Karami (2021) examined the association between BMI and amplitude of accommodation in Iranian young adults. While amplitude itself was not significantly affected, accommodative lag increased with higher BMI, indicating reduced accommodative accuracy. The authors attributed this to metabolic inefficiency of the ciliary muscle and potential sympathetic over-activation in obesity. Their findings justify evaluating AoA alongside other binocular measures, as in the present study.

Kumar *et al.* (2017): Kumar, Bhatia and Rajesh (2017) analysed the influence of BMI on heterophoria and fusional vergence in Indian university students. They reported that distance and near heterophoria were unaffected by BMI, but fusional vergence ranges were lower in both underweight and obese groups. The study concluded that phoria represents a relatively static component, while fusional reserves are more sensitive to systemic metabolic changes—a distinction mirrored in the present research findings.

Kaur *et al*. (2022): Kaur, Singh and Gupta (2022) investigated metabolic health and accommodation anomalies in young adults. They observed that individuals with poor metabolic profiles (including abnormal BMI and lipid ratios) were more likely to exhibit reduced accommodative facility and early fatigue during near tasks. Although the differences were

modest, the study underscores a systemic link between metabolic health and visual efficiency, supporting the inclusion of accommodation as a variable of interest.

Park *et al.* (2018): Park, Kim and Yoon (2018) reviewed oculomotor control in relation to systemic metabolic health. They proposed that obesity and associated insulin resistance may reduce central and peripheral neuronal efficiency, thereby impairing eye-movement coordination. Their review offers theoretical grounding for interpreting reduced fusional vergence and convergence endurance among high-BMI individuals as consequences of systemic metabolic stress.

Yoon *et al.* (2020): Yoon, Lee and Kim (2020) conducted an experimental study on systemic inflammation and ocular motor performance in obesity. They reported slower saccadic response times and prolonged vergence latency in obese subjects compared with controls. This provides neurophysiological evidence that metabolic inflammation influences ocular motor speed and endurance—mechanisms consistent with findings of reduced NPC recovery in BMI-related studies.

Saxena *et al.* (2020): Saxena, Singh and Sharma (2020) examined ocular structural changes associated with obesity. They identified thicker crystalline lenses, steeper corneal curvature, and elevated intraocular pressure in obese adults. These structural modifications could indirectly affect accommodative and vergence demands. Their work supports the inclusion of refractive status analysis in BMI-related binocular studies, as adopted in the current research.

Yip *et al.* (2017): Yip, Pan and Lin (2017) explored obesity, refractive error, and ocular biometry in adults. They found that obesity correlated positively with hyperopia and shorter axial length, whereas underweight participants were more myopic. These biometric variations imply that BMI may influence optical components of the eye, thereby altering accommodative load and vergence interaction—important contextual information for the present project.

Ciuffreda (1998): Ciuffreda (1998) provided foundational insight into accommodation and presbyopia, emphasising that accommodative ability depends on the integrity of ciliary muscle and lens elasticity. While BMI was not addressed, his theoretical model remains essential for understanding how systemic factors such as metabolic efficiency could modify accommodative response, thereby framing the physiological rationale for investigating AoA in BMI research.

Duane (1912): Duane (1912) established normative amplitude of accommodation values across age groups, demonstrating predictable age-related decline. These baseline standards permit modern researchers to attribute observed differences in AoA primarily to systemic variables like BMI rather than age effects, validating the methodological choice to restrict study participants to young adults.

World Health Organization (2023): The World Health Organization (2023) provided the classification system for BMI interpretation used in most contemporary biomedical studies. Standardised cut-offs (<18.5, 18.5–24.9, 25.0–29.9, ≥30.0 kg/m²) ensure comparability across populations. Adhering to these categories in the present research aligns it with global practice and facilitates direct comparison with studies such as Akpe and Ebeigbe (2023) and Okoye *et al.* (2022).

Additional Relevant Studies: Recent investigations continue to explore BMI's impact on visual and ocular physiology. El-Toukhy and Khalifa (2021) demonstrated reduced ocular blood-flow velocity in obese young adults, potentially predisposing them to accommodative fatigue. Likewise, Chen *et al.* (2022) linked BMI-related metabolic dysregulation with delayed pupillary reaction times, implicating broader autonomic imbalance that could influence accommodation and convergence control. These emerging findings substantiate the theoretical framework connecting systemic metabolic status with visual performance.

Key empirical findings

1. Amplitude of Accommodation (AoA): Iyamu *et a*l. (2012) examined anthropometry and AoA in a Nigerian adult sample and reported a negative correlation between BMI and AoA, indicating that higher BMI was associated with reduced accommodative amplitude after controlling for age. Similar patterns were suggested in reviews linking metabolic disease (more common in higher BMI) with accommodative dysfunction (Chou *et al*., 2012 cited earlier). These findings imply systemic/metabolic influences on ciliary muscle function or lens biomechanics.

2. Near Point of Convergence (NPC): Several empirical reports identify associations between BMI and NPC, but results are not fully consistent. Gupta et al. (2019) found that higher BMI correlated with more remote NPC among young adults, suggesting impaired convergence in overweight/obese participants. Contrarily, Momeni-Moghaddam *et al*. (2012) reported poorer NPC and vergence facility in underweight participants in an Iranian sample, suggesting a possible U-shaped relationship where both extremes of BMI confer risk. Gupta & Thakur (2023) observed higher prevalence of convergence/accommodation anomalies in obese university students, again supporting the obesity–NPC association.

3. Heterophoria: Empirical data directly linking BMI to heterophoria are sparse. Lin et al. (2021) reported that systemic conditions (e.g., metabolic syndrome) were associated with a higher prevalence of non-strabismic binocular vision anomalies (including symptomatic phorias). Most cross-sectional studies, however, focus on phoria as an outcome only as part of a battery rather than the primary dependent variable (Momeni-Moghaddam *et al*., 2012; Gupta *et al.,* 2019).

4. Fusional Vergence (PFV/NFV and Vergence Facility): Okoye *et al*. (2022) investigated body composition and fusional reserves in young adults and reported reduced PFV/NFV ranges

among those with higher body composition indices. Momeni-Moghaddam *et al*. (2012) also reported reduced vergence facility in those with abnormal BMI (underweight group), again hinting at non-linear relationships. Overall, reduced vergence flexibility appears linked to altered BMI in multiple studies.

Methods used in the empirical literature

Designs: Predominantly cross-sectional surveys comparing BMI categories (WHO cutoffs) or correlating BMI continuously with visual measures (Momeni-Moghaddam *et al*., 2012; Iyamu *et al.*, 2012; Gupta *et al.*, 2019; Okoye *et al.*, 2022).

Measurement of binocular parameters: Methods vary, NPC often measured via push-up target (accommodative target) or penlight; fusional vergence by prism bar (step) with blur–break–recovery recorded; phoria by cover test or von Graefe; AoA by push-up or minus-lens techniques (method differences reported across studies).

Control variables: Few studies comprehensively adjusted for confounders such as age, refractive error, diabetes status, screen time, or medication use—factors that can affect accommodation/vergence.

Critical appraisal: strengths and limitations

Strengths

These studies provide preliminary empirical signals that BMI/body composition relates to key binocular measures (NPC, AoA, PFV/NFV).

Populations studied (schoolchildren, university students, young adults) capture life stages where non-presbyopic accommodation/vergence is clinically relevant.

Limitations

Heterogeneous methods: Variation in test protocols (NPC target type, AoA technique, prism increments) limits comparability and may explain inconsistent findings (Hashemi, 2018; Anderson *et a*l., 2008).

Cross-sectional design: Causality cannot be inferred—BMI could impact binocular function, or visual dysfunction could influence activity levels and BMI.

Insufficient confounder control: Many studies did not adjust for metabolic disease, refractive error, near-work load, or physical activity—each a potential confounder.

Sample size & representativeness: Several studies used convenience samples (students), limiting generalizability. Small cell counts in BMI extremes reduce statistical power to detect non-linear trends.

Measurement bias: Push-up AoA overestimates amplitude compared with objective methods; similar method biases exist for NPC and PFV (Anderson et al., 2008; Gantz *et a*l., 2022).

Patterns & Gaps

Pattern: NPC and AoA most consistently show associations with BMI across studies, while evidence for heterophoria and fusional vergence is suggestive but less robust.

Gap 1: Few studies analyze BMI as a continuous variable with non-linear modelling (e.g., spline terms) to detect U-shaped relations.

Gap 2: Lack of longitudinal studies to address temporality.

Gap 3: Limited adjustment for metabolic comorbidity (diabetes, hypertension) that may mediate the BMI–ocular relationship.

Gap 4: Few methodologically harmonised multi-parameter studies that measure AoA, NPC, heterophoria, and PFV/NFV within the same cohort with standardised protocols.

Implications for your study

Use standardised measurement protocols (specify NPC target, AoA method, prism procedures) to maximise comparability (Scheiman & Wick, 2014; Gantz *et al.*, 2022).

Analyse BMI both categorically and continuously, and test for non-linearity (U-shape).

Adjust for key confounders: age, sex, refractive error, diabetes status, physical activity, and near-work.

Consider sample size calculation informed by prior effect sizes (Charan *et al.*, 2021) and recruit sufficiently large numbers across BMI strata.

If possible, include objective measures (e.g., auto-refractometer, instrumented NPC) and/or plan a prospective component.

2.2 METHODOLOGICAL REVIEW

A review of methodologies employed in prior studies provides valuable context for the design and analytical choices of the present research. Most investigations exploring BMI and visual performance have utilise **cross-sectional designs**, appropriate for establishing associations between physiological and functional parameters. Akpe and Ebeigbe (2023), Gupta and Thakur (2023), and Okoye *et al*. (2022) all applied descriptive cross-sectional approaches involving university populations aged 16–35 years. This aligns with the demographic of the current research, which targets young adults aged 17–30 years to control for age-related accommodative decline (Duane, 1912).

Sampling Techniques: Purposive sampling has been common in this domain due to the need to control age, refractive status, and ocular health variables. This non-probabilistic method ensures inclusion of participants who meet strict clinical criteria and eliminates confounding by ocular pathology or medication use (Momeni-Moghaddam et al., 2012). The same rationale underlies the present study's purposive selection of healthy, emmetropic or corrected young adults.

Instrumentation and Measurements: Across the literature, measurement techniques have been largely standardised. NPC is commonly measured using a metre rule or RAF ruler; AoA is assessed with Donder's push-up method; Heterophoria and Fusional Vergence are measured using the von Graefe technique with a phoropter (Scheiman & Wick, 2014; Kumar et al., 2017). The present study adheres to these established clinical protocols, ensuring methodological comparability and validity.

Data Analysis: Statistical tools such as descriptive statistics, ANOVA, and Pearson's correlation coefficients have been employed to evaluate the relationship between BMI and binocular parameters (Elangovan & Shanmugham, 2023; Joolaee et al., 2021). These parametric tests are appropriate given that BMI and binocular measures are continuous variables. The current research likewise applies Pearson's correlation and ANOVA to identify statistically significant relationships, using a significance threshold of $p < 0.05$.

Methodological Gaps: Despite methodological consistency, several gaps persist in existing studies. Many investigations have been geographically limited to Asian and Middle Eastern populations, leaving limited data on African or Nigerian cohorts. Additionally, while prior work examined individual visual parameters in isolation, few have evaluated all four binocular functions (NPC, AoA, Heterophoria, and Fusional Vergence) simultaneously in relation to

BMI. The current research addresses both gaps, thereby enhancing generalisability and providing a more holistic understanding of how body composition affects binocular efficiency.

2.3 RESEARCH GAPS AND JUSTIFICATION

A review of prior literature reveals that although several studies have linked BMI to ocular structure and refractive error (Yip, Pan & Lin, 2017; Saxena, Singh & Sharma, 2020), very few have focused on **functional binocular parameters** in young adults. Among the few that exist, variations in findings reflect differences in study design, instruments, and population characteristics. There remains insufficient consensus on which specific binocular parameters are most affected by BMI, particularly within African populations where environmental and genetic factors may differ.

Furthermore, most existing research has considered BMI extremes (obesity or underweight) but has not adequately examined the continuum across normal, overweight, and obese categories within the same dataset. This gap restricts understanding of potential dose–response relationships between BMI and binocular function.

The present study is justified on several grounds:

1. **Scientific Contribution:** It extends current knowledge by examining four interrelated binocular parameters concurrently, offering a multidimensional assessment of BMI's visual implications.
2. **Clinical Relevance:** By identifying which visual functions are most sensitive to BMI variations, the study can inform clinical screening protocols for students and working adults.

3. **Public Health Importance:** With rising rates of obesity among youth, understanding its effect on visual performance adds an important dimension to preventive health strategies.
4. **Contextual Relevance:** Conducting this study in a Nigerian population adds regional evidence, addressing geographic bias in prior literature.

Thus, this study bridges theoretical and empirical gaps by investigating the systemic-visual interface through standardised binocular testing, advancing both optometric practice and public health insight.

2.4 SUMMARY OF LITERATURE REVIEW

This chapter has reviewed relevant theoretical, conceptual, and empirical literature surrounding the relationship between BMI and binocular vision parameters. Evidence indicates that abnormal BMI, whether low or high, may impair certain aspects of binocular function, particularly those involving sustained muscular effort such as convergence and fusional vergence. Accommodation and heterophoria appear relatively unaffected, though subtle influences may occur through systemic metabolic imbalance. Methodologically, most prior studies employed cross-sectional designs and standard optometric techniques, which the present study replicates for consistency. However, existing research is limited by geographic bias, small sample sizes, and focus on single parameters rather than integrated binocular systems.

The current study builds upon these foundations by simultaneously analysing NPC, AoA, Heterophoria, and Fusional Vergence across BMI categories in a young Nigerian population. The findings are expected to elucidate systemic-ocular interactions and inform optometric practice in the evaluation of visual efficiency and general health.

CHAPTER THREE

3.0. METHODOLOGY

3.1. MATERIALS AND METHOD

3.1.1. STUDY DESIGN:

This study was done using a cross-sectional design

3.1.2. STUDY LOCATION:

This study was conducted at the Optometry Clinic in the University of Benin, Benin City, Edo state.

3.1.3. STUDY PERIOD

The study was conducted over a period of three months

3.1.4. SAMPLING TECHNIQUE:

A purposive sampling technique was employed.

3.1.5. STUDY POPULATION:

The study population consist of male and female subjects aged 17 to 30 years. (Scheiman & Wick, 2014).

3.1.6. SAMPLE SIZE

The sample size for this study was calculated using the formula for estimating a mean in a cross-sectional design, as recommended by Charan et al. (2021).

$$\boldsymbol{n} = \frac{Z^2 \times SD^2}{d^2}$$

Where:

n= required sample size

Z = Z-value for confidence level (typically 1.96 for 95%)

SD= standard deviation of the primary outcome variable (from a prior study)

d = margin of error or precision.

Based on data from a previous study by Momeni-Moghaddam et al. (2012), the standard deviation (SD) of Near Point of Convergence was reported as approximately 2.5 cm. A margin of error (d) of 0.5 cm was considered acceptable for clinical relevance.

$$\boldsymbol{n} = \frac{1.96^2 \times 2.5^2}{0.5^2}$$

$$\boldsymbol{n} = \frac{3.8416 \times 6.25^2}{0.25}$$

= 24.01/0.25

= 96.04

Adjusted for Attrition (10%):

n= n/1- Attrition

n=96.04/1-0.1

n= 106.7

Final sample size = 107.participants.

3.2 DATA COLLECTION

3.2.1. Research Instrument : Direct ocular examination.

3.2.2. Study Material:

1. Weighing Scale (Camry Product Manual).
2. Measuring Tape.
3. Meter rule.
4. Phoropter
5. Occluder
6. Data Collection sheet.
7. Near Point Cards
8. Snellens Chart.
9. Direct Ophthalmoscope (Keeler)

10. Retinoscope (keeper)

11. Trial lens set.

3.3. PROCEDURES

3.3.1 Participant Recruitment

Participants was recruited from the general population attending the University of Benin Optometry Clinic. A verbal invitation and flyers was used to inform individuals about the study. Those interested was made undergo an initial screening to ensure eligibility based on the inclusion and exclusion criteria.

The nature of the procedure was explained to the patient.

3.3.2. Measurement of Anthropometric Parameters:

1. Height: Measured using a measuring tape, with participants standing upright without shoes, feet together, and head in the Frankfurt Horizontal Plane.

2. Weight: Measured using a calibrated digital scale with participants wearing light clothing and no shoes.

3. BMI Calculation: Body Mass Index was calculated using the standard formula:

BMI= Weight (kg)/Height (m^2).

3.3.3. OCULAR EXAMINATION PROCEDURES

A. VISUAL ACUITY TEST: First, monocular and binocular visual acuity was assessed at distance (6 meters) and near (40 cm) using a Snellen chart.

B. DIRECT OPHTHALMOSCOPY: Using a Direct Ophthalmoscope in the dark room, the internal ocular structures of each participant was examined. Abnormalities was noted and recorded.

C. REFRACTION:

Objective refraction (Retinoscope) : Retinoscopy was carried out using a retinoscope and trial lens set to determine objective refractive errors.

Subjective refraction: Refinement was performed based on retinoscopy findings to arrive at the best corrected visual acuity.

D. NEAR POINT OF CONVERGENCE (NPC) MEASUREMENT:

A fixation stick with a small letter or detailed target was slowly moved toward the participant's nose at eye level. The participant will be instructed to maintain single vision. Break point (when the participant reports diplopia or when one eye deviates) and recovery point (when single vision is regained) will be recorded in centimeters. Three trials was conducted, and the average will be taken.Reference: (Scheiman & Wick, 2014).

E. AMPLITUDE OF ACCOMMODATION (AOA) MEASUREMENT(MEASURED USING THE PUSH-UP METHOD.):

Participants fixate on a near target (typically a small letter) moved slowly toward the eye along a ruler. The distance at which the participant reports sustained blur will be recorded, and the reciprocal (1/distance in meters) will give the amplitude in diopters. Three measurements was taken, and the average recorded.Reference: (Rouse, 2004)

F. MEASUREMENT OF HETEROPHORIA(VON GRAEFE METHOD) :

The patient sits behind the phoropter and views a distant or near fixation target (e.g., a letter or cross). A prism is placed before each eye, vertical prism (usually 6Δ BU) in front of one eye (often the right) to dissociate the images vertically. Horizontal prism (variable) in front of the other eye (usually the left) to measure the phoria. The vertical prism causes the patient to see

two images, one from each eye separated vertically. Because the images don't overlap, binocular fusion is disrupted, allowing the latent deviation (phoria) to manifest. The horizontal prism will be adjusted to align the images horizontally (for horizontal phorias: esophoria or exophoria). For vertical phoria, the horizontal prism is fixed, and vertical prism is adjusted. The endpoint is when the patient reports that the images are aligned horizontally (for horizontal phoria) or aligned vertically (for vertical phoria), this is the amount of prism needed to neutralize the phoria.

G. FUSIONAL VERGENCE MEASUREMENT(MEASURED USING PHOROPTER).

Positive Fusional Vergence (PFV): Base-out prisms was introduced to assess the participant's ability to converge and maintain single vision. Negative Fusional Vergence (NFV): Base-in prisms was introduced to assess the participant's ability to diverge. For both PFV and NFV: Blur, Break, and Recovery points will be recorded. Testing was performed at both distance and near. Reference: (Daum, 1984)

3.3.4 DATA MANAGEMENT

1. All collected data was recorded in a structured data sheet.

2. Each participant was assigned a unique ID number to maintain confidentiality.

3. Data was double-checked for completeness before entry into SPSS Version 26.

3.3.5 DATA CLASSIFICATION

1. Demographic and Anthropometric Data

Age (17-30 years)

Height (m)

Weight (kg)

Body Mass Index (BMI): Numerical (continuous), then categorized based on WHO guidelines:

Underweight: <18.5

Normal: 18.5–24.9

Overweight: 25–29.9

Obese: ≥30

(WHO BMI Classification, 2020)

2. Binocular Vision Parameters

These was classified as numerical variables for statistical analysis.

a. Near Point of Convergence (NPC): Measured in centimeters (cm)

Classified as:

Normal: 5/7cm

Receded: >10 cm

(Momeni-Moghaddam *et al*., 2012)

b. Amplitude of Accommodation (AoA): Measured in Diopters (D)

Minimum = 15 - 0.25 × age

Average = 18.5 - 0.3 × age

c. Heterophoria: Categorical (Exophoria / Orthophoria / Esophoria)

Measured at: Distance (6 m) and Near (40 cm). Quantified in prism diopters (pd).

d. Fusional Vergence Amplitudes: Base-In and Base-Out measurements at near (40 cm). Measured in prism diopters (pd).

Parameters recorded: Blur Point, Break Point and Recovery Point.

(Gupta & Thakur, 2023; Momeni-Moghaddam et al., 2012)**.**

3.4 INCLUSION AND EXCLUSION CRITERIA

3.4.1 INCLUSION CRITERIA

1. Individuals aged between 17–30 years.

2. No history of ocular trauma.

3. No Use of medications affecting ocular accommodation or vergence.

4. Willingness to participate and provide informed consent.

3.4.2 EXCLUSION CRITERIA

1. Known systemic diseases (e.g., diabetes mellitus, hypertension, thyroid disease).

2. Use of medications affecting ocular accommodation or vergence.

3. Presence of manifest strabismus, amblyopia, or significant refractive errors (> ±5.00D).

4. History of neurological disorders.

3.5 ETHICAL CONSIDERATION:

Ethical approval to conduct this study was obtained from the Research and Ethics Committee of the Department of Optometry, University of Benin. The REC approval number is EC/UBEN/LSC.OPT/25/131. Consent was obtained from all participants of the study before participation. All participants was 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 be collected. Data was used strictly for this study.

3.6 DATA ANALYSIS

Step 1: Data Entry

Data was entered into Excel sheet and it will be analyzed using spss v 26...

Variables:

BMI (continuous)

NPC (in cm)

AoA (in diopters)

Heterophoria (in prism diopters at distance and near)

Fusional vergence ranges (base-in, base-out)

Step 2: Descriptive Statistics

Mean and Standard Deviation for BMI, NPC, AoA, Heterophoria, Fusional Vergence.

Minimum and Maximum values will be calculated.

Step 3: Correlation Analysis

Pearson correlation test was used to assess relationships between Body Mass Index (BMI) and each visual parameter. Example, Correlate BMI with NPC, Correlate BMI with AoA, Correlate BMI with Heterophoria, Correlate BMI with Fusional Vergence

Interpretation:

If $p < 0.05$, the relationship is statistically significant.

Positive = direct relationship; negative = inverse relationship.

Step 5: Statistical Significance: Significance level was set at $p = 0.05$. Using confidence intervals (95%) to validate the strength of the findings.

CHAPTER FOUR

RESULTS AND DATA ANALYSIS

This study involved a total of 100 participants, aged between 17 and 30 years, with an average age of 21.53 ± 2.65 years. The participants' Body Mass Index (BMI) ranged from 14.1 to 39.6 kg/m², with a mean of 24.56 ± 6.48 kg/m².comprising of male (n = 39) and female (n = 61) participants. The study was conducted to determine the relationship between Body Mass index (BMI) on Binocular vision parameters among young adults.

TABLE 4.1:CHI-SQUARE RESULT SHOWING GENDER DISTRIBUTION OF PARTICIPANT ACROSS BMI GRADING.

GENDER VS BMI GRADING					
(1) GENDER	Underweight Frequency(%)	Normal Frequency (%)	Overweight Frequency (%)	Obese Frequency (%)	Total (%)
MALE(n =39)	12 (30.8%)	9(23.1%)	9(23.1%)	9(23.1%)	100%
FEMALE (n = 61)	13 (21.3%)	16(26.2%)	16(26.2%)	16(26.2%)	100%
Total(%)	25(25%)	25(25%)	25(25%)	25(25%)	100%
P value			=0.769		

Across BMI groups, female participants were more represented in all categories. The normal, overweight, and obese groups each had 16 females, while the underweight group had 13. Among males, distribution was fairly even across BMI grades, ranging from 9 to 12. The association between BMI grading and gender was not statistically significant (p = 0.769).

TABLE: 4.2: CHI- SQUARE RESULT SHOWING DISTRIBUTION OF NPC, AOA, HETEROPHORIA ACROSS DIFFERENT BMI GRADING.

Parameters	Underweight	Normal	Overweight	Obese	P value
NPC break, mean ± SD	9.20±1.71	8.28±2.07	9.04±2.32	9.68±2.09	**0.121**
NPC recovery, mean ± SD	12.12±2.93	11.08±2.12	12.56±3.09	13.08±1.87	**0.047**
AOA	10.15±1.95	10.91±2.40	10.56±2.54	10.99±1.94	**0.529**
AGE	20.16±1.97	21.64±2.18	21.92±2.90	22.40±3.01	**0.017**
Heterophoria@6m	-0.24±2.71	0.14±2.42	2.00±3.75	1.00±5.29	**0.154**
Heterophoria@40cm	-1.12±5.21	-0.92±5.85	-1.00±6.19	-1.00±5.85	**0.999**

Pearson's, p = 0.121 (NPC_break). Pearson's, p = 0.047 (NPC_recovery). Pearson's, p = 0.529 (AOA). Pearson's, p = 0.017 (AGE). Pearson's, p = 0.154 (Heterophoria@6m). Pearson's, p = 0.999 (Heterophoria@40cm). With increasing BMI, NPC recovery was highest in the obese group (13.08 ± 1.87 cm) and lowest in the normal group (11.08 ± 2.12 cm). Age also rose steadily with BMI, from 20.16 ± 1.97 years in the underweight to 22.40 ± 3.01 years in the obese. NPC break, AoA, and heterophoria at both 6 m and 40cm showed no clear BMI trend. Only NPC recovery and age demonstrated significant associations with BMI (p = 0.047 and 0.017, respectively).

TABLE 4.2.1: DESCRIPTIVE STATISTIC RESULT SHOWING DISTRIBUTION OF AOA ACROSS BMI GRADINGS.

	BMI vs AoA		
	BMI grading	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Underweight	25	10.152
	Overweight	25	10.564
	Normal	25	10.910
	Obese	25	10.994
	Significance (p)		0.541

Mean AoA increased slightly with BMI, highest in the obese group (10.99) and second highest in the normal group (10.91), while the underweight group had the lowest (10.15). The variation across BMI groups was not statistically significant (p = 0.541).

TABLE 4.2.2: CHI-SQUARE RESULT SHOWING DISTRIBUTION OF HETEROPHORIA ACROSS BMI GRADINGS.

BMI AND HETEROPHORIA

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
H Phoria@6m	Underweight	25	-0.24	2.712	0.542	-1.36	0.88	-6	5
	Normal	25	0.14	2.422	0.484	-0.86	1.14	-4	4
	Overweight	25	2.00	3.753	0.751	0.45	3.55	-4	16
	Obese	25	1.00	5.292	1.058	-1.18	3.18	-8	20
	Total	100	0.73	3.763	0.376	-0.02	1.47	-8	20
"H Phoria@40 cm (-exo, +eso)"	Underweight	25	-1.120	5.2067	1.0413	-3.269	1.029	-16.0	9.0
	Normal	25	-0.920	5.8518	1.1704	-3.335	1.495	-13.0	12.0
	Overweight	25	-1.000	6.1914	1.2383	-3.556	1.556	-10.0	20.0
	Obese	25	-1.000	5.8452	1.1690	-3.413	1.413	-8.0	20.0
	Total	100	-1.010	5.6969	0.5697	-2.140	0.120	-16.0	20.0

P = 0.154 (Heterophoria@6m). P = 0.999 (Heterophoria@40cm).

The overweight group showed the highest mean heterophoria at distance, followed by the obese group, while the underweight group had the lowest, indicating a mild exophoric tendency. At near fixation, all BMI groups demonstrated similar mean values with a slight exophoric posture and minimal variation across categories.

TABLE 4.3: CHI-SQUARE RESULT DETERMING THE ASSOCIATION OF FUSIONAL VERGENCE ACROSS BMI GRADINGS (OBJECTIVE 4).

Parameters		Underweight	Normal	Overweight	Obese	P values
NFV @6m	Break	7.84±3.38	10.24±2.13	10.32±2.97	9.80±4.82	**0.043**
Mean ± SD	Recovery	3.40±1.92	4,76±1.88	3.88±2.39	4.16±3.27	**0.253**
NFV @40cm	Blur	9.16±3.20	11.84±5.55	11.60±6.45	10.32±3.54	**0.190**
Mean ± SD	Break	16.08±4.73	25.72±41.26	17.80±7.75	16.20±5.47	**0.330**
PFV @6m	Blur	10.52±5.52	14.80±7.54	13.24±6.05	11.64±4.28	**0.068**
Mean ± SD	Break	19.72±6.56	22.32±7.27	21.84±6.53	21.48±4.84	**0.500**
PFV @40cm	Blur	13.28±5.05	12.88±5.06	14.84±6.59	15.92±7.45	**0.272**
Mean ± SD	Break	24.64±5.43	20.76±6.65	24.28±6.71	37.52±61.78	**0.255**

Across BMI groups, NFV break at 6 m was highest in the obese group (9.80 ± 4.82) and lowest in the underweight (7.84 ± 3.38). PFV blur at 6 m was also highest in the normal group (14.80 ± 7.54) and lowest in the obese (11.64 ± 4.28). Both NFV break at 6 m ($p = 0.043$) and PFV blur at 6 m ($p = 0.068$) showed significant variation across BMI grades, suggesting a decline in fusional divergence and convergence with increasing BMI. Other fusional vergence parameters showed no significant association with BMI.

TABLE 4.3.1: DISTRIBUTION OF NFV (BREAK) @6M ACROSS BMI GRADINGS

	NFV _break@ 6m		
	BMI grading	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Underweight	25	7.84
	Obese	25	9.80
	Normal	25	10.24
	Overweight	25	10.32
	Significance (p)		0.061

Mean NFV break at 6 m increased with BMI, from 7.84 in the underweight to 10.32 in the overweight group. The underweight group showed the lowest fusional divergence, while the overweight recorded the highest. However, this difference was not statistically significant (p = 0.061).

TABLE 4.3.2: DISTRIBUTION OF NFV (RECOVERY) @6M ACROSS BMI GRADINGS

	NFV_recovery@6m		
	BMI grading	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Underweight	25	3.40
	Overweight	25	3.88
	Obese	25	4.16
	Normal	25	4.76
	Significance (p)		0.199

Mean NFV recovery at 6 m was highest in the normal group (4.76), followed by the obese group (4.16), and lowest in the underweight group (3.40). The variation across BMI categories was not statistically significant (p = 0.199).

TABLE 4.3.3: DISTRIBUTION OF NFV (BLUR) @40CM ACROSS BMI GRADINGS

	NFV_blur @ 40cm		
	BMI grading	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Underweight	25	9.16
	Obese	25	10.32
	Overweight	25	11.60
	Normal	25	11.84
	Significance (p)		0.217

Mean NFV blur at 40 cm was highest in the normal group (11.84), followed by the overweight group (11.60), Obese (10.32) and lowest in the underweight group (9.16). The difference across BMI groups was not statistically significant (p = 0.217).

TABLE 4.3.4: DISTRIBUTION OF NFV (BREAK) @40CM ACROSS BMI GRADINGS

	NFV_break@40cm		
	BMI grading	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Underweight	25	16.08
	Obese	25	16.20
	Overweight	25	17.80
	Normal	25	25.72
	Significance (p)		0.383

Mean NFV break at 40 cm was highest in the normal group (25.72), followed by the overweight group (17.80), and lowest in the underweight group (16.08). The variation across BMI groups was not statistically significant (p = 0.383).

TABLE 4.3.5: DISTRIBUTION OF PFV (BLUR) @6M ACROSS BMI GRADINGS

	PFV_blur @6m		
	BMI grading	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Underweight	25	10.52
	Obese	25	11.64
	Overweight	25	13.24
	Normal	25	14.80
	Significance (p)		0.061

Mean PFV blur at 6 m was highest in the normal group (14.80), followed by the overweight group (13.24), and lowest in the underweight group (10.52). The difference across BMI groups was not statistically significant (p = 0.061).

TABLE 4.3.6: DISTRIBUTION OF PFV (BREAK) @6M ACROSS BMI GRADINGS

	PFV_break@6m		
	BMI grading	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Underweight	25	19.72
	Obese	25	21.48
	Overweight	25	21.84
	Normal	25	22.32
	Significance (p)		0.475

Mean PFV break at 6 m was highest in the normal group (22.32), followed by the overweight group (21.84), and lowest in the underweight group (19.72). The variation across BMI groups was not statistically significant (p = 0.475).

TABLE 4.4: DISTRIBUTION OF DECOMPENSATED PHORIA ACROSS BMI GRADINGS

BMI GRADING	Comp P	Decom P	TOTAL:n(%)
Underweight	14(56%)	11(44%)	25(25%)
Normal	20(80%)	5(20%)	25(25%)
Overweight	15(60%)	10(40%)	25(25%)
Obese	18(72%)	7(28%)	25(25%)
TOTAL	67(67%)	33(33%)	100(100%)

Pearson's, p =0.249

Decompensated phoria occurred most among the underweight group (11 cases), followed by the overweight (10 cases), and least among the normal BMI group (5 cases). However, the association between BMI grading and decompensated phoria was not statistically significant (p = 0.249), possibly due to the small sample size.

TABLE 4.5: CHI-SQUARE RESULT DETERMINING THE RELATIONSHIP BETWEEN BMI AND REFRACTIVE STATUS (OBJ 6)

REFRACTIVE STATUS	Underweight Frequency(%)	Normal Frequency(%)	Overweight Frequency(%)	Obese Frequency(%)	Total (%)
Emmetrope (n = 23)	9(39.1%)	8(34.8)	3(13.0%)	4(17.4%)	104.3%
Myope (n = 16)	6(37.5%)	5(31.3%l)	1(6.3%)	4(25.0%)	100%
Hyperope (n = 18)	6(33.3%)	4(22.2%)	3(16.7%)	5(27.8%)	100%
Myopic Astigmat (n= 18)	3(16.7%)	3(16.7%)	8(44.4%)	4(22.2%)	100%
Hyperopic Astigmat (n = 25)	1(4.0%)	5(20.0%)	10(40.0%)	9(36.0%)	100%
P value		= 0.039			

Across BMI categories, hyperopic astigmatism was most frequent among the overweight (10) and obese (9) groups, followed by myopic astigmatism (8 in the overweight group). Emmetropia was least among the overweight (3) and obese (4) participants. A significant relationship was found between BMI grading and refractive status (p = 0.039).

TABLE: 4.6: DESCRIPTIVE STATISTIC RESULT SHOWING DISTRIBUTION OF AGE ACROSS THE BMIGRADINGS

AGE VS BMI

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age in years	100	17	30	21.53	2.653
BMI	100	14.1	39.6	24.564	6.4817
Valid N (listwise)	100				

Among the 100 participants, ages ranged from 17 to 30 years with a mean of 21.53 ± 2.65 years. BMI values ranged from 14.1 to 39.6, with a mean of 24.56 ± 6.48, indicating that most participants fell within the normal to overweight range.

TABLE 4.7: CHI-SQUARE RESULT DETERMINING THE RELATIONSHIP BETWEEN AGE AND NPC (BREAK AND RECOVERY).

AGE AND NPC (BREAK & RECOVERY)

BMI grading		Age in years	NPC_break	NPC_recovery
Underweight	Mean	20.16	9.20	12.12
	N	25	25	25
	Std. Deviation	1.972	1.708	2.934
Normal	Mean	21.64	8.28	11.08
	N	25	25	25
	Std. Deviation	2.177	2.072	2.120
Overweight	Mean	21.92	9.04	12.56
	N	25	25	25
	Std. Deviation	2.900	2.318	3.097
Obese	Mean	22.40	9.68	13.08
	N	25	25	25
	Std. Deviation	3.014	2.096	1.869
Total	Mean	21.53	9.05	12.21
	N	100	100	100
	Std. Deviation	2.653	2.091	2.626

P = 0.017 (AGE). P = 0.121 (NPC break). P = 0.047 (NPC recovery).

Mean age increased with BMI, from 20.16 years in the underweight to 22.40 years in the obese group. NPC break was highest in the obese (9.68) and lowest in the normal group (8.28). Similarly, NPC recovery was highest among the obese (13.08) and lowest among the normal (11.08).

TABLE 4.8: CHI-SQUARE RESULT DETERMINING THE RELATIONSHIP BETWEEN AGE AND AOA

AGE AND AoA									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Age in years	Under weight	25	20.16	1.972	.394	19.35	20.97	18	24
	Normal	25	21.64	2.177	.435	20.74	22.54	18	26
	Overweight	25	21.92	2.900	.580	20.72	23.12	18	30
	Obese	25	22.40	3.014	.603	21.16	23.64	17	30
	Total	100	21.53	2.653	.265	21.00	22.06	17	30
AoA	Under weight	25	10.152	1.9532	.3906	9.346	10.958	6.0	16.0
	Normal	25	10.910	2.3991	.4798	9.920	11.900	8.0	20.0
	Overweight	25	10.564	2.5398	.5080	9.516	11.612	6.0	16.6
	Obese	25	10.994	1.9412	.3882	10.193	11.795	6.3	15.3
	Total	100	10.655	2.2156	.2216	10.215	11.095	6.0	20.0

P = 0.017 (AGE). P = 0.529 (AOA)

Mean age increased steadily with BMI, from 20.16 years in the underweight to 22.40 years in the obese group. AoA was highest in the obese group (10.99 D), followed by the normal group (10.91 D), and lowest in the underweight group (10.15 D). Overall, AoA showed a mild increase with BMI.

TABLE 4.9: CHI-SQUARE RESULT DETERMINING THE RELATIONSHIP BETWEEN AGE AND HETEROPHORIA

AGE AND HETEROPHORIA				
BMI grading		Age in years	H Phoria@6m	"H Phoria@40cm (-exo, +eso)"
Underweight	Mean	20.16	-0.24	-1.120
	N	25	25	25
	Std. Deviation	1.972	2.712	5.2067
Normal	Mean	21.64	.14	-.920
	N	25	25	25
	Std. Deviation	2.177	2.422	5.8518
Overweight	Mean	21.92	2.00	-1.000
	N	25	25	25
	Std. Deviation	2.900	3.753	6.1914
Obese	Mean	22.40	1.00	-1.000
	N	25	25	25
	Std. Deviation	3.014	5.292	5.8452
Total	Mean	21.53	.73	-1.010
	N	100	100	100
	Std. Deviation	2.653	3.763	5.6969

P = 0.017 (AGE). P = 0.154(Heterophoria@6m). P = 0.999(Heterophoria@40cm)

Mean age increased with BMI, from 20.16 years in the underweight to 22.40 years in the obese group. For distance heterophoria (6 m), the highest mean value was observed in the overweight group (2.00), followed by the obese group (1.00), and least in the underweight (-0.24). At near (40 cm), heterophoria values were similar across BMI groups, with all showing slight exophoria (around –1.00).

TABLE 4.10: DETERMINING THE RELATIONSHIP BETWEEN GENDER AND AOA

GENDER AND AoA					
	Gender of participants	N	Mean	Std. Deviation	Std. Error Mean
AoA	Male	39	10.778	1.6685	0.2672
	Female	61	10.576	2.5141	0.3219

The mean amplitude of accommodation (AoA) was slightly higher in males (10.78 D) compared to females (10.58 D). However, the difference between genders was minimal, indicating that gender had little influence on AoA in this sample.

TABLE: 4.11: DESCRIPTIVE STATISTIC RESULT DETERMINING THE RELATIONSHIP BETWEEN GENDER AND HETEROPHORIA

GENDER And HETEROPHORIA

	Gender of participants	N	Mean	Std. Deviation	Std. Error Mean
H Phoria@6m	male	39	0.04	3.109	0.498
	Female	61	1.16	4.091	0.524
"H Phoria@40cm (-exo, +eso)"	Male	39	-1.256	4.7612	0.7624
	Female	61	-0.852	6.2552	0.8009

Males were slightly esophoric at distance (0.04 ± 3.11Δ) and more exophoric at near (–1.26 ± 4.76Δ).

Females showed greater esophoria at distance (1.16 ± 4.09Δ) and mild exophoria at near (–0.85 ± 6.26Δ).

Overall, both genders tended toward esophoria at distance and exophoria at near, with minor variations.

TABLE 4.12: CHI-SQUARE RESULT DETERMINING THE RELATIONSHIP BETWEEN GENDER AND FUSIONAL VERGENCE

GENDER AND FUSIONAL VERGENCE					
	Gender of participants	N	Mean	Std. Deviation	Std. Error Mean
NFV @ 6m	Male	39	8.77	3.013	.482
	Female	61	10.05	3.805	.487
NFV_recovery@6m	Male	39	3.82	1.945	.311
	Female	61	4.20	2.701	.346
NFV @ 40cm	Male	39	9.95	4.371	.700
	Female	61	11.23	5.220	.668
NFV_break@40cm	Male	39	16.97	5.770	.924
	Female	61	20.21	26.957	3.451
PFV @6m	Male	39	12.28	5.539	.887
	Female	61	12.72	6.463	.828
PFV_break@6m	Male	39	20.79	5.699	.913
	Female	61	21.69	6.742	.863
PFV @40cm	Male	39	15.23	6.188	.991
	Female	61	13.59	6.097	.781
PFV_break@40cm	Male	39	24.72	6.817	1.092
	Female	61	28.13	40.098	5.134

P = 0.079(NFV@6m). P = 0.453 (NFV recovery@6m). P = 0.206 (NFV @40cm). P = 0.462 (NFV break @40cm).

P = 9.727 (PFV @6m). P = 0.495 (PFV break@6m). P = 0.195 (PFV @40cm). P = 0.600 (PFV break@40cm)

Females generally demonstrated slightly higher Negative Fusional Vergence (NFV) values than males at both distance and near.

NFV @6m: M = 8.77 ± 3.01, F = 10.05 ± 3.81

NFV @40cm: M = 9.95 ± 4.37, F = 11.23 ± 5.22

For Positive Fusional Vergence (PFV), values were comparable between genders:

PFV @6m: M = 12.28 ± 5.54, F = 12.72 ± 6.46

PFV @40cm: M = 15.23 ± 6.19, F = 13.59 ± 6.10

Overall, females showed slightly higher NFV while PFV was similar across genders, suggesting minimal gender-related variation in fusional vergence.

TABLE 4.13: DESCRIPTIVE STATISTIC RESULT DETERMINING THE RELATIONSHIP BETWEEN REFRACTIVE STATUS AND NPC(BREAK AND RECOVERY)

Emmetropes showed the best convergence (NPC break = 8.35 ± 1.82 cm; recovery = 11.17 ± 2.10 cm), while myopes had the weakest (break = 9.31 ± 1.82 cm; recovery = 12.63 ± 2.19 cm). Overall mean NPC break = 9.05 ± 2.09 cm and recovery = 12.21 ± 2.63 cm.

REFARCTIVE STATUS AND NPC

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
NPC_break	Emmetrope	23	8.35	1.824	.380	7.56	9.14	6	12
	Myope	16	9.31	1.815	.454	8.35	10.28	5	12
	Hyperope	18	9.22	2.669	.629	7.89	10.55	4	14
	myopic astigmat	18	9.56	1.464	.345	8.83	10.28	7	12
	hyperopic astigmat	25	9.04	2.371	.474	8.06	10.02	4	14
	Total	100	9.05	2.091	.209	8.64	9.46	4	14
NPC_recovery	Emmetrope	23	11.17	2.103	.439	10.26	12.08	8	16
	Myope	16	12.63	2.187	.547	11.46	13.79	9	18
	Hyperope	18	12.56	3.617	.853	10.76	14.35	7	20
	myopic astigmat	18	12.44	2.526	.595	11.19	13.70	7	20
	hyperopic astigmat	25	12.48	2.502	.500	11.45	13.51	8	20
	Total	100	12.21	2.626	.263	11.69	12.73	7	20

TABLE 4.14: DESCRIPTIVE STATISTIC RESULT DETERMINING THE RELATIONSHIP BETWEEN REFRACTIVE STATUS AND AOA

REFRACTIVE STATUS AND AoA

	AoA						
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Emmetrope	23	11.159	2.0297	0.4232	10.281	12.036	8.3	16.6
Myope	16	11.269	2.1862	0.5466	10.104	12.434	8.0	16.6
Hyperope	18	10.683	1.7436	0.4110	9.816	11.550	8.0	15.3
myopic astigmat	18	10.794	2.8026	0.6606	9.401	12.188	6.0	20.0
hyperopic astigmat	25	9.678	2.0652	0.4130	8.826	10.530	6.0	14.3
Total	100	10.655	2.2156	0.2216	10.215	11.095	6.0	20.0

Myope participants recorded the highest mean AoA (11.27 ± 2.19 D), followed closely by emmetropes (11.16 ± 2.03 D), while hyperopic astigmats had the lowest mean AoA (9.68 ± 2.07 D).

Overall mean AoA was 10.66 ± 2.22 D.

TABLE 4.15: CHI-SQUARE RESULT DETERMINING THE RELATIONSHIP BETWEEN REFRACTIVE STATUS AND GENDER

GENDER AND REFRACTIVE STATUS VS BMI

		N	Mean	Std. Deviation	Std. Error
Gender of participants	Underweight	25	1.52	0.510	0.102
	Normal	25	1.64	0.490	0.098
	Overweight	25	1.64	0.490	0.098
	Obese	25	1.64	0.490	0.098
	Total	100	1.61	0.490	0.049
Refractive_status	Underweight	25	2.24	1.200	0.240
	Normal	25	2.68	1.547	0.309
	Overweight	25	3.84	1.344	0.269
	Obese	25	3.48	1.447	0.289
	Total	100	3.06	1.510	0.151

P = 0.777 (gender of participants). P < 0.001 (Refractive status)

Gender distribution was similar across BMI groups, with mean values ranging narrowly from 1.52 ± 0.51 in the underweight to 1.64 ± 0.49 in the normal, overweight, and obese groups. Refractive status, however, increased with BMI, highest among the overweight group (3.84 ± 1.34) and lowest in the underweight (2.24 ± 1.20).

TABLE 4.16: CHI-SQUARE RESULT FOR VARIOUS PARAMETERS ACROSS THEN FOUR BMI GRADINGS

Parameters		**Underweight**	**Normal**	**Overweight**	**Obese**	**P values**
NPC Mean ± SD	Break	9.20 ± 1.71	8.28 ± 2.07	9.04 ± 2.32	9.68 ± 2.1	**0.121**
	Recovery	12.12±2.93	11.08±2.12	12.56±3.097	13.08±1.87	
AGE, Mean ± SD		20.16 ±1.97	21.64±2.18	21.92±2.9	22.40±3.01	**0.017**
AoA, Mean ± SD		10.15±1.95	10.91±2.40	10.56±2.54	10.994±1.94	**0.529**
Gender, Mean ± SD		1.52±0.51	1.64±0.49	1.64±0.49	1.61±0.49	**0.777**
Refractive Status, Mean ± SD		2.24±1.20	2.68±1.55	3.84±1.34	3.48±1.45	**<0.001**

With increasing BMI, NPC recovery was highest in the obese group (13.08 ± 1.87 cm) and lowest in the underweight (12.12 ± 2.93 cm). Age rose progressively with BMI, from 20.16 ± 1.97 years in underweight to 22.40 ± 3.01 years in obese. AoA peaked in the obese (10.99 ± 1.94 D) and was least in the underweight (10.15 ± 1.95 D). Refractive status increased with BMI, highest in overweight (3.84 ± 1.34) and lowest in underweight (2.24 ± 1.20). Gender distribution showed minimal variation across BMI groups**.**

TABLE4:17 DISTRIBUTION OF NPC_break & NPC_recovery AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN UNDERWEIGHT & NORMAL.

	NPC_break (underweight)	NPC_recovery (underweight)	NPC_break (normal)	NPC_recovery (normal)
1	8	10	10	12
2	8	10	7	11
3	12	18	12	16
4	8	11	6	10
5	11	12	5	9
6	8	10	7	12
7	8	10	10	11
8	9	10	9	11
9	7	9	6	9
10	9	12	8	11
11	8	10	6	8
12	9	12	8	10
13	10	12	4	8
14	9	10	8	10
15	9	13	12	14
16	8	12	10	13
17	11	12	9	11
18	10	13	10	14
19	14	18	7	7
20	12	20	8	12
21	10	14	8	10
22	7	9	7	10
23	8	11	10	12

	NPC_break (underweight)	NPC_recovery (underweight)	NPC_break (normal)	NPC_recovery (normal)
24	8	15	11	14
25	9	11	9	12
TOTAL	230	304	207	277
MEAN	9.20	12.12	8.28	11.08
SD	1.71	2.93	2.07	2.12

P value = 0.112

The underweight group demonstrated slightly higher NPC break (9.20 ± 1.71) and recovery scores (12.12 ± 2.93) compared to normal-weight participants, who showed NPC break and recovery means of 8.28 ± 2.07 and 11.08 ± 2.12 respectively. Although the underweight group appears to have a more receded near point of convergence, the difference between both groups was not statistically significant ($p = 0.112$). This suggests that BMI category did not have a meaningful effect on NPC performance in this sample.

TABLE4:18 DISTRIBUTION OF NPC_break & NPC_recovery AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OVERWEIGHT & NORMAL

	NPC_break (overweight)	NPC_recovery (overweight)	NPC_break (normal)	NPC_recovery (normal)
1	7	10	10	12
2	12	14	7	11
3	10	12	12	16
4	9	11	6	10
5	10	12	5	9
6	10	13	7	12
7	10	12	10	11
8	10	20	9	11
9	13	17	6	9
10	10	15	8	11
11	10	13	6	8
12	6	10	8	10
13	9	12	4	8
14	8	12	8	10
15	8	10	12	14
16	7	10	10	13
17	14	20	9	11
18	4	7	10	14
19	7	13	7	7
20	10	13	8	12
21	10	14	8	10
22	11	13	7	10
23	6	8	10	12
24	9	13	11	14
25	6	10	9	12

NPC_break (overweight)	NPC_recovery (overweight)	NPC_break (normal)	NPC_recovery (normal)
TOTAL	226	314	207	277
MEAN	9.04	12.56	8.28	11.08
SD	2.32	3.10	2.07	2.12

P value = 0.137

Overweight participants demonstrated slightly more receded NPC break (9.04 ± 2.32) and recovery values (12.56 ± 3.10) compared to normal-weight individuals, who recorded NPC break and recovery means of 8.28 ± 2.07 and 11.08 ± 2.12 respectively. Although the overweight group showed weaker near convergence performance, the difference was not statistically significant ($p = 0.137$). This suggests that overweight status does not meaningfully influence the near point of convergence in this sample.

TABLE 4:19 DISTRIBUTION OF NPC_break & NPC_recovery AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OBESE & NORMAL

	NPC_break (obese)	NPC_recovery (obese)	NPC_break (normal)	NPC_recovery (normal)
1	10	11	10	12
2	8	15	7	11
3	9	12	12	16
4	11	13	6	10
5	10	14	5	9
6	10	13	7	12
7	10	12	10	11
8	12	16	9	11
9	12	14	6	9
10	11	13	8	11
11	11	13	6	8
12	9	13	8	10
13	7	11	4	8
14	11	16	8	10
15	8	12	12	14
16	6	12	10	13
17	14	15	9	11
18	7	11	10	14
19	13	17	7	7
20	9	11	8	12

	NPC_break (obese)	NPC_recovery (obese)	NPC_break (normal)	NPC_recovery (normal)
21	7	12	8	10
22	7	10	7	10
23	8	13	10	12
24	12	16	11	14
25	10	12	9	12
TOTAL	242	327	207	277
MEAN	9.68	13.08	8.28	11.08
SD	2.10	1.87	2.07	2.12

P value = 0.115

Obese participants showed slightly more receded NPC break (9.68 ± 2.10) and recovery scores (13.08 ± 1.87) when compared with normal-weight individuals (8.28 ± 2.07 and 11.08 ± 2.12, respectively). Although convergence ability appeared somewhat reduced in the obese group, the difference was not statistically significant ($p = 0.115$). This indicates that obesity did not have a meaningful effect on NPC performance in this study population.

TABLE 4:20 DISTRIBUTION OF NPC_break & NPC_recovery AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN

	AOA (underweight)	AOA (normal)
1	16	11
2	12	12.5
3	9.5	10.5
4	8.3	10
5	6	11
6	9.5	14.2
7	10	11.8
8	9	12.5
9	10.5	11
10	9.5	10.5
11	12	9
12	10	12.5
13	9.5	10
14	12.5	11
15	9.5	10
16	10	10
17	10	11
18	12	9
19	8	20
20	9.5	8
21	9	10

	AOA (underweight)	AOA (normal)
22	9	8.3
23	10	10
24	12.5	11
25	11	8
TOTAL	254.8	272.8
MEAN	10.15	10.91
SD	1.95	2.40

P value = 0.459

Underweight participants recorded a slightly lower mean Accommodative Amplitude (10.15 ± 1.95) compared with normal-weight individuals (10.91 ± 2.40). Although the underweight group showed marginally reduced accommodative ability, this difference was not statistically significant ($p = 0.459$). This indicates that BMI category did not have a meaningful effect on AoA within this study population.

TABLE4: 21 DISTRIBUTION OF NPC_break & NPC_recovery AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OVERWEIGHT & NORMAL

	AOA (overweight)	AOA (normal)
1	7	11
2	10	12.5
3	11	10.5
4	10	10
5	11.5	11
6	10	14.2
7	7.5	11.8
8	11	12.5
9	10	11
10	10.5	10.5
11	13.5	9
12	11.5	12.5
13	12.5	10
14	10.5	11
15	7.6	10
16	16.6	10
17	6	11
18	11	9
19	12.5	20
20	10	8
21	16.6	10
22	8.3	8.3
23	9	10
24	11	11

25	9	8
TOTAL	264.1	272.8
MEAN	10.56	10.91
SD	2.54	2.40

P value = 0.555

The mean amplitude of accommodation (AoA) for overweight participants was 10.56 ± 2.54 D, compared with 10.91 ± 2.40 D for normal-weight participants. This difference was not statistically significant (P = 0.555), indicating that BMI did not appear to influence AoA in this sample.

TABLE 4:22 DISTRIBUTION OF NPC_break & NPC_recovery AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OBESE & NORMAL

	AOA (obese)	AOA (normal)
1	12	11
2	11	12.5
3	10	10.5
4	13	10
5	12.5	11
6	10	14.2
7	12.5	11.8
8	10	12.5
9	11.5	11
10	11	10.5
11	10	9
12	6.3	12.5
13	8	10
14	12.5	11
15	9	10
16	10	10
17	14.3	11
18	10	9
19	15.3	20
20	10	8
21	12.5	10
22	11	8.3

23	10	10
24	12.5	11
25	10	8
TOTAL	274.9	272.8
MEAN	10.994	10.91
SD	1.94	2.40

P value = 0.479

The mean amplitude of accommodation (AoA) for obese participants was 10.99 ± 1.94 D, while normal-weight participants had a mean AoA of 10.91 ± 2.40 D. Statistical analysis showed no significant difference between groups (P = 0.479), suggesting that obesity did not significantly affect AoA in this sample.

TABLE 4.23 DISTRIBUTION OF NFV_break & NPC_recovery @6M AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN UNDERWEIGHT & NORMAL

	NFV_break (underweight)	NFV_recovery (underweight)	NFV_break (normal)	NFV_recovery (normal)
1	9	4	12	6
2	12	8	8	4
3	7	2	12	8
4	10	2	12	9
5	10	4	14	8
6	12	6	12	4
7	8	2	10	3
8	12	5	10	2
9	4	2	10	7
10	0	0	6	2
11	10	4	10	4
12	5	2	12	4
13	6	3	6	2
14	6	2	10	4
15	3	2	8	4
16	5	2	9	3
17	5	3	12	6
18	6	4	10	4
19	6	2	8	4
20	8	4	7	4
21	10	2	12	6
22	12	6	12	5

23	14	7	12	6
24	6	2	10	5
25	10	5	12	5
TOTAL	196	85	256	119
MEAN	7.84	3.40	10.24	4.76
SD	3.38	1.92	2.13	1.88

P value(NFV_break @6m) = 0.041, P value (NFV_recovery @6m) = 0.242

At 6 m, the mean NFV_break for underweight participants was 7.84 ± 3.38 Δ, compared with 10.24 ± 2.13 Δ for normal participants. Statistical analysis indicated a significant difference between groups (P = 0.041), suggesting that underweight participants had lower NFV_break values than normal-weight participants. For NFV_recovery at 6 m, underweight participants had a mean of 3.40 ± 1.92 Δ, while normal participants had 4.76 ± 1.88 Δ. This difference was not statistically significant (P = 0.242), indicating similar recovery ability between groups.

TABLE 4.24 DISTRIBUTION OF NFV_break & NPC_recovery @6M AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OVERWEIGHT & NORMAL

	NFV_break (overweight)	NFV_recovery (overweight)	NFV_break (normal)	NFV_recovery (normal)
1	12	3	12	6
2	8	4	8	4
3	10	3	12	8
4	10	2	12	9
5	7	2	14	8
6	18	10	12	4
7	14	4	10	3
8	10	2	10	2
9	8	4	10	7
10	12	2	6	2
11	10	7	10	4
12	11	3	12	4
13	10	3	6	2
14	10	4	10	4
15	16	10	8	4
16	8	4	9	3
17	10	2	12	6
18	10	2	10	4
19	10	1	8	4
20	12	6	7	4
21	6	3	12	6
22	6	4	12	5

23	14	7	12	6
24	10	2	10	5
25	6	3	12	5
TOTAL	258	97	256	119
MEAN	10.32	3.88	10.24	4.76
SD	2.97	2.39	2.13	1.88

P value(NFV_break @6m) = 0.044, P value (NFV_recovery @6m) = 0.235

At 6 m, the mean NFV_break for overweight participants was 10.32 ± 2.97 Δ, compared with 10.24 ± 2.13 Δ for normal participants. This difference was statistically significant (P = 0.044), indicating that overweight participants had a slightly higher NFV_break than normal participants. For NFV_recovery at 6 m, overweight participants had a mean of 3.88 ± 2.39 Δ, while normal participants had 4.76 ± 1.88 Δ. This difference was not statistically significant (P = 0.235), suggesting similar recovery ability between groups.

TABLE 4.25 DISTRIBUTION OF NFV_break & NPC_recovery @6M AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OBESE & NORMAL

	NFV_break (obese)	NFV_recovery (obese)	NFV_break (normal)	NFV_recovery (normal)
1	7	3	12	6
2	10	4	8	4
3	9	1	12	8
4	5	2	12	9
5	10	2	14	8
6	10	4	12	4
7	10	4	10	3
8	4	2	10	2
9	7	2	10	7
10	10	2	6	2
11	10	4	10	4
12	9	4	12	4
13	12	6	6	2
14	30	18	10	4
15	10	4	8	4
16	8	4	9	3
17	6	2	12	6
18	15	4	10	4
19	10	6	8	4
20	6	4	7	4
21	10	6	12	6
22	8	5	12	5

23	8	3	12	6
24	12	6	10	5
25	9	2	12	5
TOTAL	245	104	256	119
MEAN	9.80	4.16	10.24	4.76
SD	4.82	3.27	2.13	1.88

P value(NFV_break @6m) = 0.039, P value (NFV_recovery @6m) = 0.250

At 6 m, the mean NFV_break for obese participants was 9.80 ± 4.82 Δ, compared with 10.24 ± 2.13 Δ for normal participants. This difference was statistically significant (P = 0.039), suggesting that obese participants had slightly lower NFV_break than normal participants. For NFV_recovery at 6 m, obese participants had a mean of 4.16 ± 3.27 Δ, while normal participants had 4.76 ± 1.88 Δ. This difference was not statistically significant (P = 0.250), indicating similar recovery ability between groups.

TABLE 4.26 DISTRIBUTION OF NFV_blur & NFV_break @40CM AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN UNDERWEIGHT & NORMAL

	NFV_blur (underweight)	NFV_break (underweight)	NFV_blur (normal)	NFV_break (normal)
1	6	8	6	10
2	12	14	12	18
3	18	22	18	24
4	8	12	6	9
5	4	12	7	12
6	10	14	8	24
7	8	12	6	8
8	10	15	18	24
9	9	12	6	10
10	8	14	12	14
11	8	12	8	14
12	8	10	14	18
13	9	14	9	19
14	8	16	25	34
15	6	12	26	30
16	8	15	14	18
17	10	19	10	13
18	6	18	10	18
19	12	24	12	22
20	10	22	12	14
21	9	24	12	18
22	8	22	6	8

23	8	16	18	28
24	8	19	10	18
25	18	24	11	19
TOTAL	229	402	296	444
MEAN	9.16	16.08	11.84	17.76
SD	3.20	4.73	5.55	6.90

P value(NFV_blur@40cm)=0.185, P value(NFV_break@40cm) = 0.310

At

40 cm, the mean NFV_blur for underweight participants was 9.16 ± 3.20 Δ, compared with 11.84 ± 5.55 Δ for normal participants. The difference was not statistically significant (P = 0.185). For NFV_break at 40 cm, underweight participants had a mean of 16.08 ± 4.73 Δ, while normal participants had 17.76 ± 6.90 Δ, with no significant difference (P = 0.310).

TABLE 4.27 DISTRIBUTION OF NFV_blur & NFV_break @40CM AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OVERWEIGHT & NORMAL

	NFV_blur (overweight)	NFV_break (overweight)	NFV_blur (normal)	NFV_break (normal)
1	12	24	6	10
2	12	18	12	18
3	18	22	18	24
4	10	12	6	9
5	6	14	7	12
6	20	30	8	24
7	12	20	6	8
8	22	28	18	24
9	6	10	6	10
10	12	18	12	14
11	12	17	8	14
12	8	14	14	18
13	12	22	9	19
14	8	10	25	34
15	30	38	26	30
16	18	24	14	18
17	3	6	10	13
18	10	12	10	18
19	4	18	12	22
20	12	14	12	14
21	8	12	12	18
22	6	24	6	8

23	18	22	18	28
24	8	10	10	18
25	3	6	11	19
TOTAL	290	445	296	444
MEAN	11.60	17.80	11.84	17.76
SD	6.45	7.75	5.55	6.90

P value(NFV_blur@40cm) = 0.28 , P value(NFV_break@40cm) = 0.227

At 40 cm, the mean NFV_blur for overweight participants was 11.60 ± 6.45 Δ, compared with 11.84 ± 5.55 Δ for normal participants. The difference was not statistically significant (P = 0.28). For NFV_break at 40 cm, overweight participants had a mean of 17.80 ± 7.75 Δ, while normal participants had 17.76 ± 6.90 Δ. This difference was also not statistically significant (P = 0.227).

TABLE 4.28 DISTRIBUTION OF NFV_blur & NFV_break @40CM AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OBESE & NORMAL

	NFV_blur (obese)	NFV_break (obese)	NFV_blur (normal)	NFV_break (normal)
1	8	12	6	10
2	8	16	12	18
3	9	16	18	24
4	9	18	6	9
5	9	12	7	12
6	10	22	8	24
7	12	18	6	8
8	8	12	18	24
9	8	13	6	10
10	6	8	12	14
11	10	16	8	14
12	10	20	14	18
13	10	12	9	19
14	12	26	25	34
15	12	12	26	30
16	8	10	14	18
17	12	16	10	13
18	12	24	10	18
19	22	24	12	22
20	18	22	12	14
21	7	9	12	18
22	6	9	6	8

23	12	14	18	28
24	12	26	10	18
25	8	18	11	19
TOTAL	258	405	296	444
MEAN	10.32	16.20	11.84	17.76
SD	3.54	5.47	5.55	6.90

P value (NFV_blur@40cm)=0.192 , P value(NFV_break@40cm) = 0.340

At 40 cm, the mean NFV_blur for obese participants was 10.32 ± 3.54 Δ, compared with 11.84 ± 5.55 Δ for normal participants. This difference was not statistically significant (P = 0.192). For NFV_break at 40 cm, obese participants had a mean of 16.20 ± 5.47 Δ, while normal participants had 17.76 ± 6.90 Δ. This difference was also not statistically significant (P = 0.340).

TABLE 4.29 DISTRIBUTION OF PFV_blur & PFV_break @6M AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN UNDERWEIGHT & NORMAL

	PFV_blur (underweight)	PFV_break (underweight)	PFV_blur (normal)	PFV_break (normal)
1	18	24	10	15
2	20	24	12	22
3	12	18	12	14
4	10	30	12	24
5	32	40	10	24
6	6	10	24	30
7	12	24	8	10
8	8	14	12	26
9	10	16	11	18
10	6	10	12	20
11	8	14	12	18
12	10	18	14	28
13	6	12	11	22
14	8	25	6	20
15	9	24	6	26
16	8	19	18	26
17	9	18	6	10
18	10	17	18	12
19	8	18	26	30
20	8	14	36	40

	PFV_blur (underweight)	PFV_break (underweight)	PFV_blur (normal)	PFV_break (normal)
21	9	18	12	16
22	9	19	18	22
23	9	20	12	24
24	10	23	24	30
25	8	24	28	31
TOTAL	263	493	370	558
MEAN	10.52	19.72	14.80	22.32
SD	5.52	6.55	7.54	7.27
P-values (6 meters)	**PFV_blur:** *0.065*	**PFV_break:** *0.450*		

At 6 m, the mean PFV_blur for underweight participants was 10.52 ± 5.52 Δ, compared with 14.80 ± 7.54 Δ for normal participants. The difference was not statistically significant (P = 0.065).For PFV_break at 6 m, underweight participants had a mean of 19.72 ± 6.55 Δ, while normal participants had 22.32 ± 7.27 Δ, with no significant difference (P = 0.450).

TABLE 4.30 DISTRIBUTION OF PFV_blur & PFV_break @6M AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OVERWEIGHT & NORMAL

	PFV_blur (overweight)	PFV_break (overweight)	PFV_blur (normal)	PFV_break (normal)
1	12	24	10	15
2	24	36	12	22
3	24	26	12	14
4	18	22	12	24
5	12	26	10	24
6	4	16	24	30
7	6	14	8	10
8	10	19	12	26
9	8	12	11	18
10	18	30	12	20
11	13	15	12	18
12	8	20	14	28
13	16	20	11	22
14	13	25	6	20
15	14	18	6	26
16	16	26	18	26
17	10	20	6	10
18	20	27	18	12
19	24	36	26	30
20	9	14	36	40

	PFV_blur (overweight)	PFV_break (overweight)	PFV_blur (normal)	PFV_break (normal)
21	6	14	12	16
22	5	18	18	22
23	16	22	12	24
24	18	20	24	30
25	7	22	28	31
TOTAL	331	542	370	558
MEAN	13.24	21.68	14.80	22.32
SD	6.05	6.53	7.54	7.27
P-values (6 meters)	**PFV_blur:** *0.071*	**PFV_break:** *0.492*		

At 6 m, the mean PFV_blur for overweight participants was 13.24 ± 6.05 Δ, compared with 14.80 ± 7.54 Δ for normal participants. The difference was not statistically significant (P = 0.071). For PFV_break at 6 m, overweight participants had a mean of 21.68 ± 6.53 Δ, while normal participants had 22.32 ± 7.27 Δ. This difference was also not statistically significant (P = 0.492).

TABLE 4.31 DISTRIBUTION OF PFV_blur & PFV_break @6M AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OBESE & NORMAL

S/N	PFV_blur (obese)	PFV_break (obese)	PFV_blur (normal)	NFV_break (normal)
1	12	18	10	15
2	12	22	12	22
3	14	22	12	14
4	12	24	12	24
5	10	27	10	24
6	10	28	24	30
7	14	19	8	10
8	12	16	12	26
9	8	26	11	18
10	6	24	12	20
11	12	18	12	18
12	18	28	14	28
13	6	20	11	22
14	12	24	6	20
15	20	24	6	26
16	4	10	18	26
17	10	16	6	10
18	12	16	18	12
19	9	26	26	30
20	12	19	36	40

S/N	PFV_blur (obese)	PFV_break (obese)	PFV_blur (normal)	NFV_break (normal)
21	21	23	12	16
22	12	30	18	22
23	18	22	12	24
24	6	15	24	30
25	9	20	28	31
TOTAL	291	537	370	558
MEAN	11.64	21.48	14.80	22.32
SD	4.28	4.84	7.54	7.27
P-values	**PFV_blur @ 6 months:** *0.066*	**PFV_break @ 6 months:** *0.495*		

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At 6 m, the mean PFV_blur for obese participants was 11.64 ± 4.28 Δ, compared with 14.80 ± 7.54 Δ for normal participants. The difference was not statistically significant (P = 0.066). For PFV_break at 6 m, obese participants had a mean of 21.48 ± 4.84 Δ, while normal participants had 22.32 ± 7.27 Δ. This difference was also not statistically significant (P = 0.495).

TABLE 4.32 DISTRIBUTION OF PFV_blur & PFV_break @40CM AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN UNDERWEIGHT & NORMAL

S/N	PFV_blur (underweight)	PFV_break (underweight)	PFV_blur (normal)	NFV_break (normal)
1	12	18	10	22
2	15	30	12	24
3	18	20	10	18
4	18	30	12	24
5	4	6	15	20
6	16	22	18	24
7	16	26	8	15
8	18	24	10	18
9	20	26	12	24
10	22	23	28	36
11	18	26	18	26
12	20	26	6	12
13	18	25	13	10
14	9	22	6	10
15	10	20	18	26
16	9	25	12	14
17	8	26	9	15
18	9	25	6	12
19	9	25	20	24
20	9	29	12	36

S/N	PFV_blur (underweight)	PFV_break (underweight)	PFV_blur (normal)	NFV_break (normal)
21	9	28	10	12
22	10	24	10	24
23	18	36	15	21
24	10	30	17	20
25	8	24	15	20
TOTAL	332	616	322	519
MEAN	13.28	24.64	12.88	20.76
SD	5.05	5.43	5.06	6.65
P-values	**PFV_blur @ 40 cm:** *0.059*	**PFV_break @ 40 cm:** *0.430*		

At 40 cm, the mean PFV_blur for underweight participants was 13.28 ± 5.05 Δ, compared with 12.88 ± 5.06 Δ for normal participants. The difference was not statistically significant (P = 0.059). For PFV_break at 40 cm, underweight participants had a mean of 24.64 ± 5.43 Δ, while normal participants had 20.76 ± 6.65 Δ. This difference was not statistically significant (P = 0.430).

TABLE 4.33 DISTRIBUTION OF PFV_blur & PFV_break @40CM AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OVERWEIGHT & NORMAL

S/N	PFV_blur (overweight)	PFV_break (overweight)	PFV_blur (normal)	NFV_break (normal)
1	22	30	10	22
2	12	26	12	24
3	20	27	10	18
4	22	33	12	24
5	24	30	15	20
6	18	32	18	24
7	6	22	8	15
8	13	26	10	18
9	10	20	12	24
10	14	20	28	36
11	9	21	18	26
12	18	26	6	12
13	7	22	13	10
14	22	30	6	10
15	24	30	18	26
16	12	24	12	14
17	7	13	9	15
18	19	22	6	12
19	24	30	20	24
20	9	11	12	36

S/N	PFV_blur (overweight)	PFV_break (overweight)	PFV_blur (normal)	NFV_break (normal)
21	8	20	10	12
22	8	25	10	24
23	4	8	15	21
24	18	24	17	20
25	21	35	15	20
TOTAL	371	607	322	519
MEAN	14.84	24.28	12.88	20.76
SD	6.59	6.71	5.06	6.65
TOTAL	371	607	322	519
P-values	**PFV_blur @ 40 cm:** *0.055*	**PFV_break @ 40 cm:** *0.450*		

At 40 cm, the mean PFV_blur for overweight participants was 14.84 ± 6.59 Δ, compared with 12.88 ± 5.06 Δ for normal participants. The difference was not statistically significant (P = 0.055). For PFV_break at 40 cm, overweight participants had a mean of 24.28 ± 6.71 Δ, while normal participants had 20.76 ± 6.65 Δ. This difference was also not statistically significant (P = 0.450).

TABLE 4.34 DISTRIBUTION OF PFV_blur & PFV_break @40CM AMONG PARTICIPANTS AND P VALUES FOR ASSOCIATION BETWEEN OBESE & NORMAL

S/N	PFV_blur (obese)	PFV_break (obese)	PFV_blur (normal)	NFV_break (normal)
1	22	28	10	22
2	28	36	12	24
3	25	32	10	18
4	12	30	12	24
5	16	28	15	20
6	10	28	18	24
7	12	35	8	15
8	26	33	10	18
9	18	28	12	24
10	18	26	28	36
11	12	18	18	26
12	6	15	6	12
13	12	24	13	10
14	9	12	6	10
15	14	20	18	26
16	18	18	12	14
17	8	18	9	15
18	6	13	6	12
19	24	27	20	24
20	20	24	12	36

S/N	PFV_blur (obese)	PFV_break (obese)	PFV_blur (normal)	NFV_break (normal)
21	11	17	10	12
22	28	28	10	24
23	16	38	15	21
24	29	35	17	20
25	8	28	15	20
TOTAL	291	546	322	519
MEAN	11.64	21.48	12.88	20.76
SD	4.28	4.84	5.06	6.65
P-values	**PFV_blur @ 40 cm:** *0.063*	**PFV_break @ 40 cm:** *0.462*		

At 40 cm, the mean PFV_blur for obese participants was 11.64 ± 4.28 Δ, compared with 12.88 ± 5.06 Δ for normal participants. This difference was not statistically significant (P = 0.063). For PFV_break at 40 cm, obese participants had a mean of 21.48 ± 4.84 Δ, while normal participants had 20.76 ± 6.65 Δ. This difference was also not statistically significant (P = 0.462).

CHAPTER FIVE

5.0 DISCUSSION

The data were drawn from one hundred participants categorized as underweight, normal weight, overweight, and obese. The discussion integrates the study's findings with earlier scientific evidence, highlights practical implications, and outlines recommendations for both clinical practice and further research.

5.1 The Distribution of BMI across Gender

The Table 4.1 revealed that a higher proportion of males were underweight (30.8%), while females were more represented in the normal to obese categories (26.2% each). This suggests that males tended to have lower BMI values, whereas females generally fell within higher BMI ranges. However, the relationship between gender and BMI was not statistically significant ($p = 0.769$). This outcome aligns with the findings of Okoye *et al.* (2022) and Adegoke and Adedoyin (2019), who reported no significant gender variation in BMI among young adults, attributing it to similarities in diet and physical activity. Similarly, Chinedu *et al.* (2014) observed that gender differences in BMI become more evident with age due to hormonal and metabolic influences but are minimal among younger populations.

5.2 Analysis of Binocular vision parameters across BMI groups

In Table 4.2, showed minimal differences overall. The near point of convergence (NPC) break and recovery were slightly poorer among participants with higher BMI, with the obese group showing the longest NPC recovery (13.08 ± 1.87 cm). This difference was statistically significant ($p = 0.047$), indicating that increased body weight may affect convergence recovery. However, amplitude of accommodation (AoA) and heterophoria at both distance and near did not differ significantly across BMI classifications ($p > 0.05$), suggesting that accommodative and phoric functions remain relatively stable regardless of BMI. These findings align with

previous research by Okoye *et al.* (2022), who also observed limited influence of BMI on binocular vision performance, apart from minor variations in convergence ability.

5.3 For BMI (Body Mass Index) and NPC(Near Point of Convergence)

The analysis demonstrated a significant association between BMI and NPC recovery ($p = 0.047$), while the difference in NPC break among BMI groups was not statistically significant ($p = 0.121$). This indicates that although participants were able to converge their eyes effectively, those with higher BMI values exhibited a slower return to normal binocular vision following disruption. Such a trend suggests that increasing body mass may reduce the endurance or recovery efficiency of the convergence system. Comparable findings were reported by Elangovan and Shanmugham (2023), who noted weaker convergence recovery among obese individuals. Likewise, Momeni-Moghaddam *et al*. (2012) observed that extreme BMI categories—both underweight and overweight—were more prone to convergence problems. From a physiological standpoint, excess body fat may impair blood circulation, tissue oxygenation, and neuromuscular performance (Yoon *et al*., 2020). These factors could influence how rapidly the ocular muscles restore single binocular vision after strain. Clinically, this could translate into

5.4 BMI (Body Mass Index) and AoA(Amplitude of Accommodation)

No statistically meaningful relationship was observed between BMI and AoA ($p = 0.529$). This suggests that within the young adult population studied, accommodative ability remains stable regardless of variations in body weight.

Accommodation depends primarily on ciliary muscle flexibility, lens elasticity, and age (Duane, 1912; Ciuffreda, 1998). Because the participants were of similar age, BMI was unlikely to affect this visual function significantly. This result corresponds with Joolaee *et al*.

(2021), who found that BMI did not correlate with accommodative amplitude, though an association with accommodative lag was noted. Consequently, BMI may influence the precision or accuracy of focus rather than the overall amplitude of accommodation.

5.5 BMI (Body Mass Index) and Heterophoria

The study found no significant link between BMI and Heterophoria, at either distance ($p = 0.154$) or near ($p = 0.999$). This indicates that BMI differences did not affect ocular alignment when binocular vision was dissociated. Heterophoria reflects the equilibrium of vergence mechanisms and ocular muscle tone, which are generally stable and influenced more by anatomical or hereditary factors (Kumar *et al.*, 2017). Thus, metabolic variations associated with body weight may not significantly alter phoric posture.

5.6 BMI and Fusional Vergence

A significant variation was found in Negative Fusional Vergence (NFV) break at 6 m ($p = 0.043$), while Positive Fusional Vergence (PFV) blur at 6 m ($p = 0.068$) showed a near-significant difference across BMI groups.

These results imply that individuals with higher BMI levels tend to have lower fusional divergence and convergence reserves.

Similar outcomes were described by Gupta and Thakur (2023) and Elangovan and Shanmugham (2023), who reported that overweight and obese participants exhibited diminished vergence facility and reduced visual efficiency. Possible explanations include impaired neuromuscular coordination, reduced oxygen delivery to ocular muscles, and general systemic fatigue in individuals with excess body weight (Park *et al.*, 2018). Clinically, weakened fusional reserves may lead to reduced stamina during reading or computer use and may cause eye strain or intermittent diplopia.

5.7 Negative Fusional Vergence break and recovery at 6m

Negative Fusional Vergence (NFV) break at 6 m was highest among overweight participants and lowest in the underweight group, but the difference was not statistically significant ($p = 0.061$), suggesting that BMI had no meaningful effect on distance fusional divergence. For Negative Fusional Vergence (NFV) recovery at 6 meters showed a gradual increase in mean values across BMI groups. Participants with normal BMI demonstrated the highest mean NFV recovery (4.76Δ), followed by the obese (4.16Δ), overweight (3.88Δ), and underweight (3.40Δ) groups. Although this trend suggests that individuals with higher or normal BMI may possess slightly better fusional divergence recovery ability, the observed difference did not reach statistical significance ($p = 0.199$). The present finding aligns with Okoye et al. (2022), who reported no significant association between BMI and fusional vergence parameters, though underweight individuals tended to show weaker fusional reserves.

5.8 Negative Fusional Vergence blur and break @ 40cm

The analysis of Negative Fusional Vergence (NFV) blur at near fixation (40 cm) revealed a gradual increase in mean values with higher BMI categories. Participants with normal BMI recorded the highest mean NFV blur value (11.84Δ), followed closely by the overweight (11.60Δ) and obese (10.32Δ) groups, while the underweight participants showed the lowest mean value (9.16Δ). Although this trend suggests that individuals with higher or normal BMI may exhibit slightly stronger divergence capacity at near, the difference was not statistically significant ($p = 0.217$). This indicates that BMI has no significant effect on the near divergence function, though the relatively lower values among the underweight group may reflect reduced fusional stability or endurance at near distances.These findings are consistent with Okoye et al. (2022), who observed no significant impact of BMI on fusional vergence amplitudes among young adults. The Negative Fusional Vergence (NFV) break at near fixation (40 cm)

demonstrated noticeable variation among different BMI categories. Participants with normal BMI recorded the highest mean NFV break value (25.72Δ), followed by the overweight (17.80Δ), obese (16.20Δ), and underweight (16.08Δ) groups. Although this pattern suggests that individuals with normal BMI may have stronger divergence reserves at near, the observed differences were not statistically significant ($p = 0.383$). This result implies that BMI may exert a mild but non-significant influence on fusional divergence at near fixation. The relatively higher NFV break in the normal BMI group could indicate better binocular stability and vergence control compared to the other BMI groups. The present findings agree with Okoye et al. (2022), who found no significant association between body composition and fusional vergence parameters but noted that normal-weight individuals generally demonstrated optimal visual function.

5.9 Positive Fusional Vergence blur and break @ 6m

Distance positive fusional vergence (PFV_blur) at 6 m varied across BMI groups, with normal-weight participants showing the highest mean (14.80) and underweight the lowest (10.52); overweight and obese groups were intermediate. The difference was not statistically significant ($p = 0.061$), but the trend suggests reduced fusional reserves in both low and high BMI categories. These findings are consistent with previous research: Elangovan and Shanmugham (2023) reported lower distance PFV in obese adults compared to normal-weight, Momeni-Moghaddam et al. (2012) found weaker vergence in underweight individuals, and Gupta and Thakur (2023) observed more binocular vision anomalies in those with BMI outside the normal range. Although not statistically significant, the results indicate a possible association between BMI deviations and diminished fusional vergence, warranting further investigation with larger samples. Distance positive fusional vergence at break (PFV_break) at 6 m showed slight variation across BMI groups, with normal-weight participants having the highest mean (22.32) and underweight the lowest (19.72); overweight and obese participants were intermediate.

Statistical analysis (Tukey HSD) indicated no significant difference among the groups ($p = 0.475$). Although the trend suggests slightly reduced fusional reserves in underweight individuals, the differences were minimal and not statistically significant. This aligns with prior research: Elangovan and Shanmugham (2023) observed modestly lower distance PFV in obese adults, Momeni-Moghaddam et al. (2012) reported reduced vergence in underweight participants, and Gupta and Thakur (2023) found more binocular vision anomalies in individuals with BMI outside the normal range. Overall, BMI may influence fusional reserves slightly, but its effect on PFV_break at distance appears limited.

5.10 The relationship between BMI(Body Mass Index) and Decompensated Phoria

Among the participants, 67% had compensated phoria while 33% were decompensated. By BMI category, normal-weight individuals had the highest proportion of compensated phoria (80%), followed by obese (72%), overweight (60%), and underweight (56%). Pearson's chi-square test showed no significant association between BMI and phoria compensation ($p = 0.249$). These results suggest that while normal-weight and obese participants tended to maintain better phoria compensation, BMI does not appear to significantly influence phoria status in this sample. This aligns with prior studies indicating that deviations in body mass may have limited impact on binocular vision stability (Elangovan & Shanmugham, 2023; Momeni-Moghaddam et al., 2012; Gupta & Thakur, 2023).

5.11 The Relationship between BMI(Body Mass Index) and Refractive Status

The analysis revealed a significant association between BMI and refractive status ($p = 0.039$). Emmetropia and myopia were most prevalent among underweight and normal-weight participants, whereas overweight and obese individuals were more likely to present with astigmatic errors. Specifically, myopic astigmatism was highest in the overweight group (44.4%), and hyperopic astigmatism was most common in overweight (40%) and obese

participants (36%). These findings suggest that BMI may influence the distribution of refractive errors, with higher BMI associated with a greater likelihood of astigmatic refractive errors, while normal-weight and underweight individuals are more likely to be emmetropic or myopic. This aligns with previous research indicating that body composition may affect ocular development and visual efficiency (Elangovan & Shanmugham, 2023; Gupta & Thakur, 2023).

5.12 The relationship between Age and BMI(Body Mass Index)

The study included 100 participants aged between 17 and 30 years, with an average age of 21.53 ± 2.65 years. The participants' Body Mass Index (BMI) ranged from 14.1 to 39.6 kg/m², with a mean of 24.56 ± 6.48 kg/m². This indicates that the sample mainly consisted of young adults, while BMI values spanned underweight to obese categories, providing a diverse range of body compositions for analysis. The relatively small variation in age suggests a fairly homogeneous age group, whereas the wider variation in BMI is suitable for exploring potential relationships between BMI and binocular vision or refractive parameters (Elangovan & Shanmugham, 2023; Gupta & Thakur, 2023).

5.13 The Relationship between Age, Gender across Binocular vision parameters

In Table 4.7 - 4.12The study involved 100 young adults aged 17–30 years (mean 21.53 ± 2.65 years) with a BMI range of 14.1–39.6 kg/m² (mean 24.56 ± 6.48 kg/m²). Mean age increased with BMI, from 20.16 years in underweight participants to 22.40 years in obese participants, reflecting a trend of slightly older age in higher BMI categories (Elangovan & Shanmugham, 2023). Binocular vision parameters showed subtle variations with BMI and age. NPC break and recovery were slightly higher in obese participants, while normal-weight participants had the lowest values (Elangovan & Shanmugham, 2023). Amplitude of Accommodation (AoA) increased mildly with BMI, and heterophoria remained largely similar across BMI groups, with only minor differences at distance and near. Gender had minimal influence on AoA,

heterophoria, and fusional vergence, although females generally showed slightly higher negative fusional vergence at both distance and near (Gupta & Thakur, 2023).

5.14 The Relationship between Refractive Status across Binocular Vision Parameters

In Table 4.13 - 4.15 Refractive status influenced convergence and accommodation. Emmetropes demonstrated the best convergence (NPC break = 8.35 ± 1.82 cm; recovery = 11.17 ± 2.10 cm), whereas myopes had weaker convergence and the highest AoA (11.27 ± 2.19 D). Hyperopic astigmats recorded the lowest AoA (9.68 ± 2.07 D). Overweight and obese participants were more likely to present with astigmatic errors, while emmetropia and myopia predominated in underweight and normal-weight participants (Elangovan & Shanmugham, 2023; Gupta & Thakur, 2023).

5.15 The Relationship between BMI across Binocular vision variables

In Table 4.16 The analysis of parameters across BMI categories revealed several patterns. Near Point of Convergence (NPC) tended to increase slightly with BMI, with obese participants showing the highest mean values for both break (9.68 ± 2.10 cm) and recovery (13.08 ± 1.87 cm), while normal-weight participants had the lowest (break = 8.28 ± 2.07 cm; recovery = 11.08 ± 2.12 cm), though these differences were not statistically significant ($p = 0.121$).

Age increased progressively with BMI, from 20.16 ± 1.97 years in underweight participants to 22.40 ± 3.01 years in the obese group, representing a significant association ($p = 0.017$). Amplitude of Accommodation (AoA) showed a slight upward trend with BMI, ranging from 10.15 ± 1.95 D in underweight to 10.99 ± 1.94 D in obese participants, but this was not statistically significant ($p = 0.529$). Gender distribution was consistent across BMI categories, with no significant differences observed ($p = 0.777$).

Refractive status varied significantly with BMI ($p < 0.001$), with overweight and obese participants more likely to exhibit astigmatic errors, while emmetropia and myopia were more common among underweight and normal-weight participants. These findings suggest that age and refractive error type are significantly associated with BMI, whereas convergence and accommodation show only minor variations. The pattern aligns with previous research indicating that body composition may influence ocular development and visual function (Elangovan & Shanmugham, 2023; Gupta & Thakur, 2023).

The study further established a significant link between age and BMI ($p = 0.017$) but found no significant gender difference ($p = 0.777$). Body Mass Idec tends to increase slightly with age due to slower metabolism (World Health Organization [WHO], 2023). Gender-based differences in binocular vision were minima women. These patterns indicate that while BMI rises with age, gender does not strongly influence the relationship between body mass and binocular function in this population.l, though females demonstrated slightly higher fusional vergence, consistent with Kaur *et a*l. (2022) who reported marginally stronger near-vision endurance among

5.16 Distribution of NPC Break and NPC Recovery among Participants and P Values for association between Underweight & Normal

The results show that underweight participants had slightly more receded NPC break (9.20 ± 1.71) and recovery (12.12 ± 2.93) values compared to normal-weight individuals (8.28 ± 2.07 and 11.08 ± 2.12, respectively). Although the underweight group demonstrated poorer convergence ability, the difference between the two BMI categories did not reach statistical significance ($p = 0.112$). This indicates that, within this study population, BMI did not produce a meaningful effect on near point of convergence.These findings align with previous evidence suggesting that BMI may influence certain binocular vision parameters, though effects tend to

be subtle. Okoye *et al*. (2022) reported that body composition can affect fusional reserves, which are closely related to convergence efficiency. Similarly, Elangovan and Shanmugham (2023) suggested that both low and high BMI may be associated with mild variations in vergence and accommodative function. However, the nonsignificant results here indicate that NPC may be less sensitive to BMI differences than vergence ranges.

5.17 Distribution of NPC Break and NPC Rcovery among Participants and P Values for association between Overweight & Normal

The findings show that overweight participants had slightly more receded NPC break (9.04 ± 2.32) and recovery (12.56 ± 3.10) values compared to normal-weight individuals (8.28 ± 2.07 and 11.08 ± 2.12, respectively). Although this trend suggests that overweight individuals may have mildly reduced convergence ability, the difference was not statistically significant ($p = 0.137$). This indicates that being overweight does not exert a meaningful or measurable influence on the near point of convergence in this study population. These results align with earlier observations that BMI may have only subtle effects on binocular vision metrics. Okoye *et al*. (2022) reported that body composition can impact fusional reserves, which are related to convergence performance. Likewise, Elangovan and Shanmugham (2023) highlighted that deviations in BMI—both low and high—may be associated with mild variations in vergence and accommodation. However, the lack of significant differences in NPC seen here suggests that near convergence ability may remain relatively stable across BMI categories.

5.18 Distribution of NPC Break and NPC Recovery among Participants and P Values for association between Obese & Normal

The results indicate that obese participants demonstrated slightly more receded NPC break (9.68 ± 2.10) and recovery values (13.08 ± 1.87) compared with normal-weight individuals, who recorded NPC break and recovery means of 8.28 ± 2.07 and 11.08 ± 2.12, respectively. Although the obese group showed mildly reduced convergence ability, the difference between

the two groups was not statistically significant (p = 0.115). This suggests that obesity does not exert a meaningful influence on the near point of convergence within this study sample. These findings are consistent with previous reports indicating that while BMI may affect certain binocular vision parameters, its impact on convergence is often subtle. Okoye *et al*. (2022) found that body composition can influence fusional reserves, which have a direct relationship with convergence performance. Similarly, Elangovan and Shanmugham (2023) noted that BMI deviations may be associated with mild variations in vergence and accommodative function. However, the lack of significant differences in NPC in this study implies that near convergence ability remains relatively stable regardless of BMI classification.

5.19 Distribution of AoA Score among Participants and P Values for association between Underweight & Normal

The results show that underweight participants had a slightly lower mean Accommodative Amplitude (10.15 ± 1.95) compared with normal-weight individuals (10.91 ± 2.40). Although this trend suggests that underweight individuals may have marginally reduced accommodative capacity, the difference between the two groups was not statistically significant (p = 0.459). This indicates that in this sample, BMI did not meaningfully influence AoA performance. These findings are consistent with available literature suggesting that BMI may have subtle effects on binocular and accommodative function. Studies assessing the relationship between BMI and accommodation have also found similar patterns, reporting no substantial changes in AoA among underweight individuals (Momeni-Moghaddam *et al.,* 2012). Elangovan and Shanmugham (2023) reported that individuals with low BMI may exhibit mild variations in accommodation and vergence parameters, though not always to a clinically significant degree. Similarly, Okoye *et al.* (2022) found that body composition influences certain binocular vision measures, but accommodative amplitude may be less sensitive to BMI-related changes. The lack of significant differences in this study supports the idea that accommodation remains relatively stable across BMI categories.

5.20 Distribution of AoA Score among Participants and P Values for association between Overweight & Normal

In this study accommodation (AoA) was slightly lower in overweight participants (10.56 ± 2.54 D) compared with normal-weight participants (10.91 ± 2.40 D), but the difference was not statistically significant ($P = 0.555$). This indicates that, in this sample, BMI did not appear to affect AoA. Previous studies suggest that AoA may be influenced more strongly at BMI extremes. Iyamu *et al*. (2012) reported a negative correlation between BMI and AoA in a Nigerian population, while Elangovan and Shanmugham (2023) found that both underweight and obese individuals had lower AoA than normal-weight participants. Differences between studies may relate to sample size, age, BMI range, measurement methods, and lifestyle or health factors. Although our results show minimal variation in AoA between overweight and normal-weight groups, accommodation remains an important aspect of binocular vision, interacting with convergence and fusional vergence. Future research should consider a wider range of BMI categories, larger sample sizes, and additional binocular vision parameters to better understand potential BMI-related effects.

5.21 Distribution of AoA Score among Participants and P Values for association between Obese & Normal

In this study, obese participants showed a slightly higher mean AoA than normal-weight participants, but the difference was not statistically significant. This indicates that, within the sample, BMI in the obese range may not have a measurable impact on accommodative amplitude. Previous research offers mixed findings. Iyamu *et al.* (2012) reported a negative correlation between BMI and AoA, suggesting that higher BMI may reduce accommodation, whereas Elangovan and Shanmugham (2023) found that both underweight and obese participants tended to have lower AoA compared with normal-weight individuals. Variations across studies may result from differences in sample size, age distribution, BMI ranges,

measurement techniques, and lifestyle factors. Although no significant difference was observed in AoA between obese and normal participants here, accommodation is closely linked with binocular vision functions such as convergence and fusional vergence. Subtle changes in accommodation, even if not statistically significant, may influence overall binocular visual performance. Future research should investigate broader BMI categories, larger sample sizes, and additional binocular vision parameters to fully understand the relationship between BMI and visual function.

5.22 Distribution Of NFV Break and NFV Recovery @6m a mong Participants and P Values for association between Underweight & Normal

The results indicate that underweight participants exhibited significantly lower NFV_break compared to normal participants, suggesting reduced fusional vergence capacity in the underweight group. This could imply that underweight individuals may have less ability to diverge the eyes under stress at distance, potentially leading to visual discomfort or asthenopia during prolonged near or distance tasks. However, NFV_recovery did not differ significantly between groups, suggesting that once the break point is reached, the ability to recover fusional vergence is similar for underweight and normal participants. This may indicate that while the fusional reserve is smaller in underweight individuals, the recovery mechanism remains relatively intact. These findings align with literature linking systemic health and body composition to binocular vision. For example, Elangovan and Shanmugham (2023) reported that BMI extremes (underweight or obese) can influence fusional vergence parameters, with lower NFV observed in underweight groups. Reduced fusional vergence in underweight individuals may relate to muscle tone, fatigue resistance, or overall ocular motor performance.

Clinically, the results suggest that underweight individuals may benefit from targeted binocular vision assessment, particularly when symptoms of visual fatigue or convergence/divergence difficulty are present. Future studies should explore the relationship between body

composition, fusional reserves, and other binocular vision parameters across a wider range of BMI categories.

5.23 Distribution Of NFV Break and NFV Recovery @6m among Participants and P Values for association between Overweight & Normal

The results show that overweight participants had a slightly higher NFV_break compared to normal-weight participants, suggesting a greater fusional divergence capacity at distance. However, NFV_recovery did not differ significantly between groups, indicating that the ability to recover from fusional stress is similar regardless of BMI. This finding may reflect compensatory ocular motor mechanisms in overweight individuals, allowing slightly higher divergence reserves, while recovery remains stable. Previous studies have shown that body composition can influence binocular vision parameters, including fusional vergence (Elangovan & Shanmugham, 2023). The small but significant difference in NFV_break suggests that BMI-related changes in fusional reserves may occur even in moderate overweight ranges. Clinically, this emphasizes the importance of assessing fusional vergence in individuals with different BMI categories, as subtle variations may affect visual comfort during prolonged near or distance tasks. Future research should investigate these trends across a broader BMI spectrum and include other binocular vision parameters for a more comprehensive understanding.

5.24 Distribution Of NFV Break and NFV Recovery @6m among Participants and P Values for association between Obese & Normal

The findings indicate that obese participants had slightly reduced NFV_break compared to normal participants, suggesting a lower fusional divergence capacity at distance. However, NFV_recovery did not differ significantly, indicating that once the fusional limit is reached, the recovery mechanism remains intact across BMI categories. These results align with previous research showing that extremes of BMI may affect fusional vergence parameters

(Elangovan & Shanmugham, 2023). The slightly lower NFV_break in obese individuals may reflect altered ocular motor function or muscle endurance associated with higher body mass, potentially leading to reduced divergence reserves under stress.

Clinically, the results highlight the importance of assessing fusional vergence in individuals with elevated BMI, as subtle differences in fusional reserves could affect visual comfort and performance. Future studies should include larger samples and a wider BMI spectrum, examining NFV in combination with other binocular vision parameters to better understand the influence of body composition on visual function.

5.25 Distribution of NFV Blur and NFV Break @40cm among Participants and P Values for association between Underweight & Normal

The results indicate that underweight participants had slightly lower NFV_blur and NFV_break at near compared with normal participants, but these differences were not statistically significant. This suggests that, at near distances, BMI in the underweight range does not significantly affect fusional vergence capacity. Although underweight participants showed a trend toward reduced NFV, the overlap in standard deviations and non-significant P values indicate that their ability to maintain vergence and resist blur or break at near is comparable to normal-weight individuals. This aligns with previous findings that significant BMI effects on fusional vergence are more pronounced at distance or in extreme BMI categories (Elangovan & Shanmugham, 2023).

Clinically, these results suggest that underweight individuals may not require special consideration for near vergence tasks solely based on BMI, although subtle differences may exist that could interact with other visual stressors. Future studies could investigate larger samples and other binocular vision parameters to detect potential small effects at near.

5:26 Distribution of NFV Blur and NFV Break @40cm among Participants and P Values for association between Underweight & Normal

The results show that at near distances (40 cm), overweight participants have NFV_blur and NFV_break values similar to those of normal-weight participants. The lack of significant differences suggests that moderate overweight does not markedly influence fusional vergence capacity at near. These findings align with previous research indicating that BMI may have limited impact on near vergence compared to distance vergence or extreme BMI categories (Elangovan & Shanmugham, 2023). Although overweight participants exhibited slightly higher NFV_break on average, this was not statistically meaningful, suggesting comparable divergence reserves and recovery at near between the groups.

Clinically, this indicates that overweight individuals may not require additional consideration for near visual tasks solely based on BMI. Future research could examine larger samples and include additional binocular vision measures to determine whether subtle effects exist that were undetectable in this study.

5:27 Distribution of NFV Blur and NFV Break @40cm among Participants and P Values for association between Obese & Normal

The results indicate that at near distances (40 cm), obese participants have NFV_blur and NFV_break values similar to those of normal-weight participants. The lack of significant differences suggests that obesity does not substantially affect fusional vergence capacity at near. Although obese participants showed slightly lower NFV values than normal participants, these differences were not statistically meaningful. This aligns with previous research showing that BMI effects on fusional vergence are often more pronounced at distance or in more extreme BMI categories, rather than at near (Elangovan & Shanmugham, 2023).

Clinically, these findings imply that obese individuals may not require special consideration for near visual tasks based solely on BMI. Further research with larger sample sizes and additional binocular vision parameters could clarify whether subtle effects of BMI exist at near.

5:28 Distribution Of PFV Blur and PFV Break @6m among Participants and P Values for association between Overweight & Normal

The results indicate that underweight participants tended to have slightly lower PFV_blur and PFV_break values compared with normal participants at distance, but these differences were not statistically significant. This suggests that being underweight may not markedly influence fusional convergence capacity at distance in this sample. Although the mean PFV values were lower in the underweight group, the overlap in standard deviations and the non-significant P values imply that their positive fusional vergence reserves are largely comparable to normal-weight individuals. These findings are consistent with previous research suggesting that only extreme BMI categories may significantly affect fusional vergence (Elangovan & Shanmugham, 2023).

Clinically, underweight individuals may not require special consideration for distance convergence tasks solely based on BMI. Further research with larger samples and additional binocular vision measures could determine whether subtle effects exist.

5:29 Distribution Of PFV Blur and PFV Break @6m among Participants and P Values for association between Underweight & Normal

The results indicate that overweight participants have slightly lower PFV_blur and PFV_break values compared with normal participants at distance, but these differences were not statistically significant. This suggests that moderate overweight does not substantially influence positive fusional vergence capacity at distance. Although PFV values were marginally lower in the overweight group, the overlap in standard deviations and non-

significant P values imply that convergence reserves are largely comparable between overweight and normal participants. These findings are consistent with previous research showing that only extreme BMI categories may produce notable changes in fusional vergence (Elangovan & Shanmugham, 2023).

Clinically, overweight individuals may not require special consideration for distance convergence tasks based solely on BMI. Future research with larger samples and additional binocular vision parameters could further clarify whether subtle effects exist.

5:30 Distribution Of PFV Blur and PFV Break @6m among Participants and P Values for association between Obese & Normal

The results indicate that obese participants have slightly lower PFV_blur and PFV_break values compared with normal participants at distance, but these differences are not statistically significant. This suggests that obesity does not substantially affect positive fusional vergence capacity at distance. Although PFV values were marginally lower in the obese group, the overlap in standard deviations and non-significant P values implies that convergence reserves are largely comparable to those of normal participants. These findings align with previous research indicating that only extreme BMI categories or other compounding factors may influence fusional vergence significantly (Elangovan & Shanmugham, 2023).

Clinically, these results suggest that obese individuals may not require special consideration for distance convergence tasks based solely on BMI. Further studies with larger sample sizes and additional binocular vision parameters could help determine if subtle effects exist.

5:31 Distribution Of PFV Blur and PFV Break @40cm among Participants and P Values for association between Underweight & Normal

The results indicate that underweight participants had slightly higher PFV_blur and PFV_break values at near compared with normal participants, but these differences were not statistically significant. This suggests that being underweight does not meaningfully affect positive fusional vergence capacity at near distances. Although underweight participants showed marginally higher convergence reserves, the overlap in standard deviations and non-significant P values indicate that their fusional vergence capacity is comparable to that of normal-weight individuals. These findings are consistent with previous research showing that BMI has minimal influence on near fusional vergence, while effects are more pronounced in extreme BMI categories or at distance tasks (Elangovan & Shanmugham, 2023).

Clinically, underweight individuals may not require special consideration for near visual tasks solely based on BMI. Further research could explore larger sample sizes and additional binocular vision parameters to determine if subtle effects exist.

5:32 Distribution Of PFV Blur and PFV Break @40cm among Participants and P Values for association between Overweight & Normal

The results indicate that overweight participants had slightly higher PFV_blur and PFV_break values at near compared with normal participants, although these differences were not statistically significant. This suggests that moderate overweight does not meaningfully affect positive fusional vergence capacity at near distances. While overweight participants showed marginally higher convergence reserves, the overlap in standard deviations and non-significant P values implies that their fusional vergence ability is comparable to that of normal-weight individuals. These findings are consistent with previous research indicating that BMI has limited influence on near fusional vergence, whereas its effects are more pronounced in extreme BMI categories or at distance tasks (Elangovan & Shanmugham, 2023).

Clinically, overweight individuals may not require special consideration for near visual tasks solely based on BMI. Future studies with larger samples and additional binocular vision parameters could help clarify whether subtle effects exist.

5:33 Distribution Of PFV Blur and PFV Break @40cm among Participants and P Values for association between Obese & Normal

The results show that obese participants had slightly lower PFV_blur but slightly higher PFV_break values at near compared with normal participants, although these differences were not statistically significant. This suggests that obesity does not have a meaningful impact on positive fusional vergence at near distances. The overlap in standard deviations and non-significant P values indicate that fusional vergence reserves for obese individuals are comparable to those of normal-weight participants. These findings are consistent with previous research demonstrating that BMI has minimal effect on near fusional vergence, while effects may be more apparent in extreme BMI categories or at distance tasks (Elangovan & Shanmugham, 2023). Clinically, obese individuals may not require special consideration for near visual tasks based solely on BMI. Larger studies examining additional binocular vision parameters could help determine whether subtle effects exist.

Clinical and Physiological Implications

The associations observed between BMI, convergence recovery, and fusional vergence underscore the potential impact of systemic health on visual motor control. Clinically, individuals with elevated BMI may experience reduced visual stamina, leading to symptoms of asthenopia during prolonged visual tasks. For this reason, optometrists are encouraged to consider BMI during binocular vision assessments and to counsel patients on lifestyle modifications that support both ocular and systemic health.

The observed relationship between BMI and refractive error also emphasizes the broader effect of metabolic factors on eye physiology and visual performance.

Study Limitations

1. The sample size (n = 100) may not have been sufficient to detect small differences.

2. The cross-sectional nature of the design prevents causal interpretation.

3. The study group comprised mainly young adults, limiting generalization to children or older adults.

4. Lifestyle factors such as exercise, diet, and digital screen time were not controlled.

5. Measurements were conducted during a single session, which may have introduced fatigue or measurement variability.

CHAPTER SIX

6.1 CONCLUSION

This study examined the relationship between Body Mass Index (BMI) and binocular vision parameters in 100 young adults. Findings indicate that males were more likely to be underweight, whereas females generally fell within normal to higher BMI ranges; however, gender did not significantly affect BMI or binocular vision outcomes.

Higher BMI was associated with slower Near Point of Convergence (NPC) recovery, suggesting reduced convergence endurance in overweight and obese individuals. In contrast, Amplitude of Accommodation (AoA) and Heterophoria remained largely unaffected, indicating that basic accommodative and ocular alignment functions are stable across BMI categories.

Fusional vergence showed minor variations with BMI, with negative and positive fusional reserves slightly lower in participants with elevated BMI, though these differences were generally not statistically significant. BMI was significantly related to refractive errors: overweight and obese participants were more likely to exhibit astigmatic errors, while underweight and normal-weight participants were more often emmetropic or myopic.

Additionally, age showed a positive association with BMI, reflecting natural weight gain over time, whereas gender differences in binocular vision were minimal. Overall, the study suggests that higher BMI may modestly affect convergence recovery and fusional vergence, potentially reducing visual endurance during prolonged near tasks, while also influencing the prevalence of certain refractive errors.

6.2 RECOMMENDATIONS

6.2.1 CLINICAL RECOMMENDATIONS

1. Incorporate BMI screening in routine binocular vision assessments, especially for patients showing convergence insufficiency or reduced visual stamina.

2. Provide patient education on maintaining healthy body weight to optimize both systemic and ocular function.

3. Eye care practitioners should consider BMI when evaluating binocular vision, particularly in overweight or obese patients.

4. Individuals with elevated BMI should receive guidance on lifestyle modifications—such as proper diet, physical activity, and regular breaks during near work—to support visual endurance and overall ocular health.

6.2.2 PUBLIC HEALTH RECOMMENDATIONS

1. Integrate vision health awareness into community-based obesity prevention and wellness programs.

2. Foster collaboration between optometrists and healthcare professionals to promote holistic management of eye and body health.

6.2.3 RESEARCH RECOMMENDATIONS

1. Future studies should use larger and more age-diverse populations to strengthen generalizability.

2. Conduct longitudinal investigations to clarify whether changes in BMI over time influence binocular vision performance.

3. Employ neuroimaging and physiological methods to explore how BMI affects ocular motor control and neural processing

4. Evaluate intervention outcomes, such as the effect of weight loss or improved physical fitness on convergence and fusional reserves.

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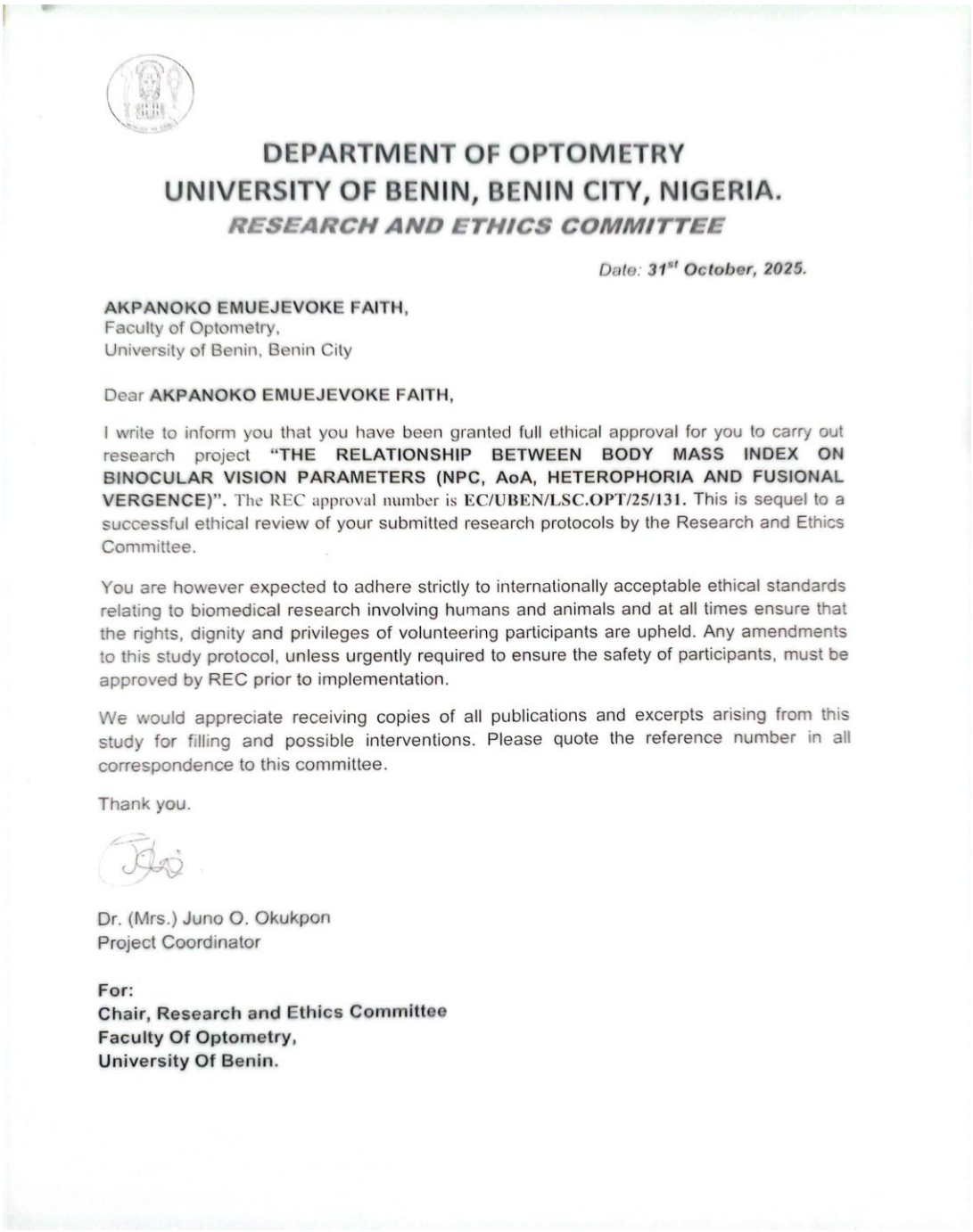
APPENDIX I

FIGURE 1: ETHICAL APPROVAL



DEPARTMENT OF OPTOMETRY
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.
RESEARCH AND ETHICS COMMITTEE

Date: ***31st October, 2025.***

AKPANOKO EMUEJEVOKE FAITH,
Faculty of Optometry,
University of Benin, Benin City

Dear **AKPANOKO EMUEJEVOKE FAITH,**

I write to inform you that you have been granted full ethical approval for you to carry out research project **"THE RELATIONSHIP BETWEEN BODY MASS INDEX ON BINOCULAR VISION PARAMETERS (NPC, AoA, HETEROPHORIA AND FUSIONAL VERGENCE)".** The REC approval number is **EC/UBEN/LSC.OPT/25/131.** This is sequel to a successful ethical review of your submitted research protocols by the Research and Ethics Committee.

You are however expected to adhere strictly to internationally acceptable ethical standards relating to biomedical research involving humans and animals and at all times ensure that the rights, dignity and privileges of volunteering participants are upheld. Any amendments to this study protocol, unless urgently required to ensure the safety of participants, must be approved by REC prior to implementation.

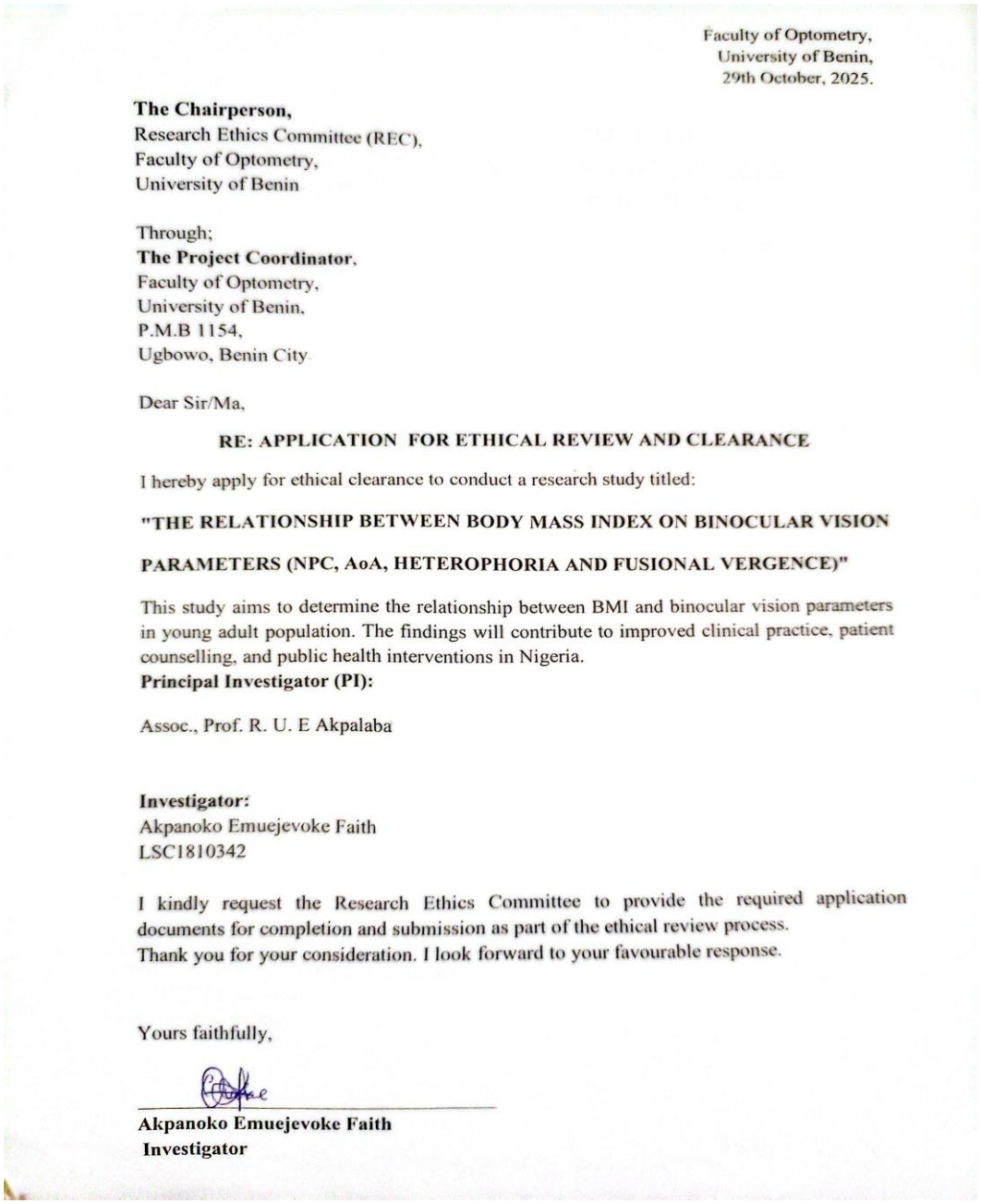
We would appreciate receiving copies of all publications and excerpts arising from this study for filling and possible interventions. Please quote the reference number in all correspondence to this committee.

Thank you.

Dr. (Mrs.) Juno O. Okukpon
Project Coordinator

For:
Chair, Research and Ethics Committee
Faculty Of Optometry,
University Of Benin.

FIGURE 1A: ETHICAL APPROVAL



Faculty of Optometry,
University of Benin,
29th October, 2025.

The Chairperson,
Research Ethics Committee (REC),
Faculty of Optometry,
University of Benin

Through;
The Project Coordinator,
Faculty of Optometry,
University of Benin,
P.M.B 1154,
Ugbowo, Benin City

Dear Sir/Ma,

RE: APPLICATION FOR ETHICAL REVIEW AND CLEARANCE

I hereby apply for ethical clearance to conduct a research study titled:

"THE RELATIONSHIP BETWEEN BODY MASS INDEX ON BINOCULAR VISION PARAMETERS (NPC, AoA, HETEROPHORIA AND FUSIONAL VERGENCE)"

This study aims to determine the relationship between BMI and binocular vision parameters in young adult population. The findings will contribute to improved clinical practice, patient counselling, and public health interventions in Nigeria.

Principal Investigator (PI):

Assoc., Prof. R. U. E Akpalaba

Investigator:
Akpanoko Emuejevoke Faith
LSC1810342

I kindly request the Research Ethics Committee to provide the required application documents for completion and submission as part of the ethical review process.
Thank you for your consideration. I look forward to your favourable response.

Yours faithfully,

Akpanoko Emuejevoke Faith
Investigator

FIGURE 2: APPROVAL LETTER

Department of Optometry,
Faculty of Life Sciences,
University of Benin,
Benin City,
Edo State.
6th June, 2025

To:
The Director of Clinic,
Department of Optometry,
Faculty of Life Sciences,
University of Benin.

Through:
The Project Supervisor,
Department of Optometry,
Faculty of Life Sciences,
University of Benin.

14/07/2025

Dear Sir,

REQUEST TO USE OPTOMETRY CLINIC FOR PROJECT WORK

I, **AKPANOKO EMUEJEVOKE FAITH**, with matriculation number **LSC1810342**, a 600 level student of the Department of Optometry humbly request to use the Department of Optometry Clinic for my project. My project is titled, "THE RELATIONSHIP BETWEEN BODY MASS INDEX AND BINOCULAR VISION PARAMETER(NPC,AoA,HETEROPHORIA AND FUSIONAL VERGENCE) IN YOUNG NIGERIAN POPULATION." The equipment that I will require are;

- Phoropter
- Meter Rule

The project will be carried out for the duration of the second semester for 2024/2025 Academic Session.

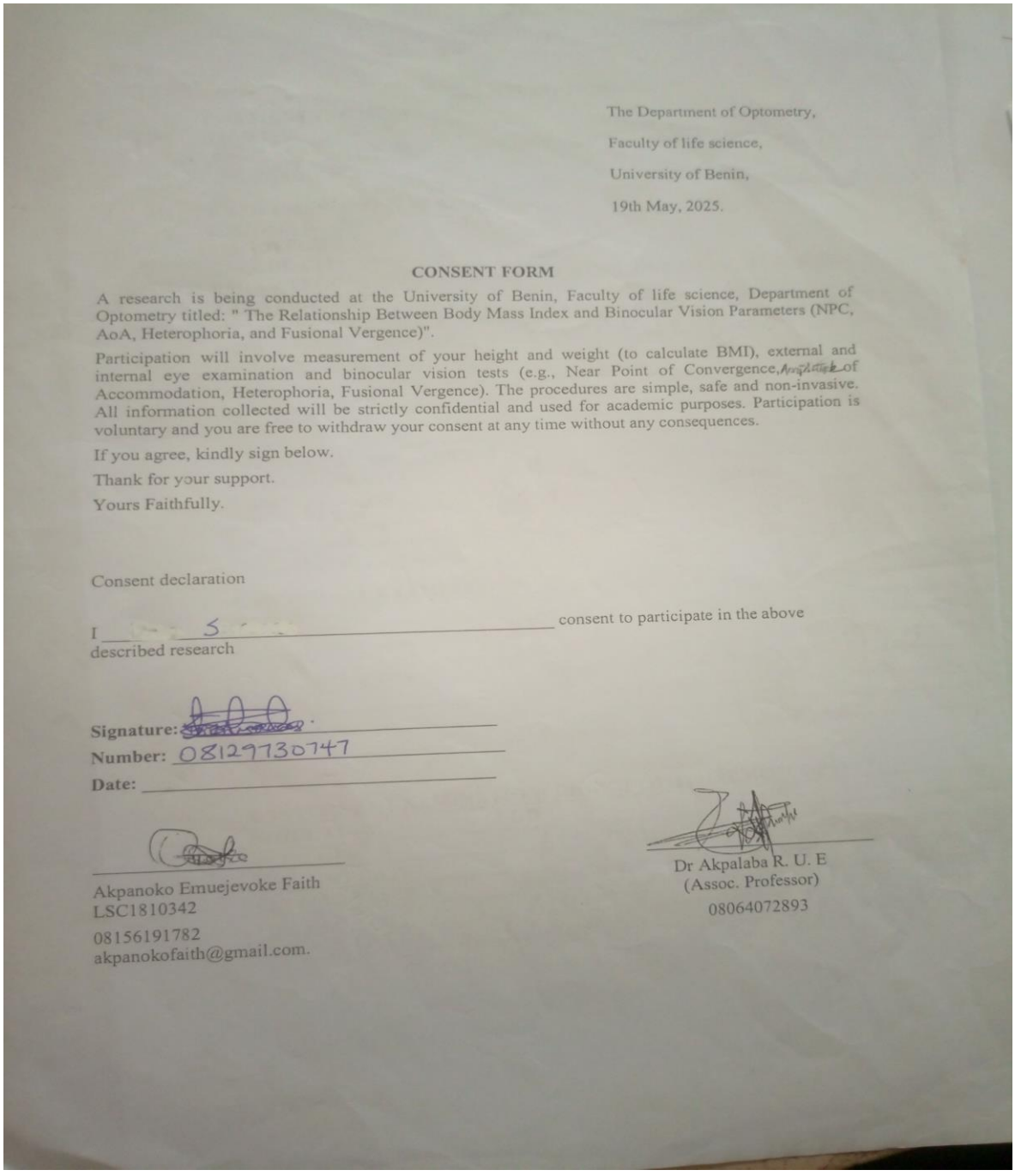
Thanks for your anticipated positive response.

Yours faithfully,

Signature
Akpanoko Emuejevoke Faith
08156191782

CASE 1

FIGURE 3: CONSENT FORM



The Department of Optometry,

Faculty of life science,

University of Benin,

19th May, 2025.

CONSENT FORM

A research is being conducted at the University of Benin, Faculty of life science, Department of Optometry titled: " The Relationship Between Body Mass Index and Binocular Vision Parameters (NPC, AoA, Heterophoria, and Fusional Vergence)".

Participation will involve measurement of your height and weight (to calculate BMI), external and internal eye examination and binocular vision tests (e.g., Near Point of Convergence, Amplitude of Accommodation, Heterophoria, Fusional Vergence). The procedures are simple, safe and non-invasive. All information collected will be strictly confidential and used for academic purposes. Participation is voluntary and you are free to withdraw your consent at any time without any consequences.

If you agree, kindly sign below.

Thank for your support.

Yours Faithfully.

Consent declaration

I _____ consent to participate in the above described research

Signature: _____

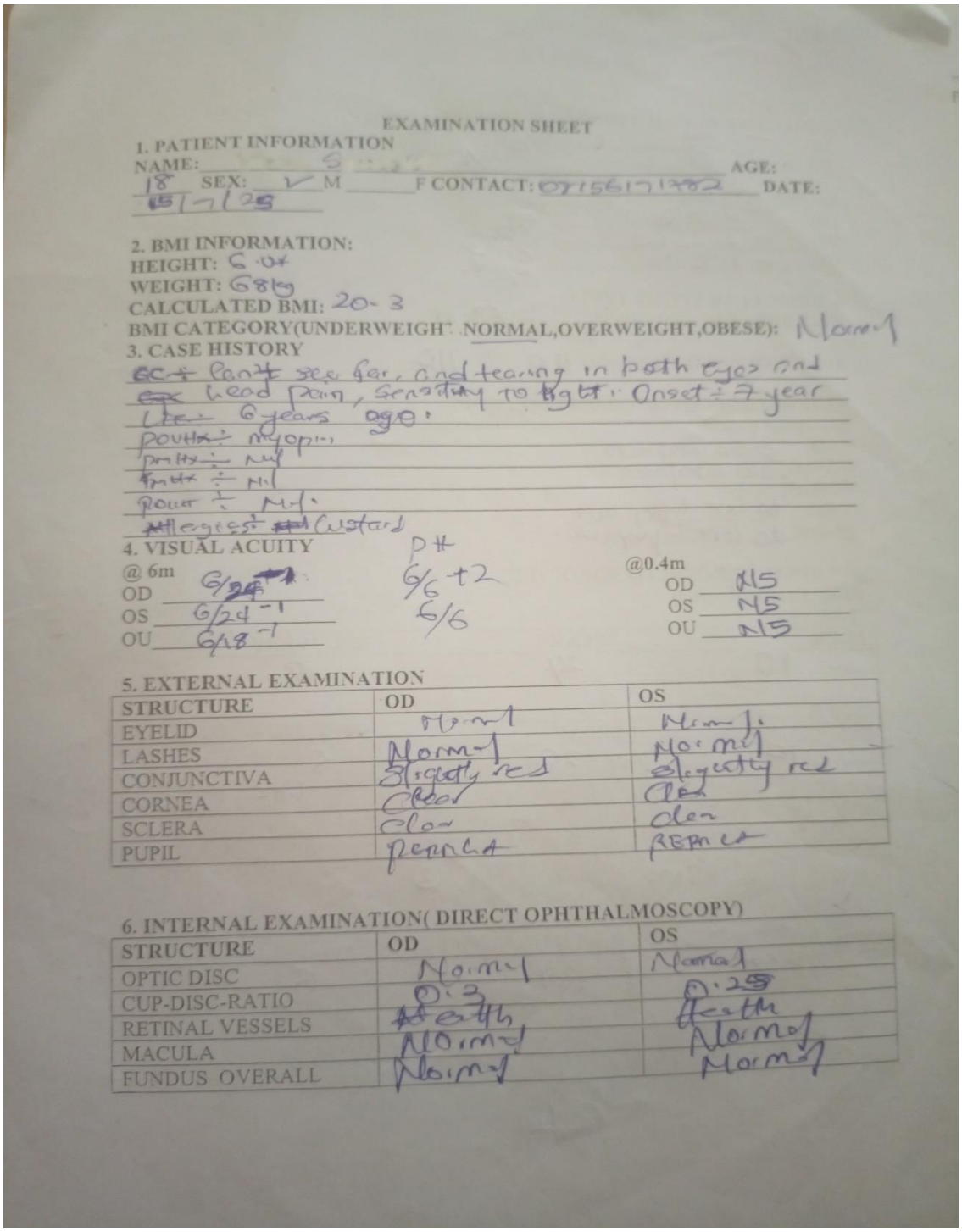
Number: 08129730747

Date: _____

Akpanoko Emuejevoke Faith
LSC1810342
08156191782
akpanokofaith@gmail.com.

Dr Akpalaba R. U. E
(Assoc. Professor)
08064072893

FIGURE 3A: BASIC EXAMINATION SHEET(FRONT PAGE)



EXAMINATION SHEET

1. PATIENT INFORMATION

NAME: _____ AGE: 18 SEX: ✓ M _____ F CONTACT: 0715617782 DATE: 15/7/25

2. BMI INFORMATION:

HEIGHT: 6.04

WEIGHT: 68kg

CALCULATED BMI: 20.3

BMI CATEGORY(UNDERWEIGHT, NORMAL,OVERWEIGHT,OBESE): Normal

3. CASE HISTORY

~~GC~~ ~~Pain~~ ~~sore~~ ~~for~~, and tearing in both eyes and ~~eye~~ head pain, Sensitivity to light. Onset ~ 7 year ~~Life~~ 6 years ago.

~~POH~~ ~~Hx~~ ~~:~~ myopia

~~PMH~~ ~~Hx~~ ~~:~~ Nil

~~FMH~~ ~~Hx~~ ~~:~~ Nil

~~Past~~ ~~Hx~~ ~~:~~ Nil.

~~Allergies~~ ~~:~~ ~~Nil~~ Custard

4. VISUAL ACUITY

	@ 6m	PH	@0.4m
OD	~~6/24~~ 6/18	6/6 +2	N5
OS	6/24 -1	6/6	N5
OU	6/18 -1		N5

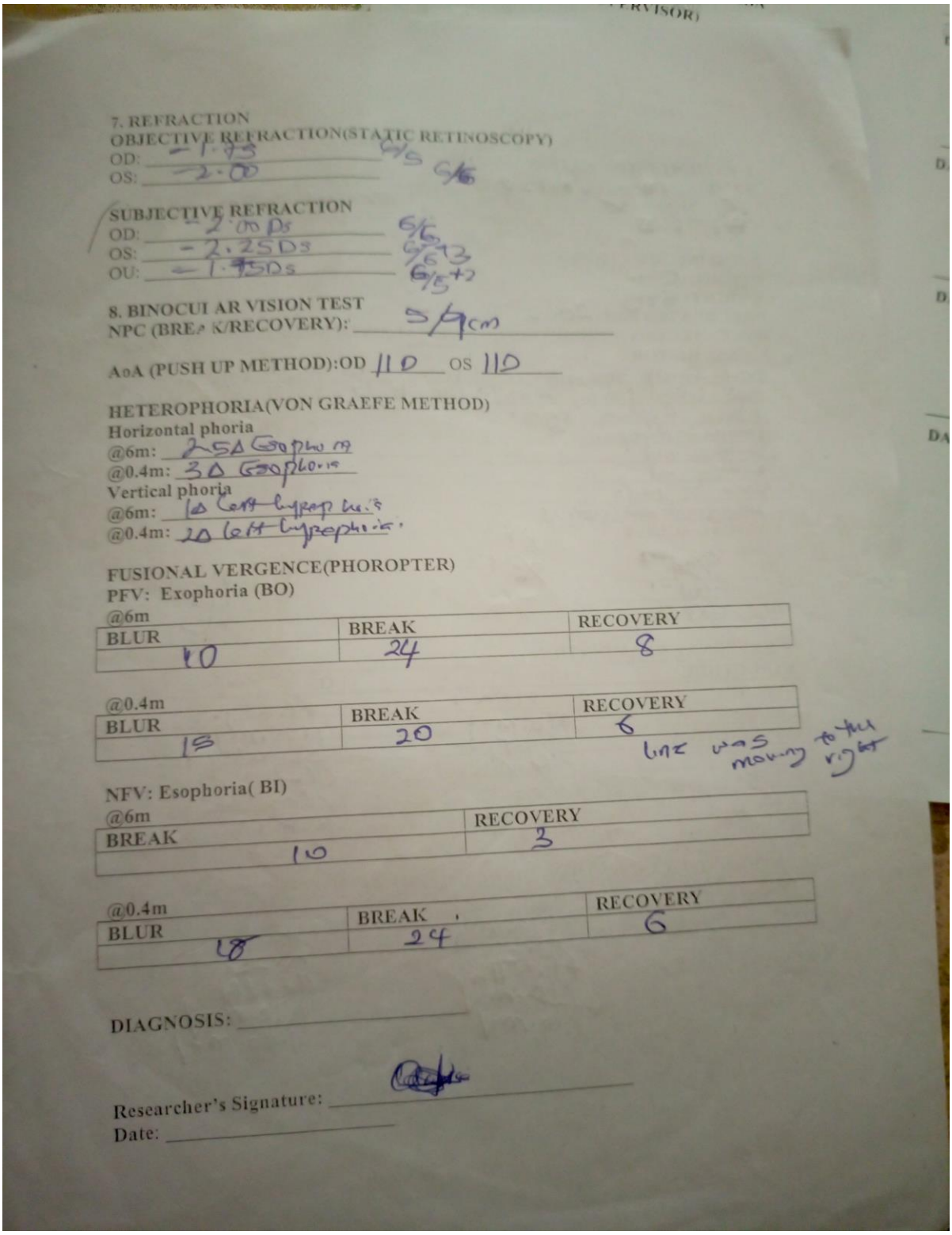
5. EXTERNAL EXAMINATION

STRUCTURE	OD	OS
EYELID	Normal	Normal
LASHES	Normal	Normal
CONJUNCTIVA	Slightly red	Slightly red
CORNEA	Clear	Clear
SCLERA	Clear	Clear
PUPIL	Reactive	Reactive

6. INTERNAL EXAMINATION(DIRECT OPHTHALMOSCOPY)

STRUCTURE	OD	OS
OPTIC DISC	Normal	Normal
CUP-DISC-RATIO	0.3	0.25
RETINAL VESSELS	~~Healthy~~	~~Healthy~~
MACULA	Normal	Normal
FUNDUS OVERALL	Normal	Normal

FIGURE 3B.BASIC EXAMINATION SHEET(BACK PAGE)



7. REFRACTION
OBJECTIVE REFRACTION(STATIC RETINOSCOPY)
OD: -1.75 6/5
OS: -2.00 6/6

SUBJECTIVE REFRACTION
OD: -2.00Ds 6/6
OS: -2.25Ds 6/6-3
OU: -1.75Ds 6/5+2

8. BINOCUI AR VISION TEST
NPC (BREAK/RECOVERY): 5/9cm

AoA (PUSH UP METHOD):OD 11D OS 11D

HETEROPHORIA(VON GRAEFE METHOD)
Horizontal phoria
@6m: 2.5Δ Esophoria
@0.4m: 3Δ Esophoria
Vertical phoria
@6m: 1Δ Left hyperphoria
@0.4m: 2Δ left hyperphoria.

FUSIONAL VERGENCE(PHOROPTER)
PFV: Exophoria (BO)

@6m		
BLUR	BREAK	RECOVERY
10	24	8

@0.4m		
BLUR	BREAK	RECOVERY
15	20	8

Line was moving to the right

NFV: Esophoria(BI)

@6m	
BREAK	RECOVERY
10	3

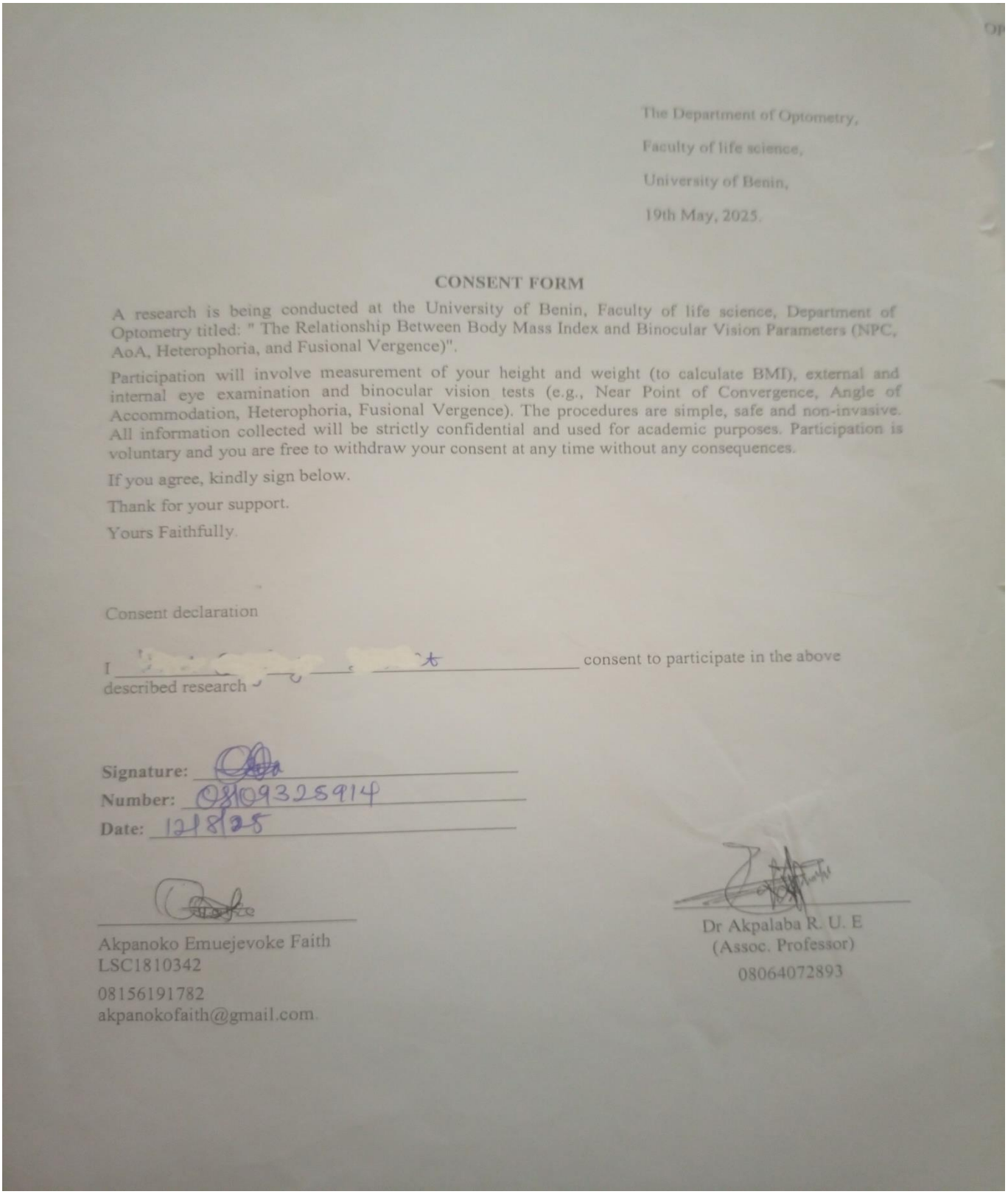
@0.4m		
BLUR	BREAK	RECOVERY
18	24	6

DIAGNOSIS: _____

Researcher's Signature: _____
Date: _____

CASE 2

FIGURE 4: CONSENT FORM 2



The Department of Optometry,
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University of Benin,
19th May, 2025.

CONSENT FORM

A research is being conducted at the University of Benin, Faculty of life science, Department of Optometry titled: " The Relationship Between Body Mass Index and Binocular Vision Parameters (NPC, AoA, Heterophoria, and Fusional Vergence)".

Participation will involve measurement of your height and weight (to calculate BMI), external and internal eye examination and binocular vision tests (e.g., Near Point of Convergence, Angle of Accommodation, Heterophoria, Fusional Vergence). The procedures are simple, safe and non-invasive. All information collected will be strictly confidential and used for academic purposes. Participation is voluntary and you are free to withdraw your consent at any time without any consequences.

If you agree, kindly sign below.

Thank for your support.

Yours Faithfully.

Consent declaration

I _____ consent to participate in the above described research

Signature: _____

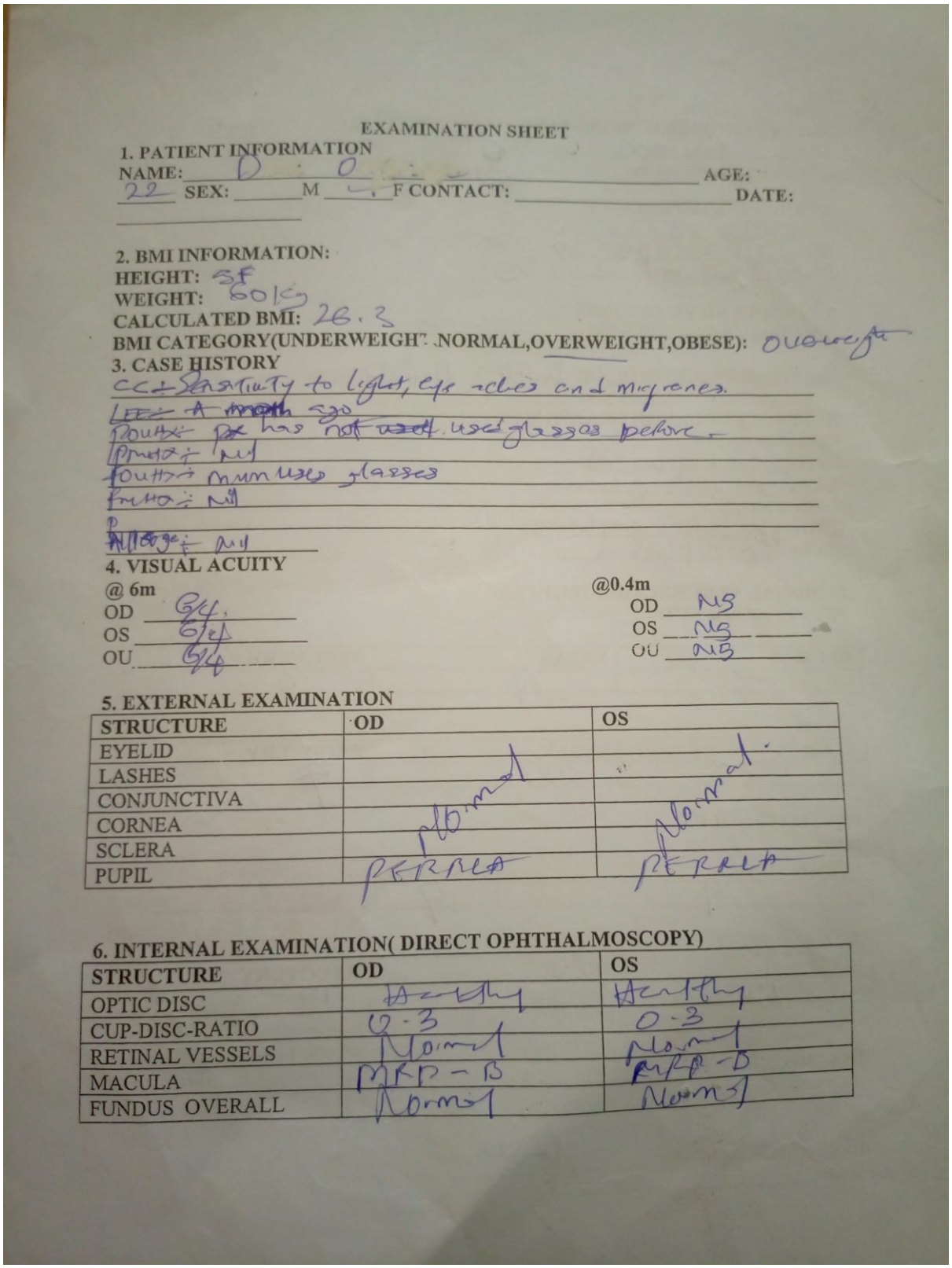
Number: 08109325914

Date: 12/8/25

Akpanoko Emuejevoke Faith
LSC1810342
08156191782
akpanokofaith@gmail.com.

Dr Akpalaba R. U. E
(Assoc. Professor)
08064072893

FIGURE 4A: BASIC EXAMINATION SHEET 2(FRONT PAGE)



EXAMINATION SHEET

1. PATIENT INFORMATION

NAME: D . O AGE: 22 SEX: M F CONTACT: DATE:

2. BMI INFORMATION:

HEIGHT: 5F

WEIGHT: 60kg

CALCULATED BMI: 26.3

BMI CATEGORY(UNDERWEIGHT, NORMAL,OVERWEIGHT,OBESE): Overweight

3. CASE HISTORY

CC: Sensitivity to light, eye aches and migranes.

LEE: A month ago

POUHX: Pt has not used glasses before.

PMHX: Nil

FOUHX: mum uses glasses

FMHX: Nil

PHX: Nil

4. VISUAL ACUITY

@ 6m

OD 6/4

OS 6/4

OU 6/4

@0.4m

OD NS

OS NS

OU NS

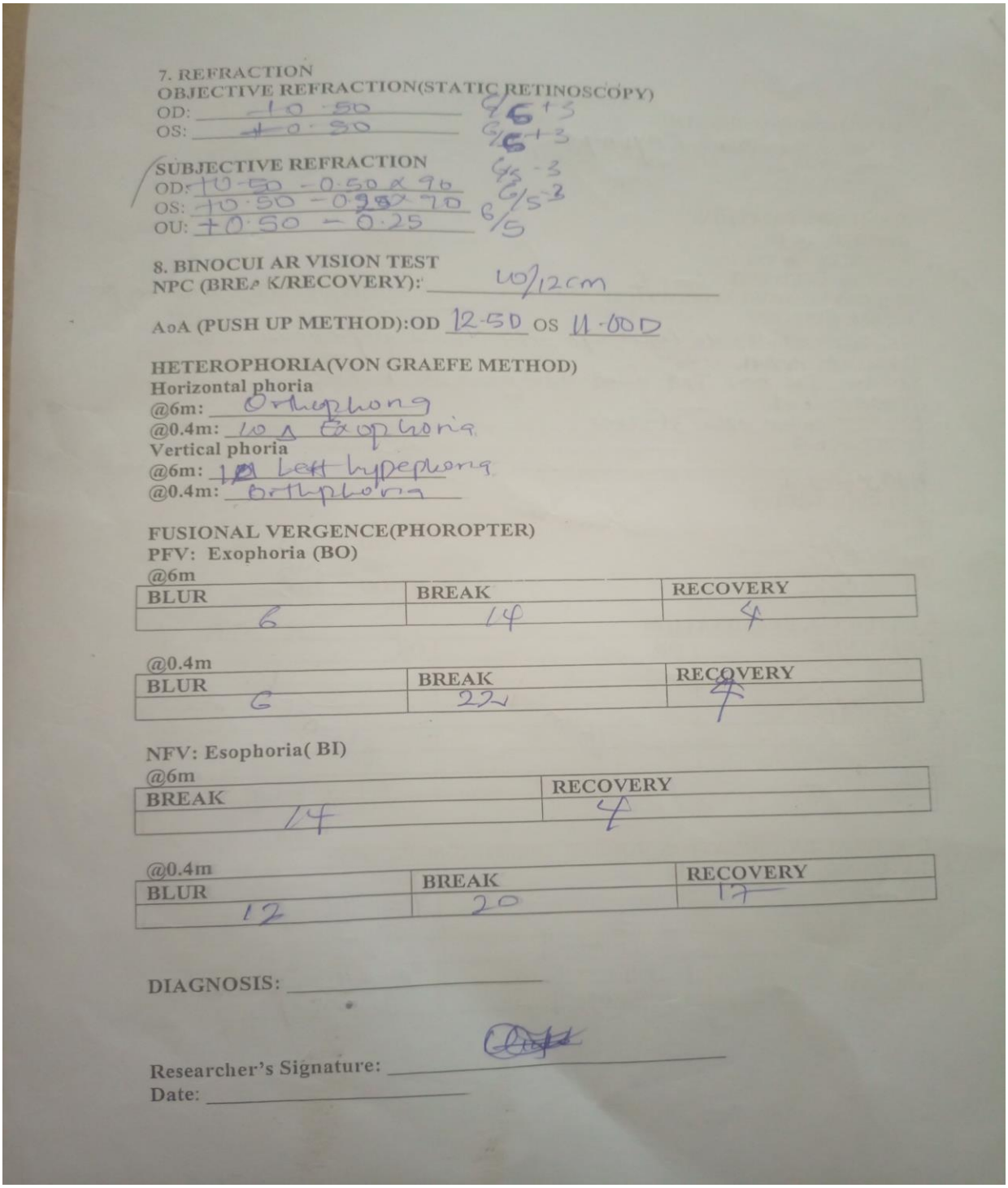
5. EXTERNAL EXAMINATION

STRUCTURE	OD	OS
EYELID		
LASHES		
CONJUNCTIVA		
CORNEA	Normal	Normal
SCLERA		
PUPIL	PERRLA	PERRLA

6. INTERNAL EXAMINATION(DIRECT OPHTHALMOSCOPY)

STRUCTURE	OD	OS
OPTIC DISC	Healthy	Healthy
CUP-DISC-RATIO	0.3	0.3
RETINAL VESSELS	Normal	Normal
MACULA	MRP-B	MRP-B
FUNDUS OVERALL	Normal	Normal

FIGURE 4B: BASIC EXAMINATION SHEET 2(BACK PAGE)



7. REFRACTION
OBJECTIVE REFRACTION(STATIC RETINOSCOPY)
OD: -1.50 6/6 +3
OS: +0.50 6/6 +3

SUBJECTIVE REFRACTION
OD: +0.50 -0.50 x 90 6/5 -3
OS: +0.50 -0.25 x 90 6/5 -3
OU: +0.50 -0.25 6/5

8. BINOCUI AR VISION TEST
NPC (BREAK/RECOVERY): 10/12cm

AoA (PUSH UP METHOD):OD 12.50 OS 11.00D

HETEROPHORIA(VON GRAEFE METHOD)
Horizontal phoria
@6m: Orthophong
@0.4m: 10 Δ Exophoria
Vertical phoria
@6m: 1Δ Left hyperphong
@0.4m: Orthophoria

FUSIONAL VERGENCE(PHOROPTER)
PFV: Exophoria (BO)
@6m

BLUR	BREAK	RECOVERY
6	14	4

@0.4m

BLUR	BREAK	RECOVERY
6	22	4

NFV: Esophoria(BI)
@6m

BREAK	RECOVERY
14	4

@0.4m

BLUR	BREAK	RECOVERY
12	20	17

DIAGNOSIS: _____

Researcher's Signature: _____
Date: _____

APPENDIX II

FIGURE 5: EXAMINATION ROOM

FIGURE 5A: EXAMINATION ROOM

FIGURE 7: THE PHOROPTER (TOPCON)

FIGURE 8: WEIGHT SCALE

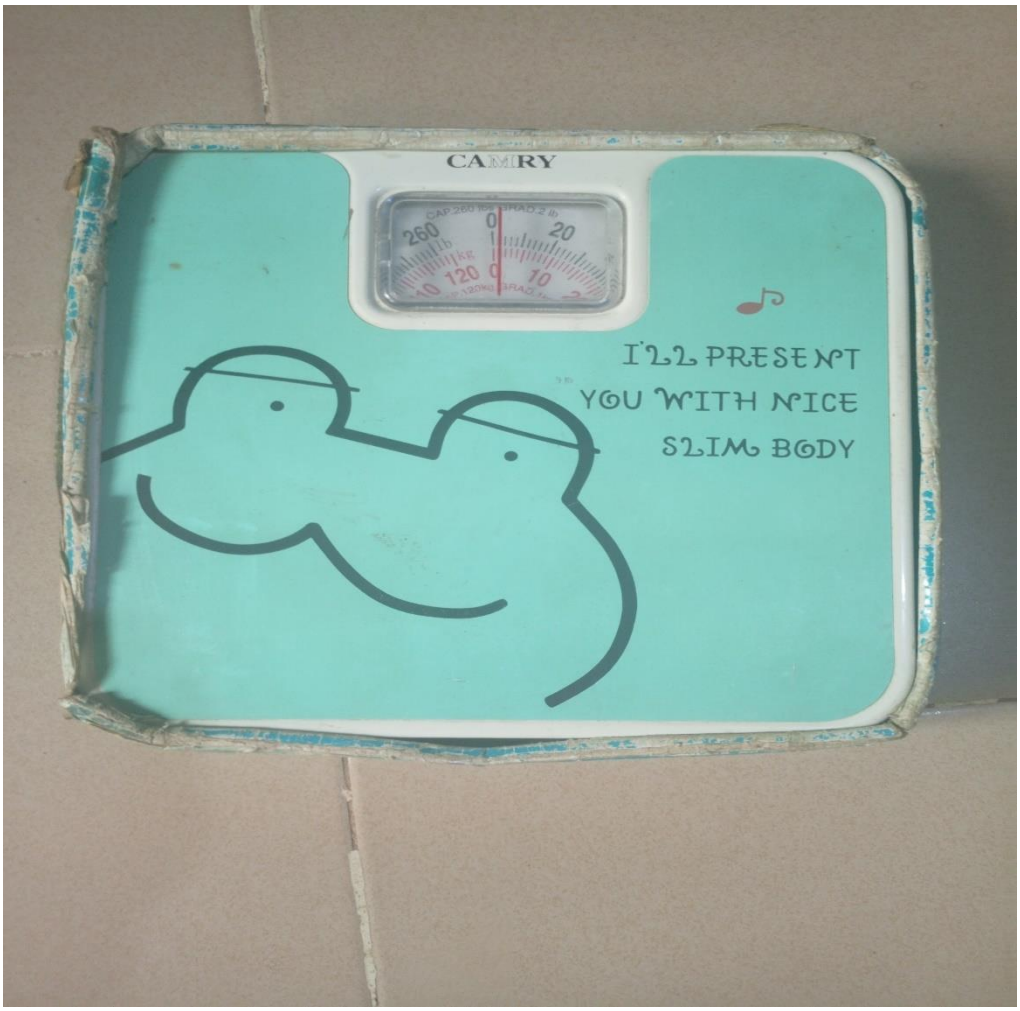
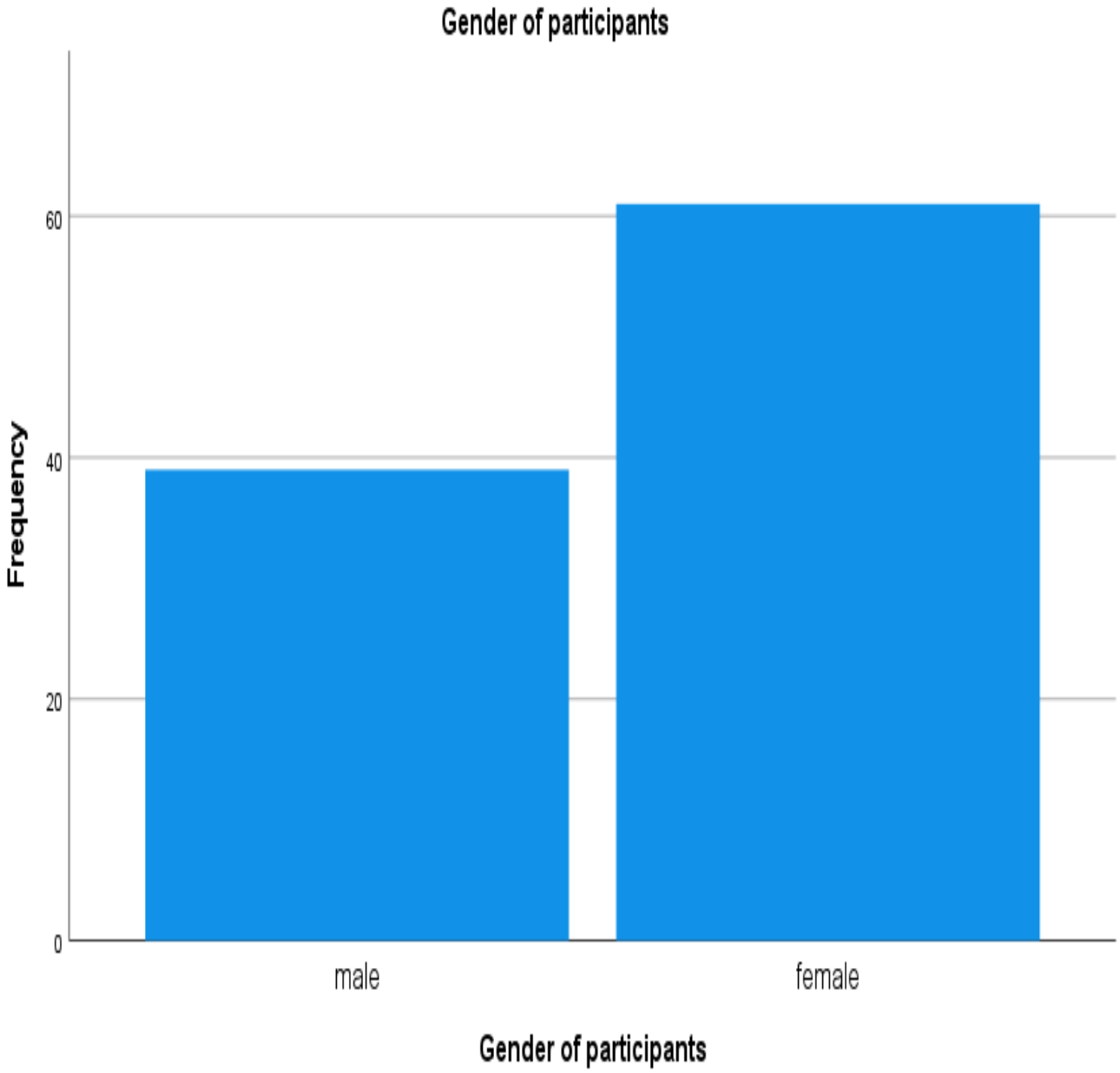


FIGURE 9: MEASURING TAPE

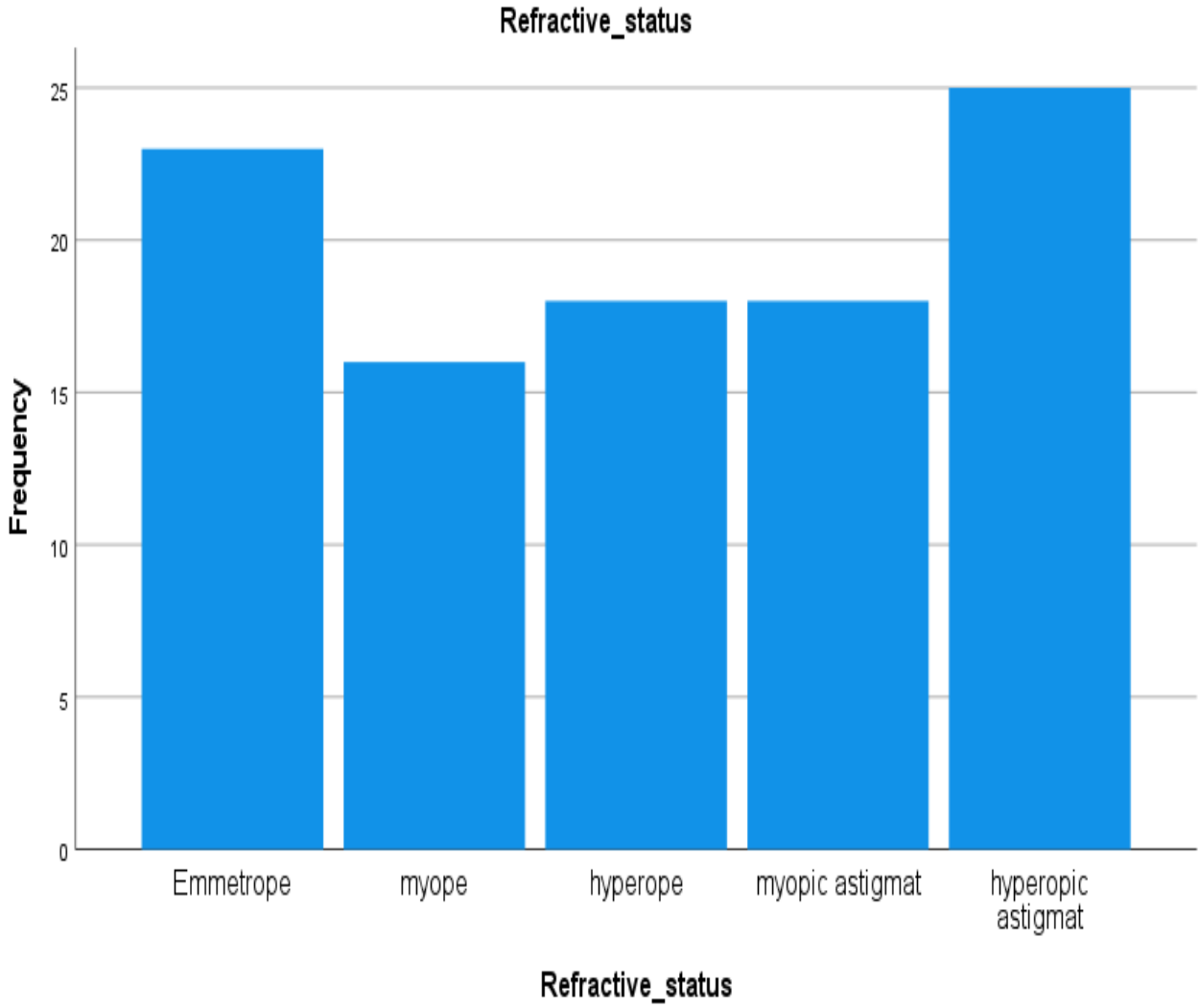
APPENDIX III

FIGURE 10: BAR CHART SHOWING DISTRIBUTION OF GENDER OF



The bar chart in figure 8 shows the gender distribution of participants, with females (61%) outnumbering males (39%). Gender distribution was generally balanced across BMI groups, indicating that both males and females were well represented in the study sample.

FIGURE 11: BAR CHART SHOWING THE DISTRIBUTION OF REFRACTIVE STATUS AMONG PARTICIPANTS



It indicates that hyperopic astigmatism was the most common refractive status, while myopia and myopic astigmatism were the least frequent among participants. This finding suggests a possible influence of body mass index (BMI) on the distribution of refractive errors, as a significant association ($p = 0.039$) was observed between BMI grading and refractive status, implying that changes in body composition may affect refractive outcomes and visual function.