# THE RELATIONSHIP BETWEEN TEAR FILM STABILITY AND BODY MASS INDEX AMONG STUDENTS VISITING THE OPTOMETRY CLINIC, UNIVERSITY OF BENIN, NIGERIA.

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**A RESEARCH PROJECT SUBMITTED TO THE FACULTY OF OPTOMETRY, UNIVERSITY OF BENIN, BENIN CITY**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF OPTOMETRY (O.D) DEGREE**

**NOVEMBER, 2025**

**CERTIFICATION**

## DEDICATION

To the One who opened my eyes before I ever studied how eyes see,

To the author of this vision, the author of my life's story. TO THE CREATOR who held my hands and supplied all that was needed for me to go through this journey and create this.

To the only one who knows me more than I know me

To God alone be all the glory, Amen. Soli Deo Gloria forever!

(Psalms 73: 23-26)

**ACKNOWLEDGEMENT**

I am forever grateful to God, the giver of wisdom and peace, who carried me through this season and all that came with it. This work is a reflection of His grace more than my strength.

Now, to the humans who contributed towards making this a reality, I'd like to first say that a page or two would never be enough to fully capture my gratitude, or even the number of persons, goodwill, and gestures that have led me here. And so, I say thank you to everyone, mentioned or not; you played a part, consciously or unconsciously.

To my parents, Mr. and Mrs. Obiajulu Ikeli, to say I'm grateful would be understating an understatement. Thank you for being parents in every sense—for sacrificing your resources, prayers, and yourselves to see me make something out of my life. The Lord bless and reward you Himself, and through me. Amen.

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And so, with grateful eyes and a full heart, I close this chapter, not as an end, but as a beginning.

Till we meet again, God willing—with all my love.

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## ABSTRACT

Tear film stability is vital for maintaining ocular surface health, visual clarity, and overall comfort. Variations in body composition, particularly Body Mass Index (BMI), have been associated with metabolic and inflammatory changes that may influence ocular physiology, including tear film quality and quantity. This study therefore investigated the relationship between BMI and tear film stability among students visiting the Optometry Clinic, University of Benin. A total of 120 participants aged 18 to 27 years (mean age 22.65 ± 2.24 years) were recruited. Data collected included age, gender, spectacle and contact lens use, BMI, Ocular Surface Disease Index (OSDI) score, Tear Meniscus Height (TMH), and Fluorescein Tear Break-Up Time (FTBUT). Descriptive statistics were used to summarise participant characteristics. Pearson's correlation coefficient was employed to determine relationships between BMI and tear film parameters, while independent samples t-tests were used to compare mean tear film values across BMI and gender groups.

The mean BMI was 24.57 ± 5.40 kg/m², the mean OSDI score was 24.68 ± 15.18, mean TMH was 0.22 ± 0.09 mm, and mean FTBUT was 11.97 ± 4.09 seconds. Statistical analysis revealed no significant correlation between BMI and any of the tear film parameters ($p > 0.05$). Similarly, gender-based comparisons showed no significant differences in mean OSDI, TMH, or FTBUT values.

In conclusion, this study found no significant influence of BMI on tear film stability among the student population. The findings suggest that within this young adult group, factors such as environmental exposure, digital device use, or lifestyle habits may exert a greater impact on tear film integrity than body mass index alone.



Keywords: Tear film stability, Body Mass Index, Dry eye disease, Ocular surface Disease Index(OSDI), Tear Break-up time(TBUT), Tear Meniscus Height(TMH).

# CHAPTER ONE

# INTRODUCTION

The tear film, a trilaminar structure comprising lipid, aqueous, and mucin layers, is a critical component of ocular surface health, as it provides lubrication, protection against microbial invasion, and ensures optimal optical clarity (Craig *et al.,*2017). Its stability, clinically assessed through tear breakup time (TBUT), tear ferning, tear meniscus height(TMH), etc, shows its ability to resist evaporation and maintain uniform optical clarity, with shorter TBUT(less than 10 seconds) indicating instability (Wolffsohn *et al.,* 2017). The tear film's instability represents a central feature of its dysfunction (Pflugfelder & Stern, 2020) which is a hallmark of dry eye disease (DED), a multifactorial disorder affecting millions worldwide (Craig *et al.,* 2017).

However, certain literatures link metabolic disorders, a.k.a, metabolic syndrome (MetS); a cluster of conditions including hypertension, dyslipidemia, insulin resistance, and obesity (defined by a high body mass index, BMI ≥30 kg/m²), to tear film instability through systemic inflammation and oxidative stress. Patients with MetS exhibit significantly higher tear osmolarity, lower TBUT, and reduced tear secretion compared to healthy individuals, alongside elevated OSDI scores (Pieńczykowska *et al.,*2025).

Obesity, defined as a BMI ≥30 kg/m², is a global epidemic with multisystemic consequences, including cardiovascular disease and diabetes (WHO, 2021). Recent studies propose a link between obesity and ocular surface disorders, possibly due to adipokine-mediated inflammation (e.g., elevated leptin) or meibomian gland dysfunction (MGD) in high-BMI

individuals (Rodríguez-Hernández *et al.,* 2013; Kim *et al.,* 2022). For instance, an Asian study found shorter TBUT and higher DED prevalence in obese populations, suggesting a direct correlation between BMI and tear film dysfunction (Alanazi, 2019). Similarly, insulin resistance which is common in high-BMI individuals has been linked to reduced corneal sensitivity and diminished lacrimal gland secretion (Ponirakis *et al.,* 2021; He *et al.,* 2020). With Nigeria's rising obesity rates—20.3% among adults aged 18–35 (NCD-RisC, 2020), and particularly among young adults in Nigerian universities (Ukegbu *et al.,*2017), understanding its ocular implications is necessary.

Yet, existing literature has notable limitations. Many studies have focused on smaller numbers or individuals with diagnosed metabolic syndrome like Diabetes, limiting generalizability to more young adults (Alanazi, 2019 ; Yellamelli *et al.,* 2023). Additionally, most accessible investigations have been conducted in homogeneous populations (e.g., Asian or Caucasian cohorts), raising questions about the applicability of findings to African demographics (Yellamelli *et al.,* 2023; Çabuk *et al.,* 2016). Furthermore, some studies have not accounted for sex differences, despite evidence that hormonal variations between males and females influence tear film characteristics (Gorimanipalli *et al.,* 2023). For instance, estrogen and androgen levels have been shown to affect meibomian gland function, which is crucial for lipid layer stability (Sullivan *et al.,*2017). Given these gaps, there is a need for research that examines tear film stability in young adults of African descent while considering sex-specific differences.

This study investigates the association between BMI and tear film stability among students visiting the Optometry Clinic at the University of Benin (UNIBEN).

## 1.1 BACKGROUND OF THE STUDY

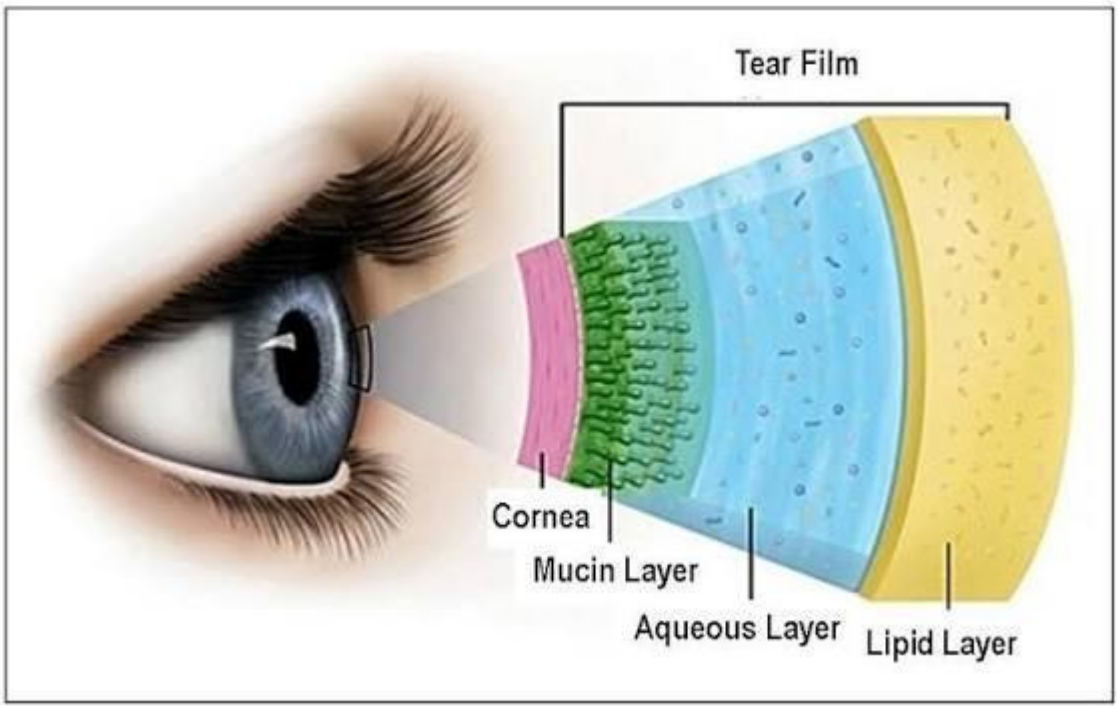
### 1.1.1 Structural Organisation and Functional Roles of the Tear Film

The human tear film is a dynamic, multi-layered fluidic interface with an average thickness ranging from 3 to 10 μm, and is typically described as consisting of three interactive layers: the mucin layer, aqueous layer, and lipid layer. These layers, though structurally distinct, function interdependently to ensure tear film stability, ocular surface lubrication, immune protection, and visual clarity (Bron *et al.,*2004; Willcox *et al.,* 2017).

1. Mucin Layer: The innermost mucin layer is primarily secreted by the goblet cells of the conjunctiva and is responsible for converting the hydrophobic corneal epithelial surface into a hydrophilic substrate, thereby facilitating uniform spreading and adhesion of the aqueous layer. Inadequate mucin production or goblet cell dysfunction leads to poor tear film stability and rapid tear break-up, predisposing the eye to desiccation and surface damage (Gipson, 2016).
2. Aqueous Layer: Lying between the mucin and lipid layers, the aqueous layer is the thickest of the three and is secreted by the main and accessory lacrimal glands. It comprises water, electrolytes, antimicrobial peptides (e.g., lysozyme, lactoferrin, and immunoglobulins), and nutrients essential for corneal and conjunctival epithelial metabolism. It also aids in flushing debris and toxic substances from the ocular surface, as well as in maintaining osmotic balance and pH stability(Bron *et al.,* 2004; McDermott, 2013).
3. Lipid Layer: The superficial lipid layer is synthesised and secreted by the meibomian glands located in the tarsal plates of the eyelids. It serves a dual purpose: reducing evaporation of the aqueous layer and stabilising the air-tear interface during blinking. A well-formed lipid layer is essential for retarding tear evaporation and prolonging

tear film break-up time. Dysfunction in meibomian gland secretion leads to increased evaporative loss and is a major contributor to evaporative dry eye disease (Knop *et al.,* 2011).

Collectively, these layers provide mechanical protection, ensure even tear distribution, facilitate gas exchange, and maintain a refractive surface that is optically smooth and clear.




### 1.1.2. Aetiology of Tear Film Instability

Tear film instability refers to a loss of continuity or integrity in the pre-corneal tear film, resulting in dry spots and ocular surface exposure. This instability may arise from qualitative or quantitative deficiencies in any of the tear film layers. Common aetiological factors include:

1. Lacrimal gland dysfunction, leading to aqueous-deficient dry eye;

2. Meibomian gland dysfunction, leading to lipid insufficiency and evaporative loss;
3. Goblet cell loss or conjunctival metaplasia, impairing mucin secretion;
4. Environmental conditions, such as low humidity, high airflow, or air pollution;
5. Behavioural factors, such as reduced blink rate during digital screen use;
6. Hormonal fluctuations, particularly in postmenopausal women;
7. Systemic conditions, such as autoimmune diseases (e.g., Sjögren's syndrome), diabetes mellitus, or vitamin A deficiency;
8. Use of certain medications, such as antihistamines, antidepressants, and isotretinoin.

The Tear Film and Ocular Surface Society (TFOS) Dry Eye Workshop II (DEWS II) classified dry eye disease into two principal subtypes—aqueous-deficient and evaporative dry eye—with many patients presenting a mixed clinical picture (Craig *et al.,* 2017; Nelson *et al.,* 2011).

As the first refractive medium encountered by incoming light, the Tear Film is responsible for creating a smooth anterior surface of the cornea, thereby facilitating optimal light refraction and high-quality visual acuity. Disruption in the integrity or uniformity of the tear film results in optical aberrations, decreased contrast sensitivity, and fluctuating vision (Craig *et al.,* 2017; King-Smith *et al.,* 2004). Hence, beyond its traditionally understood roles in ocular hydration and protection, the tear film is now increasingly recognised as integral to functional vision, especially during tasks that require sustained visual attention such as reading, computer work, and driving.

### 1.1.3. Diagnostic Assessment of Tear Film Stability

The evaluation of tear film stability and function is essential for the diagnosis of dry eye disease and related disorders. Several clinical tools and procedures are commonly employed:

1. Tear Break-Up Time (TBUT): This assesses the interval between a complete blink and the initial appearance of a dry spot on the corneal surface after fluorescein dye instillation. A TBUT of less than 10 seconds is generally indicative of tear film instability (Lemp *et al.,* 2007).
2. Schirmer's Test: This evaluates basal and reflex aqueous tear secretion by placing a standardised strip of filter paper in the lower fornix for five minutes. Wetting values below 10 mm are suggestive of aqueous deficiency ( Craig *et al.,* 2017).
3. Tear Meniscus Height (TMH): This parameter is observed using slit-lamp biomicroscopy or anterior segment optical coherence tomography (OCT), with reduced TMH indicating low tear volume (Mainstone *et al.,* 1996).
4. Ocular Surface Disease Index (OSDI): A validated patient-reported outcome questionnaire used to quantify the frequency and severity of dry eye symptoms and their impact on daily activities (Schiffman *et al.,*2000).

Other adjunct diagnostic methods include tear osmolarity, meibography, impression cytology, and non-invasive tear break-up time (NIBUT), etc.

### 1.1.4. Epidemiology of Tear Film Instability and Dry Eye in the General and Student Populations

Dry eye disease and tear film instability are recognised as global public health concerns with a rising incidence across all age groups. Epidemiological studies report variable prevalence rates, typically ranging from 5% to over 50%, depending on diagnostic criteria, age, sex, geographic location, and environmental exposure (Stapleton *et al.,* 2017). Factors such as ageing, hormonal changes, and systemic disease increase susceptibility in the general population.

More recently, research has highlighted a growing burden of dry eye symptoms among younger adults, particularly university students and frequent users of digital visual display units. Prolonged use of smartphones, computers, and tablets has been associated with reduced blink rates, incomplete blinks, and increased ocular surface exposure, all of which contribute to tear film instability (Rosenfield, 2011). A study conducted by Uchino *et al.,* (2013) found a positive correlation between digital device usage and the prevalence of dry eye symptoms in Japanese office workers, a trend that is mirrored in student populations globally.

In Nigeria, a study by Idu (2020) among university students at the University of Benin demonstrated that prolonged smartphone use was significantly associated with reduced tear film parameters, including TBUT and Schirmer's scores. These findings point to the emerging relevance of dry eye disease among younger demographics and highlight the need for preventive strategies and increased awareness in academic environments.

### 1.1.5. Understanding Body Mass Index (BMI)

Body Mass Index (BMI) is a widely used anthropometric indicator for categorising body weight relative to height and is considered a simple and cost-effective tool for assessing an individual's weight status. It serves as a screening measure to identify underweight, normal weight, overweight, and obesity in both clinical and public health settings. Although BMI does not directly measure body fat or body composition, it correlates strongly with more direct measures of adiposity and is associated with various health outcomes including cardiovascular disease, metabolic disorders, and musculoskeletal problems (WHO, 2000; Nuttall, 2015).

#### 1.1.5.1. Definition and Calculation of BMI

BMI is defined mathematically as a person's weight in kilograms divided by the square of their height in metres ($kg/m^2$). The formula is as follows:

$$BMI = \text{Weight (kg)} / [\text{Height (m)}]^2$$

For example, an individual weighing 70 kg and measuring 1.75 metres in height would have a BMI of:

$$BMI = 70 / (1.75)^2 = 22.9 \text{ kg/m}^2$$

While BMI is easy to calculate and apply across large populations, it does not account for variations in body composition, such as the proportion of fat versus muscle mass, nor does it consider age, sex, or ethnic differences in fat distribution. Nonetheless, it remains one of the most commonly utilised measures for epidemiological studies and routine health assessments.

#### 1.1.5.2. WHO Classification of BMI Ranges

According to the World Health Organization (WHO, 2000), BMI is classified into the following categories for adults:

1. Underweight: BMI < 18.5 kg/m²
2. Normal weight: BMI 18.5 – 24.9 kg/m²
3. Overweight: BMI 25.0 – 29.9 kg/m²
4. Obese (Class I): BMI 30.0 – 34.9 kg/m²
5. Obese (Class II): BMI 35.0 – 39.9 kg/m²
6. Obese (Class III): BMI ≥ 40.0 kg/m²

These cut-offs are used to assess the risk of health complications. Overweight and obesity, in particular, have been associated with increased risks of type 2 diabetes mellitus, hypertension, coronary artery disease, and certain types of cancer (WHO, 2020).

### 1.1.5.3 Trends in BMI Among Young Adults and Students

Recent global data indicate a worrying rise in the prevalence of overweight and obesity among young adults, particularly those within the university student population. This trend has been attributed to the adoption of more sedentary lifestyles, dietary shifts towards calorie-dense and nutrient-poor foods, and increased psychological stress associated with academic demands (Keating *et al.,*2016; Pengpid & Peltzer, 2015).

Studies conducted in both developed and developing countries suggest that many university students fall outside the "normal" BMI range, with increasing rates of overweight and obesity being reported. In Nigeria, similar patterns have been observed, with nutritional transitions and urbanisation contributing to altered dietary and lifestyle behaviours among tertiary-level students (Ukegbu *et al.,* 2017; Adu *et al.,* 2009 ).

This rise in BMI among young adults is of particular concern due to the long-term health consequences that may persist into adulthood, including insulin resistance, early onset hypertension, and cardiovascular risk. Furthermore, elevated BMI has also been linked to poorer quality of life, self-esteem issues, and reduced academic productivity (Alghawrien *et al.,* 2020).

### 1.1.5.4 Lifestyle Habits Influencing BMI in Students

Several modifiable lifestyle behaviours have been identified as determinants of BMI in young adults, particularly within the university environment:

1. Dietary Habits:

Elevated consumption of fast foods and sugar-sweetened beverages, alongside widespread meal skipping, especially breakfast, are common among university students, Nigerian students included, and have been significantly associated with increased BMI. For instance, at Obafemi Awolowo University, fast food intake correlated positively with BMI (r = 0.47,

$p < 0.05$) (Bakare & Olumakaiye, 2016), while in Osun State, 86% of female undergraduates skipped meals and over 74% reported regular snacking (Ikujenlola & Adekoya, 2020).

2. Physical Activity:

A study of health professional students at the University of Maiduguri revealed that students spent around 458 minutes/day (≈61%) in sedentary activity, while only 0.3% of time was spent in vigorous physical activity (Oyeyemi *et al.,* 2017). Although 85.3% met the moderate activity guideline, very few fulfilled vigorous activity recommendations. Physical inactivity was notably associated with higher BMI and indicators of central obesity.

Another with 1,006 young adults (aged 16–39) found 41% prevalence of physical inactivity, and identified that individuals with BMI > 30 kg/m² had nearly 3 times greater odds of being physically inactive (OR = 2.88), illustrating a strong inverse relationship between activity level and overweight status (Adegoke & Oyeyemi, 2011).

3. Stress and Sleep Patterns:

Academic stress, irregular sleep schedules, and emotional eating are prevalent among university students and have been linked to metabolic dysregulation and increased adiposity. Chronic stress activates the hypothalamic–pituitary–adrenal (HPA) axis, elevating cortisol levels, which in turn promotes appetite, visceral fat accumulation, and insulin resistance (Manthey *et al.,* 2013). Chronic stress is also a driver of emotional and comfort eating, particularly of high-fat, sugary foods, which further contributes to positive energy balance and weight gain (Tomiyama, 2010)

4. Screen Time and Digital Device Use:

Prolonged screen time, particularly with smartphones, computers, and televisions, has been associated with decreased physical activity, increased snacking, and disrupted sleep—all of which contribute to elevated BMI (Akintade *et al.,* 2020).

### 1.1.6 BMI and Its Ocular Implications

Several systemic diseases associated with abnormal BMI, including diabetes mellitus, hypertension, and metabolic syndrome, have long been known to affect posterior ocular structures—manifesting as diabetic retinopathy, hypertensive retinopathy, glaucoma, and cataract.

However, beyond the posterior segment, more recent investigations have begun to explore the impact of systemic metabolic disturbances on the ocular surface, particularly the tear film and related structures.

Elevated BMI is associated with chronic low-grade inflammation, oxidative stress, and hormonal imbalance, all of which can disrupt homeostatic mechanisms in the lacrimal functional unit. Conversely, low BMI and undernutrition may impair tear production due to inadequate nutrient intake and compromised immune function (TFOS Lifestyle Report 2023; Kim *et al.,* 2022). These associations have prompted interest in investigating whether BMI could serve as a modifying or risk factor in the development of dry eye disease (DED) and tear film instability.

### 1.1.7 Evidence from Clinical and Epidemiological Studies

Alanazi *et al*., (2019) found that obese male subjects exhibited significantly reduced non-invasive tear break-up time (NITBUT), poorer lipid layer grading, and more pronounced tear ferning patterns compared to those with normal BMI. Their study suggested that while tear

quantity may not differ significantly, tear quality and stability are adversely affected by elevated BMI.

In a similar study, Fagehi *et al.,* (2022) compared high-BMI individuals to normal-weight controls and reported significantly lower tear meniscus height and lipid layer thickness in the obese group. NITBUT was also notably reduced, and there was a negative correlation between BMI and tear film stability.

More recently, Alanazi *et al.,* (2022) reported that individuals with high BMI had elevated tear osmolarity and higher Ocular Surface Disease Index (OSDI) scores, both of which were positively correlated with BMI. These findings were consistent across two measurement methods (TearLab™ and I-Pen®), further supporting the hypothesis that BMI contributes to tear film dysfunction.

Conversely, other studies have yielded contradictory outcomes. Tummanapalli *et al.,*(2020) found no significant association between BMI and tear neuromediator concentrations or corneal nerve measures. Yet the majority of recent evidence supports a significant association between increased BMI and compromised ocular surface parameters, particularly among younger and middle-aged adults.

### 1.1.8 Proposed Pathophysiological Mechanisms

Several mechanisms have been proposed to explain how abnormal BMI may contribute to ocular surface changes and dry eye symptoms:

1. Chronic Low-Grade Inflammation: Obesity leads to a systemic pro-inflammatory state, which can affect the lacrimal glands and ocular surface tissues. These inflammatory mediators may reduce goblet cell density, increase epithelial permeability, and contribute to tear hyperosmolarity (Contreras-Ruiz *et al.,*2013).

2. Hormonal Imbalance: Adipose tissue acts as an endocrine organ and influences hormonal balance. Alterations in androgens, oestrogens, leptin, and adiponectin levels—common in individuals with abnormal BMI—can negatively affect meibomian gland function and lipid secretion (Baser *et al.,* 2016).
3. Meibomian Gland Dysfunction (MGD): Structural and functional changes in the meibomian glands have been reported in obese individuals. High-fat diets and increased adiposity may lead to glandular obstruction, reduced lipid output, and tear film instability (Liu *et al.,* 2016).

4. Altered Lipid Composition and Osmolarity: Changes in systemic lipid metabolism may affect the composition and function of the tear film's lipid layer. These alterations can increase evaporation, destabilise the tear film, and lead to symptomatic dry eye (Bron *et al.,* 2004).

## 1.2. STATEMENT OF PROBLEM

While obesity has been linked to tear film dysfunction, existing studies have primarily focused on small, single-gender, or homogeneous Asian and Caucasian cohorts (Alanazi, 2019; Çabuk *et al.,* 2016; Yellamelli *et al.,* 2023), limiting their applicability to young African adults. In Nigeria—where obesity has been reported to affect 8.4% of female university students (Ukegbu *et al.,* 2017)—few or no accessible studies have examined the relationship between BMI and tear film parameters such as Florescein Tear Break-up Time (FTBUT), Tear Meniscus Height (TMH), and Ocular Surface Disease Index(OSDI) in this population. As such there is a need to fill this gap in population representativeness and contribute essential data on obesity and the ocular surface in this understudied demographic by investigating the relationship between BMI and tear film stability using these parameters in a young Nigerian adult population of both sexes.

## 1.3. AIM AND OBJECTIVES

### 1.3.1 Aim of the Study

To investigate the relationship between tear film stability and body mass index (BMI) among students visiting the Optometry Clinic, University of Benin.

### 1.3.2 Objectives of the Study

1. To determine the tear film stability (using Fluorescein Tear Break-up Time (FTBUT) and Tear Meniscus Height(TMH)) in young Nigerian students visiting the Optometry clinic, University of Benin.
2. To assess the level of dry eye symptoms using the Ocular Surface Disease Index (OSDI) in the study population.
3. To measure the body mass index (BMI) of participants and classify them based on standard categories of normal weight (BMI 18.5–24.9 kg/m²) and overweight/obese (BMI ≥ 25 kg/m²)
4. To analyse the relationship between BMI and each of the tear film parameters (FTBUT, TMH, and OSDI).
5. To compare the tear film parameters across the BMI categories.

## 1.4. RESEARCH QUESTIONS AND NULL HYPOTHESES

**Research Questions:**

1. What are the tear film parameters (FTBUT, TMH) and OSDI scores among visiting the Optometry clinic, University of Benin?
2. What is the BMI distribution among the study participants?
3. Is there a significant relationship between BMI and tear film parameters (FTBUT, TMH)?
4. Is there a significant relationship between BMI and dry eye symptoms as measured by the OSDI?

5. Do tear film parameters and OSDI scores differ significantly across BMI categories (normal, overweight, obese)?

**Null Hypotheses ($H_0$):**

1. There is no significant relationship between body mass index (BMI) and Fluorescein Tear Break-Up Time (FTBUT) among students visiting the Optometry clinic, University of Benin.
2. There is no significant relationship between BMI and Tear Meniscus Height (TMH) in the study population.
3. There is no significant relationship between BMI and Ocular Surface Disease Index (OSDI) scores among participants.
4. There is no significant difference in tear film parameters (FTBUT, TMH) and OSDI scores across different BMI categories.

## 1.5. SIGNIFICANCE OF THE STUDY

1. This study will provide local data on the relationship between BMI and tear film stability in young Nigerian students, a population underrepresented in current literature.
2. It will help identify whether high BMI is a contributing factor to tear film instability or dry eye symptoms in this demographic.
3. It can guide optometrists and other eye care professionals in recognising whether obesity is a possible risk factor for ocular surface disorders.
4. It may support the integration of dry eye assessments in general health screenings, especially in university clinics.
5. It will serve as baseline data for future research on obesity-related ocular surface changes in African populations.
6. It may influence preventive strategies and promote lifestyle interventions aimed at improving both ocular and systemic health among students.

## 1.6 DEFINITION OF TERMS

1. Tear Film

A thin fluid layer covering the eye surface, composed of lipid, aqueous, and mucin layers.

It plays a crucial role in lubrication, protection, and maintaining clear vision.

2. Tear Film Stability

The ability of the tear film to remain intact and evenly distributed over the ocular surface between blinks. A stable tear film prevents dry eye symptoms and supports clear vision.

3. Body Mass Index (BMI)

A numerical value derived from an individual's weight and height, used to categorise them as underweight, normal weight, overweight, or obese. It is calculated as weight in kilograms divided by the square of height in metres ($kg/m^2$).

4. Tear Break-Up Time (TBUT)

A clinical test that measures the interval between a blink and the appearance of the first dry spot on the cornea. It reflects tear film stability and is considered abnormal if less than 10 seconds.

5. Tear Meniscus Height (TMH)

The vertical height of the tear layer present at the lower eyelid margin. It serves as a measure of tear volume and is commonly assessed using slit-lamp biomicroscopy or imaging systems.

6. Ocular Surface Disease Index (OSDI)

A standardised questionnaire used to evaluate the symptoms of dry eye disease, including discomfort, visual disturbance, and the impact on daily activities. Scores help categorise severity.

7. Obesity

A medical condition characterised by excessive body fat accumulation, often defined as a BMI of 30 $kg/m^2$ or higher. Obesity is associated with systemic and ocular health risks.

8. Dry Eye Disease (DED)

A multifactorial ocular condition involving tear film instability and ocular surface inflammation, leading to symptoms such as dryness, burning, and visual disturbance.

9. Meibomian Glands

Sebaceous glands located in the eyelids that secrete lipids to the tear film's outer layer. Dysfunction of these glands (MGD) can lead to evaporative dry eye and tear instability.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 A Review of Tear-Film Stability and Measurement Approaches

Sweeney *et al.,* (2013) described the tear film as a dynamic, multilayered system composed of lipids, aqueous elements, mucins, and proteins, all of which interact to maintain surface integrity and optical clarity. Central to their argument was the idea that instability arises when any of these components are compromised, whether through biochemical changes, glandular dysfunction, or external stressors. Disruption in lipid secretion or alterations in its composition were identified as major drivers of instability, often leading to increased evaporation rates and reduced breakup time. Equally important were the mucins, which provide wettability by allowing the aqueous phase to spread evenly across the hydrophobic corneal epithelium. A reduction in mucin concentration or function was shown to result in poor adhesion of tears to the ocular surface, producing patchy coverage and early breakup. Tear proteins also featured prominently in their discussion, as they contribute to surface protection and antimicrobial defence, and their imbalance can further compromise tear stability. Beyond intrinsic tear film components, they also drew attention to external and systemic influences that exacerbate instability. Ageing was recognised as a natural contributor, associated with a decline in both aqueous production and lipid secretion. Contact lens wear was noted as another destabilising factor, as lenses can alter lipid distribution, disrupt tear spreading, and interfere with mucin interaction. Including the impact of ocular surgery, which may damage goblet cells or corneal nerves, thereby reducing mucin production and altering blink dynamics. Environmental conditions such as low humidity, wind, and prolonged visual tasks were similarly identified as external stressors that increase evaporation and accelerate instability.

Wilcox *et al.,* (2017) described the tear film not as three neatly separated layers but as a structurally integrated gradient in which mucins interdigitate with the aqueous component and lipids interact at both the aqueous and air interfaces. This reconceptualisation was supported by biochemical studies showing that mucins, particularly MUC5AC from conjunctival goblet cells, extend into the aqueous phase and help stabilise the film by lowering surface tension. The paper also noted that deficiencies in any component – such as reduced goblet cell density or meibomian gland dysfunction – trigger a cascade of instability across the entire tear film rather than producing isolated defects. A particular emphasis was placed on the contribution of tear proteins such as lipocalin, which binds fatty acids and cholesterol to regulate lipid layer composition, and lactoferrin, which supports antimicrobial defence and iron homeostasis. Reduced concentrations of these proteins, consistently reported in dry eye disease, were correlated with shorter breakup times and greater variability in tear film stability. The paper also highlighted that in vivo imaging techniques increasingly confirm the gradient model, with evidence of mucin penetration well beyond the traditional glycocalyx zone.

The Tear Film and Ocular Surface Society's DEWS II(Craig *et al.,* 2017) systematically reviewed evidence on tear-film structure, mechanics, and clinical measurement. Using an expert panel and structured evidence review, the report summarised that tear-film stability is a function of an integrated mucin–aqueous–lipid system, highlighted tear hyperosmolarity as a central mechanism in dry eye, and evaluated diagnostic tests (TBUT/NIBUT, osmolarity, TMH) for sensitivity and specificity across populations. TFOS DEWS II argues that tear-film instability is best understood and assessed using complementary approaches that capture mechanics (break-up), quantity (meniscus/volume) and patient symptoms, because any single test alone incompletely represents the disease state. Let us consider a few of these tests;

**Fluorescein TBUT**

Paugh *et al.,* (2019) evaluated the clinical efficacy of the fluorescein tear breakup time (TBUT) test for diagnosing dry eye. Their research comprised two components: an efficacy study comparing three methods (dry eye test strip, standard strip, and liquid fluorescein) and a verification study examining TBUT across two precise volumes of liquid sodium fluorescein—2.0 µL and 5.0 µL—using video-recorded measurements to enhance objectivity (e.g., via masked examiner). Results showed that all three methods reliably differentiated between dry eye and normal subjects with strong statistical significance. In the efficacy arm, sensitivities ranged from 90–97%, and specificities varied between 67–87%, depending on method. Receiver Operating Characteristic (ROC) analyses revealed robust discriminatory power: area under the curve (AUC) values ranged from 0.873 to 0.912. The verification arm further reinforced these findings. Using 2.0 µL of fluorescein, the optimal cutoff (~6.05 seconds) produced an AUC of 0.917, with sensitivity at 87% and specificity 81%. Similarly, with 5.0 µL, the AUC climbed to 0.940, with sensitivity and specificity of 92% and 83%, respectively, using a cutoff near 5.5 seconds. The study concluded that TBUT, when delivered with controlled volumes of fluorescein dye and measured under objective conditions, offers excellent diagnostic accuracy for dry eye—especially using thresholds around 5.3–6.0 seconds to distinguish normal from pathological

**Tear Meniscus Height (TMH)**

Niedernolte *et al.,* (2021) conducted a systematic evaluation of different clinical methods used to measure tear meniscus height (TMH), with the aim of determining their agreement and reliability in clinical practice. TMH is widely recognised as a surrogate measure for tear volume and an important parameter in diagnosing aqueous-deficient dry eye, yet its accuracy is strongly influenced by the measurement technique employed.

The study involved 60 participants, and TMH was assessed using four approaches: slit-lamp biomicroscopy with a graticule, anterior segment optical coherence tomography (AS-OCT), a keratograph, and digital slit-lamp photography. Each method was performed under controlled conditions, and repeated measurements were analysed to determine intra-observer repeatability and agreement between methods.

Results showed that the mean TMH values varied significantly depending on the technique used. AS-OCT produced the highest TMH readings, with a mean of 0.29 ± 0.09 mm, while slit-lamp biomicroscopy yielded comparatively lower values, averaging 0.22 ± 0.07 mm. The keratograph and digital photography methods produced intermediate results. Importantly, the repeatability of AS-OCT was superior, with narrower limits of agreement and lower variability across repeated measurements. By contrast, slit-lamp biomicroscopy demonstrated higher inter- and intra-observer variability, reflecting the challenges of relying on manual estimation.

The authors concluded that while all four techniques provide clinically useful information, AS-OCT offers the most reliable and reproducible method for measuring TMH. However, in settings where OCT is not available, slit-lamp–based techniques can still serve as practical alternatives, provided clinicians are aware of their tendency to underestimate tear volume and their greater susceptibility to observer bias.

In a 2010 study by Fodor *et al.,* the lower tear meniscus height (LTMH) was measured in 31 healthy volunteers (mean age 31.3 ± 4.8 years) using three techniques: Tearscope imaging, slit-lamp without fluorescein, and slit-lamp with fluorescein staining. The results showed remarkably similar mean LTMH across methods—0.21 mm (± 0.07) for Tearscope, 0.20 mm (± 0.06) without fluorescein, and 0.23 mm (± 0.07) with fluorescein. Statistical analysis revealed no significant difference among these values ($p = 0.05$), highlighting the validity of slit-lamp measurement even without specialized equipment. Although Tearscope showed

marginally better repeatability, the slit-lamp methods maintained acceptable consistency, confirming their appropriateness in routine clinical settings

Ocular Surface Disease Index (OSDI) Schiffman *et al.,*(2000), in their seminal study *Reliability and Validity of the Ocular Surface Disease Index*, developed and validated the OSDI questionnaire as a standardised tool for assessing dry eye symptoms and their impact on vision-related functioning. The validation study included 109 participants: 79 with dry eye of varying severity and 30 without ocular surface disease. The OSDI consists of 12 questions covering three subscales: ocular symptoms, vision-related function, and environmental triggers, scored on a scale from 0 to 100 (higher scores indicate greater disability). Test–retest reliability was high (intraclass correlation coefficient = 0.82), and the OSDI demonstrated strong discriminative ability, with mean scores of 44.2 ± 20.2 in the dry eye group versus 13.0 ± 14.5 in controls ($p < 0.001$). The authors concluded that the OSDI is a valid, reliable, and practical method for quantifying subjective symptoms of dry eye and is particularly valuable for complementing objective tear function tests in both clinical and research settings.

Gialelis *et al.,* (2022) in the study "Comparison of the OSDI Questionnaire, the Tear Film Break-up Time and Schirmer's test for the Evaluation of Tear Film in Computer and Contact Lens users Without Dry Eye Symptoms", evaluated the effectiveness of the OSDI questionnaire, TBUT, and Schirmer test in detecting dry eye symptoms among 50 healthy university students aged 18–24 years, comprising both contact lens wearers and non-wearers. Each participant underwent the OSDI, TBUT, and Schirmer tests. The findings revealed a statistically significant inverse correlation between OSDI scores and both TBUT and Schirmer test results ($p < 0.05$), indicating that higher subjective symptom scores were associated with lower tear film stability and volume. The study concluded that the combined

use of OSDI and TBUT is an effective approach for evaluating tear film status, even in asymptomatic individuals.

**Tear Film Instability among young persons**

Rosenfield (2011), in a comprehensive review titled *"Computer Vision Syndrome: A Review of Ocular Causes and Potential Treatments,"* synthesized observational and experimental research on how prolonged visual display terminal (VDT) use—especially computers, smartphones, and tablets—impacts tear-film stability. The review notes that extended screen exposure leads to a reduced blink rate (sometimes by over 60%) and increased incomplete blinking, both of which directly compromise tear-film integrity and reduce TBUT. Experimental studies within the review reported that even 30–45 minutes of continuous computer work can reduce TBUT by 20–25% in healthy individuals, and symptomatic surveys linked longer screen hours to increased ocular discomfort and visual fatigue. Rosenfield also discusses potential mitigations (e.g., blink reminders, ergonomic adjustments, and environmental humidity control) that restore TBUT toward baseline.

Idu *et al.,* (2024) conducted a controlled study on 300 undergraduate students of the University of Benin to assess the effects of smartphone use on tear film quantity and quality. Participants, with a mean age of 20.8 ± 2.3 years, were subjected to tear assessment before and after continuous smartphone use for 60 minutes. Tear quantity was measured using the Schirmer test, while tear quality was evaluated using the invasive tear breakup time (TBUT) method. The results demonstrated a statistically significant reduction in both tear volume and stability after the smartphone session. Specifically, mean Schirmer values dropped from 17.08 ± 3.01 mm to 14.71 ± 2.63 mm in the right eye, and from 17.01 ± 2.63 mm to 14.91 ± 2.47 mm in the left eye ($p < 0.05$). Similarly, TBUT decreased from 16.17 ± 2.90 s to 14.26 ± 2.67 s in the right eye, and from 16.17 ± 2.74 s to 14.46 ± 2.67 s in the left eye ($p < 0.05$). The study concluded that prolonged smartphone viewing induces measurable compromise of

the tear film, predisposing students to early symptoms of digital eye strain and potentially contributing to ocular surface instability.

## 2.2 REVIEW OF BMI

Originally introduced by Adolphe Quetelet in the 19th century as the *Quetelet Index*, it was later renamed BMI and gained widespread acceptance as a population-level measure of adiposity.

Nuttall (2015), in the paper *"Body Mass Index: Obesity, BMI, and Health: A Critical Review"*, examined the origins, applications, and limitations of BMI as a measurement tool for categorising individuals based on body weight relative to height. The study explained that BMI, calculated as weight in kilograms divided by height in metres squared ($kg/m^2$), has been widely adopted due to its simplicity, non-invasiveness, and low cost. It correlates moderately with more direct measures of body fat such as dual-energy X-ray absorptiometry (DEXA) and underwater weighing, making it useful in large-scale epidemiological studies. However, the review also noted that BMI does not differentiate between fat mass and lean body mass, and can misclassify muscular individuals as overweight or obese. Despite these limitations, the study concluded that BMI remains a valuable screening tool for identifying populations at risk of weight-related health conditions, especially when combined with other anthropometric or metabolic assessments.

Ukegbu *et al.,* (2020) conducted a cross-sectional study involving university students from five tertiary institutions in Southeast Nigeria to examine dietary patterns and their association with overweight and obesity. Using a validated food frequency questionnaire, the authors identified unhealthy dietary behaviours characterised by frequent consumption of snacks, fried foods, and sugar-sweetened beverages. And then using body

mass index (BMI) calculated from measured weight (kg) and height ($m^2$), the study applied World Health Organization criteria to categorize participants. Out of 580 students surveyed (mean age ≈ 24.8 years, 51.9% undergraduates), findings indicated 10.5% were underweight, 18.7% overweight, and 7.2% obese. Analysis revealed females exhibited higher rates across all BMI categories compared to males, and overweight/obese students had a significantly higher prevalence of hypertension (8.1%) and pre-hypertension (35.1%). These findings highlight the susceptibility of university students to weight-related health risks, likely influenced by poor dietary choices.

**2.3 BMI AND OCULAR HEALTH**

Panon *et al.,* (2019) investigated the correlation between BMI and various ocular parameters and their analysis revealed that higher BMI values were significantly associated with increased intraocular pressure (IOP). One of the central findings of the study was a positive correlation between higher BMI and intraocular pressure (IOP). Individuals with elevated BMI were more likely to present with increased IOP values, an observation with direct clinical relevance since raised IOP remains a major risk factor for the onset and progression of glaucoma. The authors suggested that this relationship may stem from increased episcleral venous pressure and altered aqueous humour outflow in obese individuals. Additionally, metabolic disturbances such as insulin resistance and vascular dysregulation, common in

obesity, may compromise ocular blood flow and further influence IOP regulation. The study also observed associations between BMI and corneal thickness as well as anterior chamber depth. Participants with higher BMI tended to have a thicker central cornea, which could affect tonometry readings and lead to overestimation of IOP. However, the authors pointed out that this may not be purely an artefact of measurement. Structural changes in the cornea and anterior segment may reflect genuine biomechanical alterations linked to systemic metabolic and inflammatory states in obesity.

Salehi *et al.,* (2022) synthesised findings from multiple clinical trials to determine how elevated BMI influences ocular morphology, particularly the retina and optic nerve. Across the pooled studies, one of the most consistent findings was a significant association between obesity and increased retinal nerve fibre layer (RNFL) and macular thickness. While the exact mechanism is still debated, the authors suggested that systemic metabolic dysregulation in obesity, including insulin resistance, dyslipidaemia, and chronic low-grade inflammation, could alter retinal metabolism and vascular supply. These systemic disturbances may lead to subtle swelling or thickening in retinal structures, detectable on SD-OCT. It also highlighted that obese individuals often exhibited optic nerve head changes, raising concern about the potential for increased susceptibility to optic neuropathies. These structural changes could reflect impaired ocular blood flow or increased intracranial and intraocular pressure, both of which are more common in individuals with high BMI. Salehi et al. underscored that such alterations, while subclinical in many cases, may predispose obese patients to long-term ocular complications if not monitored. Beyond structural changes, the study also indirectly points towards the ocular surface as another site of vulnerability in obesity. Although SD-OCT primarily evaluates posterior segment and optic nerve parameters, several included studies noted that metabolic and vascular dysregulation in obesity do not spare the anterior segment. Chronic inflammation, oxidative stress, and vascular dysfunction — all heightened

in obesity — may impair tear gland function, reduce meibomian gland quality, and destabilise the tear film. Salehi et al. recognised this broader implication, suggesting that obesity-related ocular changes are not confined to the retina but are part of a systemic ocular response.

Di Rosa *et al.,* (2024) investigated how body mass index (BMI) relates to primary open-angle glaucoma (POAG) risk and severity among individuals of African ancestry. Drawing on the Primary Open-Angle African American Glaucoma Genetics (POAAGG) study, the authors analysed data from 6,634 participants—2,977 diagnosed with POAG and 3,657 controls—with BMI categorised into low (< 18.5 kg/m²), moderate (18.5–24.9), high (25.0–29.9), and very high (≥ 30). Remarkably, they found a significant association between lower BMI and increased POAG risk: every 1 kg/m² decrease in BMI corresponded to an adjusted odds ratio of approximately 1.02 (95% CI: 1.007–1.023; $p = 0.0003$), indicating even mild underweight status confers elevated risk. Beyond risk, among those with POAG, lower BMI was further associated with more severe disease characteristics: larger optic cup-to-disc ratios ($p = 0.007$), poorer visual acuity ($p = 0.04$), and notably faster

functional progression of glaucoma. For instance, eyes of fast-progressing cases had an average BMI of 25.7, whereas slower progressing controls averaged around 30.0 kg/m² ($p = 0.04$). The authors concluded that obesity induces measurable structural changes in the eye that are detectable with high-resolution imaging. They recommended closer ophthalmic surveillance in obese individuals, particularly given the potential overlap between retinal and optic nerve changes and systemic vascular disease.

Bilal *et al.,* (2024) in their paper *The Weight on Sight: Exploring the Links Between Obesity and Ocular Diseases*, presented evidence that obesity is significantly associated with several ocular conditions across both the anterior and posterior segments of the eye. Their synthesis of available clinical studies highlighted obesity as an independent and modifiable risk factor. Clinically, obese individuals were reported to have an increased risk of diabetic retinopathy, largely attributable to the high prevalence of insulin resistance and type 2 diabetes within this group. Evidence also pointed to higher rates of glaucoma among obese patients, with proposed mechanisms including elevated intraocular pressure and impaired optic nerve perfusion. Obesity was further linked with age-related macular degeneration (AMD), where systemic lipid dysregulation and chronic oxidative stress were implicated in accelerating retinal degeneration. The authors also highlighted the relationship between obesity and idiopathic intracranial hypertension (IIH), a condition strongly associated with elevated BMI, often manifesting as papilloedema and visual field defects. Beyond posterior segment

disorders, the evidence reviewed also connected obesity with ocular surface disease, particularly dry eye syndrome. Inflammation and altered lipid metabolism were suggested to compromise meibomian gland function, destabilising the tear film and contributing to symptoms of ocular discomfort.

## 2.4 LINK BETWEEN OBESITY/BMI AND OCULAR PHYSIOLOGY

Pieńczykowska *et al.,* (2025) in the study "Link Between Metabolic Syndrome, Inflammation, and Eye Diseases" discussed how the adipose tissue in obesity is metabolically active, secreting cytokines such as TNF-α, IL-6, and C-reactive protein, which circulate systemically and can disrupt ocular homeostasis. This illustrates how the inflammatory cascade reduces nitric oxide (NO) levels (leading to vasoconstriction), while upregulating adhesion molecules like ICAM-1 and VCAM-1, fostering endothelial dysfunction and vascular damage throughout the ocular microvasculature. Another key pathway detailed in the review is oxidative stress. MetS's metabolic dysregulation promotes excessive production of reactive oxygen species (ROS), overwhelming antioxidant defences. Within the eye, this oxidative burden damages delicate structures: retinal photoreceptors, the optic nerve, and ocular surface cells, accelerating degenerative processes. The authors propose that oxidative mechanisms may underpin tear film disruption, epithelial damage, and ocular surface inflammation, thus linking obesity with dry eye syndromes. Also elevated circulating lipids and dyslipidaemia can compromise the integrity of the choroidal and retinal vasculature, potentially leading to structural changes and hypoperfusion. These vascular alterations are particularly damaging to avascular tissues like the optic nerve head, increasing susceptibility to glaucomatous damage and AMD progression

Rodriguez-Hernandez *et al.,* (2013) highlighted that obesity is not just an excess of body fat but a state of chronic, low-grade inflammation that influences metabolic and vascular

functions throughout the body. Adipose tissue was described as an active endocrine organ, producing adipokines such as leptin, adiponectin, and pro-inflammatory cytokines including TNF-α and interleukins. These biochemical mediators play central roles in systemic inflammation, oxidative stress, and endothelial dysfunction. In the context of ocular physiology, Rodriguez-Hernandez *et al.,* underlined how these systemic processes could compromise ocular tissues dependent on fine vascular and metabolic regulation. For example, they pointed out that oxidative stress and vascular dysregulation in obesity can lead to microvascular changes, increasing susceptibility to conditions like diabetic retinopathy and age-related macular degeneration. Hormonal imbalances, particularly elevated leptin and reduced adiponectin, were also implicated in endothelial stress, which could contribute to unstable tear film dynamics and ocular surface inflammation. Their analysis suggests that eye-related complications may arise as early manifestations of systemic dysfunction driven by excess body weight.

Braich *et al.,*(2016) conducted a case–control study investigating the potential link between dyslipidaemia and meibomian gland dysfunction (MGD), a leading cause of evaporative dry eye. The study demonstrated that individuals with elevated serum lipid levels, particularly low-density lipoprotein (LDL) cholesterol and triglycerides, had significantly higher odds of developing MGD compared to controls. Reported odds ratios ranged between 2.5 and 5 depending on the lipid subtype, indicating a strong association between abnormal lipid profiles and gland dysfunction. The authors proposed that systemic lipid abnormalities may influence meibomian gland physiology, possibly by altering the viscosity and composition of meibum secretions. Such changes could contribute to gland obstruction, reduced lipid-layer integrity, and subsequent tear film instability, thereby reinforcing the systemic–ocular connection between metabolic dysregulation and ocular surface disease.

## 2.5 EVIDENCE OF BMI AND TEAR FILM STABILITY

Alanazi (2019), in a comparative cross-sectional study titled "Tear Film Parameters in High BMI," examined tear film characteristics among 40 male participants aged 22 to 42 years, subdivided into two equal groups based on BMI classification—high and normal. Objective assessments included non-invasive tear breakup time (NITBUT), tear meniscus height (TMH), phenol red thread (PRT) test, and tear ferning (TF) test, alongside the subjective OSDI questionnaire. Findings revealed a statistically significant reduction in NITBUT among participants with high BMI (mean: 8.5 ± 2.8 seconds) compared to those with normal BMI (mean: 14.7 ± 2.8 seconds). Additionally, tear ferning grades were significantly elevated in the high BMI group, indicating reduced tear film quality. Although TMH and PRT values were slightly reduced, these differences were not statistically significant. The high BMI group also reported higher OSDI scores, suggestive of increased ocular surface discomfort, although still within a subclinical range. While the study offers valuable insight by combining both objective and subjective tear film measures, its generalisability is limited by the small sample size and exclusive inclusion of male participants.

Fagehi *et al.,*(2022) assessed tear film parameters among 90 male participants (aged 22–25 years), divided into three groups: individuals with high BMI, smokers, and healthy controls. The study utilised the EASYTEAR View+ device to evaluate NITBUT, TMH, and lipid layer patterns (LLPs), in addition to collecting OSDI data. Results demonstrated a significant reduction in both TMH and LLPs in the high BMI group compared to controls, along with lower NITBUT values. Notably, a strong positive correlation was found between NITBUT and both TMH ($r = 0.552$, $p = 0.002$) and LLPs ($r = 0.555$, $p = 0.001$), suggesting that tear film instability in individuals with elevated BMI may be linked to both aqueous and lipid layer deficiencies. However, its limitation also stems from the restriction to male, caucasian subjects, which may affect how broadly the findings can be applied.

Masmali *et al.,* (2022) investigated the impact of high body mass index on tear film parameters among young adult males. The study involved 60 participants aged 18–35 years, divided into two groups based on BMI classification: a normal-weight group (BMI 18.5–24.9 kg/m²) and an obese group (BMI ≥ 30 kg/m²). Tear film stability and quality were assessed using the tear film osmolarity test, tear meniscus height (TMH) measurement, non-invasive tear break-up time (NITBUT), and Ocular Surface Disease Index (OSDI) questionnaire. The results showed that obese participants exhibited significantly higher tear osmolarity and shorter NITBUT values compared to normal-weight individuals ($p < 0.05$), indicating increased tear evaporation and compromised tear film stability. Additionally, OSDI scores were notably higher among obese participants, reflecting greater subjective discomfort and dryness symptoms. Although the TMH values were slightly lower in the obese group, this difference did not reach statistical significance.

Masmali *et al.,*concluded that obesity exerts a measurable negative effect on tear film stability and ocular surface homeostasis even in the absence of overt systemic disease. They

attributed these changes to low-grade chronic inflammation and oxidative stress commonly associated with excess adiposity, which may alter lacrimal gland secretion and meibomian gland lipid composition. This study thus reinforces the hypothesis that metabolic dysregulation linked with obesity can impair tear film integrity and predispose individuals to dry eye symptoms, particularly through mechanisms involving inflammatory cytokine upregulation and altered lipid-layer function.

Expanding the demographic scope, a study by Bayat *et al.,*(2022) investigated the impact of childhood obesity on ocular surface parameters. This prospective comparative study included 85 eyes from obese children and 75 eyes from healthy controls. Assessments encompassed tear film break-up time (TF-BUT), TMH, tear meniscus area (TMA), Schirmer test scores, and OSDI scores. Findings indicated that the TMH, TMA, TF-BUT, and Schirmer test results were statistically significantly lower in the obesity group ($p < 0.001$ for all). Furthermore, children with obesity and insulin resistance exhibited even lower values in these parameters compared to those without insulin resistance ($p < 0.05$ for all). A significant correlation was observed between BMI and the measured ocular surface parameters ($p < 0.001$ for all). The findings reinforce the systemic impact of obesity on ocular physiology and support the need for early screening and targeted interventions in at-risk populations.

On the other hand, Tummanapalli *et al.,*(2020) examined whether age, gender and body mass index (BMI) influence concentrations of tear-film neuromediators and morphology of corneal sub-basal nerves in a cohort of healthy adults. Twenty-six volunteers (15 male; mean age 36 ± 12 years; mean BMI 25 ± 4 kg/m²) were screened to exclude neurological disease, after which tears were sampled and corneal nerve fibres imaged by in-vivo confocal microscopy. Tear concentrations of substance P and calcitonin gene-related peptide (CGRP) were quantified by enzyme-linked immunosorbent assay (ELISA), while corneal nerve parameters

(nerve fibre density, nerve fibre length, fractal dimension, etc.) were extracted using automated image analysis.

The study reported median [IQR] tear concentrations of substance P = 715 [372–1463] pg·mL$^{-1}$ and CGRP = 38 [15–74] ng·mL$^{-1}$. Moderate, statistically significant positive correlations existed between substance P concentration and corneal nerve fibre density (r =0.467, P = .016), nerve fibre length (r = 0.528, P = .006) and nerve fractal dimension ($r_s$ = 0.614, P = .002), indicating that higher tear levels of this neuropeptide accompany greater corneal nerve structural metrics. Crucially, the analysis identified clear age-related declines: substance P fell at an estimated ~6% per year (P = .001) and CGRP at ~8% per year (P < .001). Corneal nerve fibre density decreased by 0.171 fibres/mm² per year (P = .029) and nerve fractal dimension declined modestly with age (P = .021). By contrast, neither gender nor BMI showed significant independent relationships with tear neuromediator concentrations or corneal nerve measures in univariate or adjusted regression models.

From these results, the authors concluded that ageing, but not gender or BMI within this healthy sample, was associated with reductions in tear neuropeptides and measurable loss in corneal nerve architecture. The observed positive correlation between substance P and nerve metrics supports a biologically plausible link between peripheral nerve integrity and neurochemical milieu of the tear film. Methodologically, use of ELISA for neuromediator quantification and automated confocal-microscopy image analysis provided robust objective data; however, the small sample size (n = 26), the cross-sectional design and a mean BMI at the borderline of the normal/overweight range (25 ± 4 kg/m²) limit the power to detect modest BMI effects or to generalise findings to obese or metabolically disordered populations. In other words, absence of an observed BMI effect in this study should not be interpreted as definitive evidence that adiposity never influences tear neuromediators or corneal nerves—

rather, it indicates that in a group of generally healthy adults with largely normal BMI, age is the dominant determinant of the measures studied.

Clinically and conceptually, the study highlights two practical points for ocular surface research and practice: first, age must be accounted for when using tear neuromediator levels or corneal nerve metrics as biomarkers (for diagnosis, progression or response to therapy); second, investigations into BMI-related ocular changes should prioritise cohorts with a wider BMI range and metabolic characterisation to determine whether systemic metabolic dysregulation (rather than BMI per se) modifies tear neurochemistry or corneal innervation.

## 2.6 GAPS IN THE LITERATURE

Despite the growing body of research on tear film stability and its relationship with systemic or lifestyle factors, several notable gaps remain in the literature that this study aims to address. First, many of the existing studies have focused on older adults, children, or clinical populations, often overlooking young adults who form a distinct and important age bracket. Young adults, particularly students in tertiary institutions, are a unique population whose ocular health can be influenced not only by physiological factors such as body mass index (BMI), but also by lifestyle patterns, visual demands, and academic pressures. Yet, this group has not been adequately studied, leaving a gap in understanding how early manifestations of tear film instability might present in this relatively younger demographic. Studying this age population is important, as it provides an opportunity to identify early risk patterns that could predispose to ocular surface disease later in life, thereby strengthening preventive and interventional strategies.

Secondly, much of the published research on the relationship between BMI and ocular surface health originates from Western or Asian populations, with very limited contributions from African settings. This lack of data from African, and particularly Nigerian, populations

presents a significant gap given the unique genetic, environmental, and lifestyle factors that may influence ocular physiology differently across regions. Such context-specific data are essential to ensuring that conclusions drawn from international studies are not inappropriately generalised to African populations without considering regional variations.

A third limitation observed in existing literature is the tendency for studies to disproportionately sample one gender, often excluding the possibility of meaningful comparisons between males and females. Given that hormonal influences, lifestyle patterns, and ocular physiology can vary across genders, the lack of gender-inclusive sampling limits the generalisability and depth of such studies. For instance, hormonal fluctuations in females, particularly related to oestrogen and androgen levels, have been shown to influence tear film composition and stability. Similarly, differences in BMI distribution and lifestyle behaviours across genders may lead to varying ocular outcomes. Yet, by not integrating both genders in adequate proportions, many studies fail to capture these potentially significant variations. This study, therefore, takes an integrative approach by including both male and female students, allowing for the possibility of identifying gender-specific trends and differences in the relationship between BMI and tear film parameters.

Therefore this research is uniquely positioned to fill these critical gaps: it examines an underrepresented young adult student population, generates data from an African, specifically Nigerian, context where there is a scarcity of published work on the topic, and adopts a gender-inclusive framework that allows for more nuanced comparisons. These contributions are expected not only to expand the scientific understanding of tear film stability but also to provide regionally and demographically relevant insights that can inform clinical practice and guide future research directions.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 RESEARCH DESIGN
The study was done as a cross-sectional comparative study

## 3.2 RESEARCH LOCATION
The study was conducted at the Optometry Clinic, University of Benin, Edo State, Nigeria.

## 3.3 STUDY POPULATION
Undergraduate students of the University of Benin.

## 3.4 SAMPLING TECHNIQUE/SAMPLE SIZE DETERMINATION
**A convenience sampling method was used.**

The sample size for this study was calculated using the formula for a quantitative cross-sectional study

$$n = \frac{(Z_{1-}\alpha/_2)^2 \times SD^2}{d^2}$$

n = Sample size

$Z_{1-}\alpha/_2$ = Is standard normal variate (at 5% type 1 error (P<0.05) it is 1.96)

SD = Standard deviation of the FTBUT among University of Benin students (SD for SE = 2.67 seconds from a previous study by Idu *et al.,* (2020).

d = Margin of error (precision) (For high precision ± 0.5 seconds).

$$n = \frac{(1.96)^2 \times (2.67)^2}{(0.25)^2}$$

$$n = \frac{3.8416 \times 7.1289}{0.25}$$

$$n = \frac{27.42}{0.25}$$

n = 109.68

$n$ = ~ 110 participant/eyes

## 3.5 RESEARCH MATERIALS
The following materials and instruments were used for data collection:

1. Digital weighing Scale – for measuring participants' body weight in kilograms.

2. Measuring Tape – for measuring participants' height in metres.
3. BMI Calculator – for classifying body mass index according to WHO standards.
4. Slit Lamp Biomicroscope – for assessing tear film parameters, including FTBUT and TMH.
5. Fluorescein Strips – for conducting the Fluorescein Tear Break-Up Time test.
6. Timer – to measure tear break-up time in seconds.
7. OSDI Questionnaire – for evaluating participants' dry eye symptoms.
8. Data Recording Sheets or Forms – to record anthropometric, clinical, and questionnaire data.
9. Consent Forms – for obtaining informed consent from participants.

### 3.6 INCLUSION/EXCLUSION CRITERIA

**Inclusion Criteria**

1. Students aged 16–30 years
2. Willingness to participate and provide informed consent
3. No current use of ocular medications or contact lenses

**Exclusion Criteria**

1. History of ocular surgery or trauma
2. Known diagnosis of systemic conditions such as diabetes, hypertension, thyroid dysfunction
3. Smokers or individuals with known allergies affecting the eyes

### 3.7 DESCRIPTION OF PROCEDURE

**1.Recruitment and Informed Consent**

Participants were recruited within the University of Benin and only those who met the inclusion criteria (e.g., age, general health, no systemic condition, etc) were eligible to move to the next stage. They were iinformed about the study's purpose, procedures, and potential risks, and written informed consent were obtained before participation.

**2.Anthropometric Measurements**

a. Height and weight were measured using a measuring tape and a digital weighing scale, respectively. These measurements were used to calculate BMI ($kg/m^2$).

b. Participants were classified according to the World Health Organization's BMI categories for normal and overweight/obese.

**3.Symptom Evaluation (OSDI)**

Participants completed the Ocular Surface Disease Index (OSDI) questionnaire to assess their dry eye symptoms. This helped provide a subjective measure of dry eye severity, and the scores were categorized based on standard OSDI scoring guidelines.

**4. Data Recording**

All measurements (BMI, FTBUT, TMH, OSDI) were recorded on standard data collection sheets. Data was securely stored and anonymised to ensure participant confidentiality.

**5. Tear Film Stability Assessments**

a. Fluorescein Tear Break-Up Time (FTBUT): A fluorescein strip was applied to the inferior palpebral conjunctiva. After applying the strip, the participant was asked to blink, and the time until the first dry spot appeared on the cornea was measured under a slit lamp with a cobalt blue filter and recorded.

b. Tear Meniscus Height (TMH): Using the slit lamp, the tear meniscus height was measured at the inferior lid margin. The measurement was recorded in millimetres.

### 3.8 DATA ANALYSIS

All collected data were analysed using the Statistical Package for the Social Sciences (SPSS), version 25.0. Descriptive statistics such as mean, standard deviation, frequency, and percentage were employed to summarise participants' demographic characteristics and clinical parameters, including age, gender, spectacle and contact lens use, Body Mass Index (BMI), Ocular Surface Disease Index (OSDI) score, Tear Meniscus Height (TMH), and Fluorescein Tear Break-Up Time (FTBUT). Cross-tabulations were used where necessary to display categorical distributions.

Participants' BMI values were categorised according to the World Health Organization classification (underweight, normal weight, overweight, and obese). Comparative analyses of tear film parameters (FTBUT, TMH, and OSDI) across these BMI categories were performed using the independent samples t-test and one-way ANOVA, as appropriate.

Pearson's correlation coefficient (r) was used to assess the strength and direction of the linear relationship between BMI and the continuous tear film parameters (FTBUT, TMH, and OSDI). In addition, gender-based comparisons were performed to evaluate possible sex-related variations in tear film indices.

A p-value of less than 0.05 ($p < 0.05$) was considered statistically significant for all analyses

### 3.9 ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Research and Ethics Committee of the Faculty of Optometry, University of Benin. The REC approval number is EC/UBEN/LSC.OPT/25/153 Informed consent was secured from all participants. Confidentiality and data privacy was maintained throughout the study.

## 3.10 LIMITATIONS OF THE STUDY

1. The study's cross-sectional design restricts causal interpretation.
2. The sample comprised only students within a limited age range (18–27 years), limiting generalisability to broader populations.
3. Tear film assessment relied on TBUT and TMH without complementary lipid-layer analysis or inflammatory biomarker evaluation.
4. Potential confounding variables such as screen time, diet, or hormonal status were not controlled.

# CHAPTER FOUR

# RESULTS

The results are organized into sections based on demographic information, descriptive statistics of key variables, tests of normality, and the relationships between body mass index (BMI) and ocular surface parameters, including Ocular Surface Disease Index (OSDI) score, tear meniscus height, and tear break-up time (TBUT).

The demographic characteristics of respondents, as shown in Table 1, revealed that most participants (50.8%) were within the age group of 21 to 23 years, followed by 20.0% who were between 24 and 25 years, 15.8% aged 18 to 20 years, and 13.3% aged 25 to 27 years. Gender distribution indicated that females accounted for 55.8% of the sample, while males made up 44.2%.

The distribution of spectacle and contact lens use among respondents is presented in Table 2. A slight majority (51.7%) of participants reported not wearing spectacles, while 48.3% indicated that they do. Regarding contact lens use, most respondents (85.0%) reported that they do not wear contact lenses, while 15.0% indicated that they do.

Descriptive statistics of the key study variables are presented in Table 3. The mean age of respondents was 22.65 ± 2.24 years, while the mean BMI was 24.57 ± 5.40 kg/m². The mean OSDI score was 24.68 ± 15.18, with values ranging from 0.00 to 66.00. The mean tear meniscus height was 0.22 ± 0.09 mm, and the mean tear break-up time was 11.97 ± 4.09 seconds, suggesting that most participants had stable tear films within physiological limits.

Tests of normality were conducted for the main study variables. The Kolmogorov–Smirnov and Shapiro–Wilk tests indicated $p < .05$ for all variables, confirming that the data were not normally distributed. Consequently, non-parametric (Spearman's rho) correlation analyses were employed for further analysis.

Correlation analyses, presented in Tables 4 to 6, examined the relationships between BMI and ocular surface parameters. A weak positive correlation was found between BMI and OSDI score ($r = .117$, $p = .205$), a weak negative correlation between BMI and tear meniscus height ($r = –.170$, $p = .063$), and a negligible negative correlation between BMI and tear break-up time ($r = –.006$, $p = .946$). None of these relationships were statistically significant ($p > .05$).

**TABLE 4.1: DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS**

| | Categories | Frequency | Percentage |
|---|---|---|---|
| Age group | 18 - 20 | 19 | 15.8% |
| | 21 - 23 | 61 | 50.8% |
| | 24-25 | 24 | 20.0% |
| | 25-27 | 16 | 13.3% |
| | Total | 120 | 100.0% |
| Gender | Female | 67 | 55.8% |
| | Male | 53 | 44.2% |
| | Total | 120 | 100.0% |

The majority (50.8%) were aged between 21 and 23 years, followed by 20.0% who were between 24 and 25 years, 15.8% aged 18 to 20 years, and 13.3% aged 25 to 27 years. In terms of gender, 55.8% of the respondents were female, while 44.2% were male.

**TABLE 4.2: SPECTACLE AND CONTACT LENS USE AMONG PARTICIPANTS**

| | | Frequency | Percentage( %) |
|---|---|---|---|
| Do you wear spectacles? | No | 62 | 51.7% |
| | Yes | 58 | 48.3% |
| | Total | 120 | 100.0% |
| Do you wear contact lenses? | No | 102 | 85.0% |
| | Yes | 18 | 15.0% |
| | Total | 120 | 100.0% |

As shown in Table 4.2, 51.7% of respondents reported not wearing spectacles, while 48.3% indicated that they do. Regarding contact lens use, 85.0% of the respondents reported that they do not wear contact lenses, whereas 15.0% indicated that they do.

**TABLE 4.3: DESCRIPTIVE STATISTICS OF AGE, BODY MASS INDEX, AND OCULAR SURFACE PARAMETERS**

| | Mean ± S.D | Minimum | Maximum |
|---|---|---|---|
| Age (years) | 22.65 ± 2.24 | 18 | 27 |
| Body mass Index(BMI in kg/m2) | 24.57 ± 5.40 | 16.60 | 39.60 |
| OSDI Score[1] | 24.68 ± 15.18 | 0.00 | 66.00 |
| Tear Meniscus Height (mm) | 0.22 ± 0.09 | 0.09 | 0.44 |
| Tear Break up time (secs) | 11.97 ± 4.09 | 5.00 | 25.00 |

The mean age of respondents was 22.65 ± 2.24 years, with a range of 18 to 27 years. The mean body mass index (BMI) was 24.57 ± 5.40 kg/m², ranging from 16.60 to 39.60. The mean Ocular Surface Disease Index (OSDI) score was 24.68 ± 15.18, with scores ranging from 0.00 to 66.00. The mean tear meniscus height was 0.22 ± 0.09 mm , ranging from 0.09 to 0.44 mm. The average tear break-up time was 11.97 ± 4.09 seconds, ranging between 5.00 and 25.00 seconds.

[1] **Note.** OSDI = Ocular Surface Disease Index.

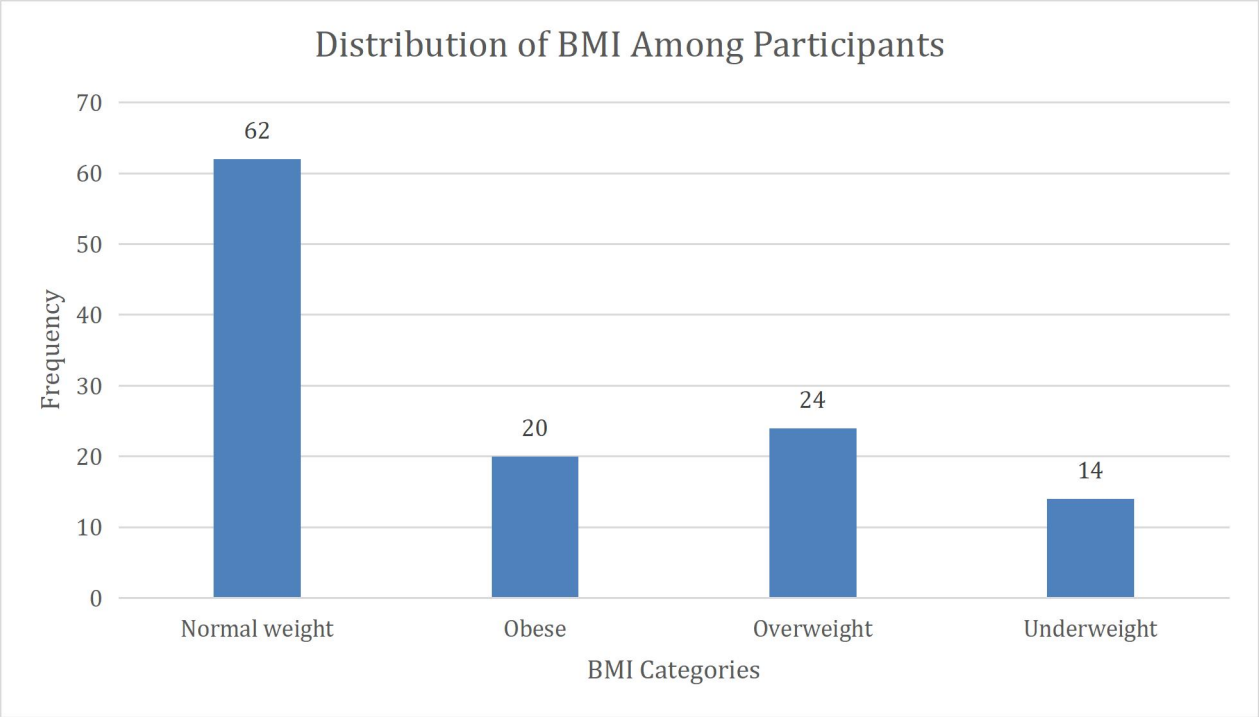



**Figure 1: Distribution of Respondents by Body Mass Index Category**
Out of 120 respondents, 51.7% were of normal weight, 20.0% overweight, 16.7% obese, and

11.7% underweight.

**TABLE 4.4: HYPOTHESIS TEST SUMMARY FOR OCULAR SURFACE PARAMETERS ACROSS BMI CATEGORIES**

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of OSDI Score is the same across categories of Body mass index categories. | Independent-Samples Kruskal-Wallis Test | .328 | Retain the null hypothesis. |
| 2 | The distribution of Tear Meniscus Height (mm) is the same across categories of Body mass index categories. | Independent-Samples Kruskal-Wallis Test | .132 | Retain the null hypothesis. |
| 3 | The distribution of Tear Break up time (secs) is the same across categories of Body mass index categories. | Independent-Samples Kruskal-Wallis Test | .921 | Retain the null hypothesis. |

The Kruskal–Wallis test results show that there were no statistically significant differences in OSDI scores ($p = 0.328$), tear meniscus height ($p = 0.132$), or TBUT ($p = 0.921$) across BMI categories.

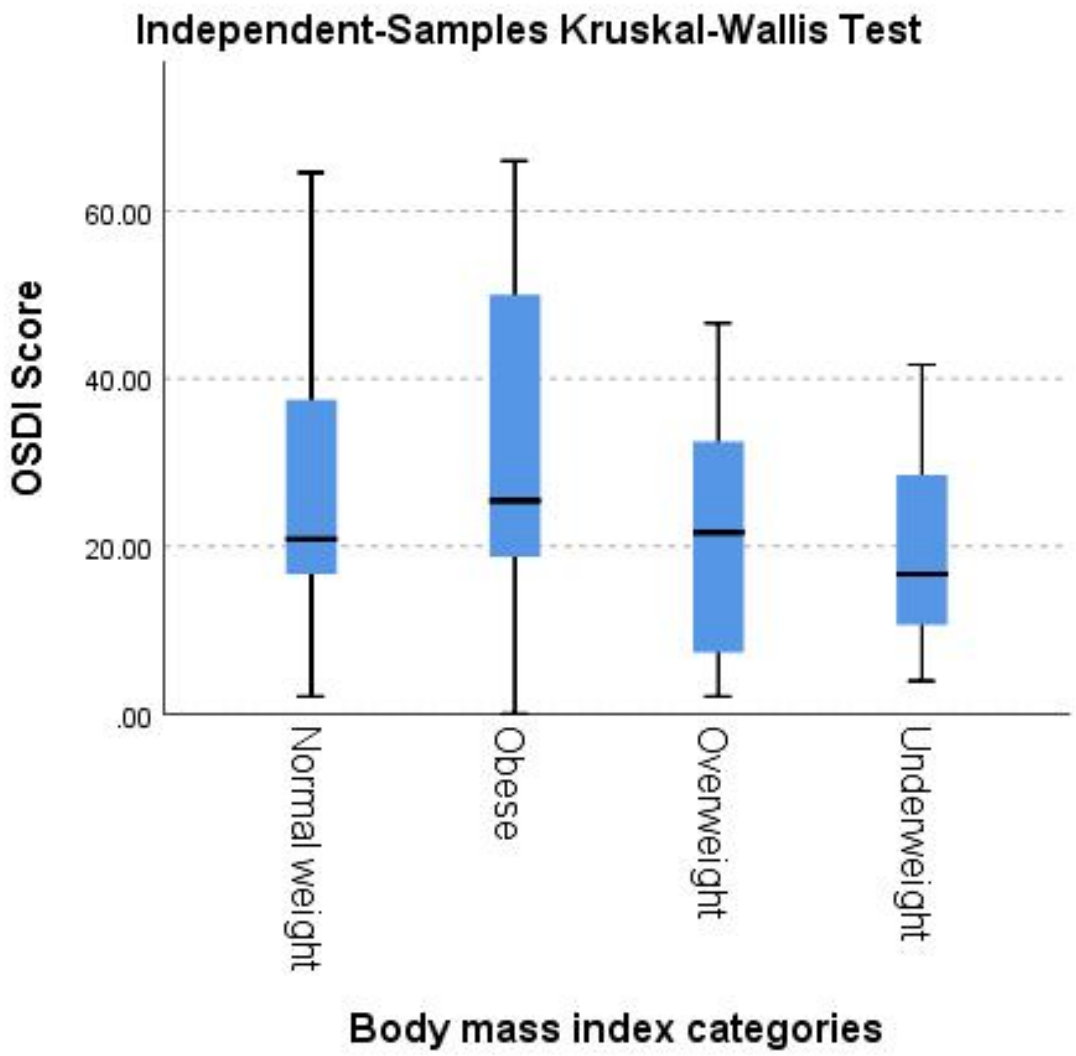



**FIGURE 2: Distribution of Ocular Surface Disease Index (OSDI) Scores across Body Mass Index Categories**

The obese category demonstrated the highest median OSDI score, approximately 25–30, and exhibited the widest range of variability, extending up to around 65. The normal weight group displayed a median OSDI score of around 20, with a broad interquartile range. Participants in the overweight category had a median OSDI score near 22, with a narrower interquartile range compared to the obese group. The underweight group recorded the lowest median OSDI score, approximately 15, with a relatively narrow range.

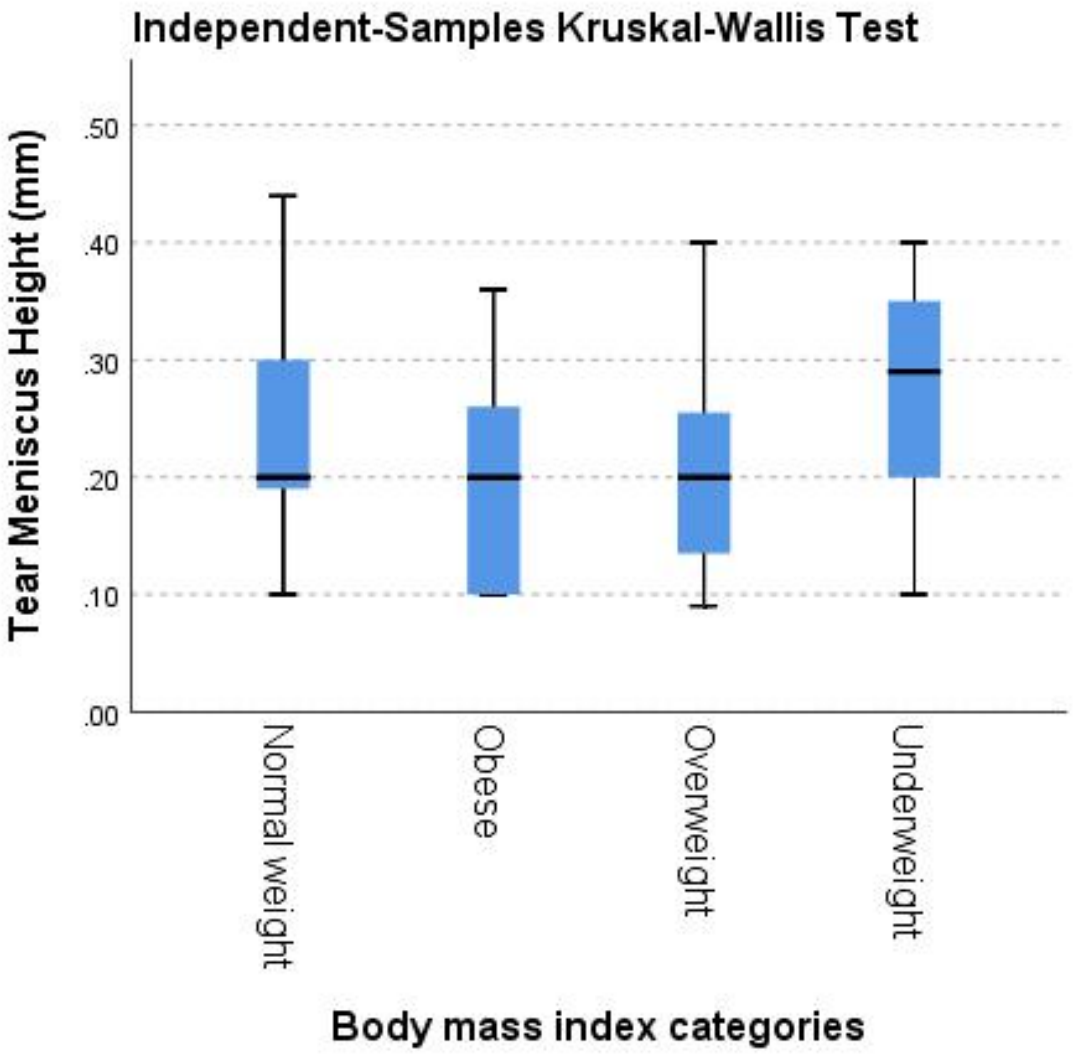



**FIGURE 3: Comparison of Tear Meniscus Height Among Different Body Mass Index Categories**

The underweight category showed the highest median value, approximately 0.30 mm, suggesting a greater tear volume. The normal weight group recorded a slightly lower median tear meniscus height of about 0.22 mm with moderate variability, while the overweight group displayed a median of roughly 0.20 mm. The obese category exhibited the lowest median tear meniscus height, approximately 0.18–0.20 mm, and the smallest interquartile range, indicating lower tear film volume and less variability within the group

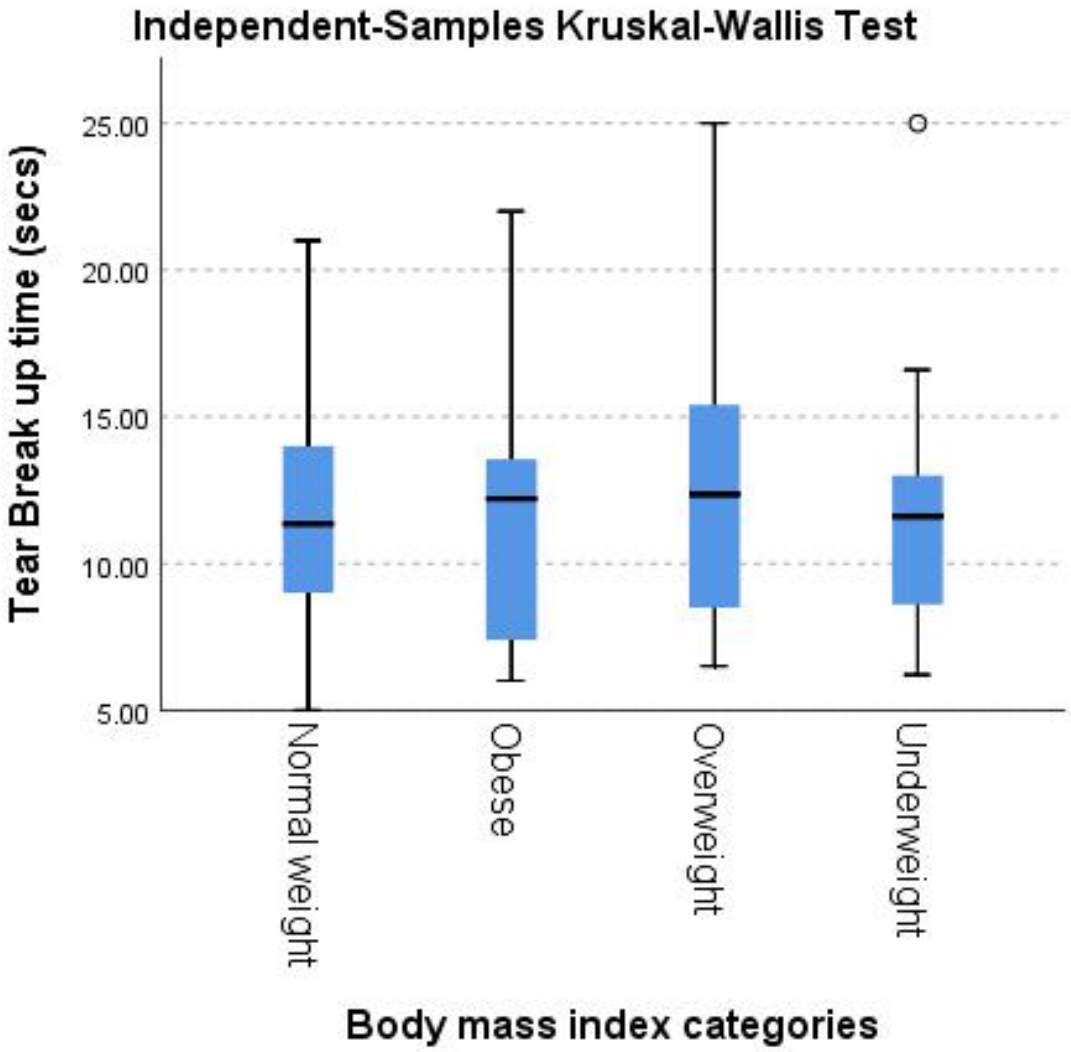



**FIGURE 4: Comparison of Tear Break-Up Time Among Different Body Mass Index Categories**

The overweight group demonstrated the highest median TBUT, approximately 13–14 seconds, with a relatively wide range extending up to about 25 seconds. The obese group had a median TBUT close to 12 seconds, with moderate variability and a range extending from around 7 to 20 seconds. The normal weight group recorded a median TBUT of roughly 11 seconds, with a slightly narrower interquartile range than the overweight and obese categories. The underweight group exhibited the lowest median TBUT, approximately 10–11 seconds, and a relatively smaller range.

# CHAPTER FIVE
# DISCUSSION

Tear film stability is essential for maintaining ocular surface integrity, visual clarity, and overall comfort. The tear film, composed of lipid, aqueous, and mucin layers, provides lubrication, nourishment, and protection against microbial invasion and desiccation. When this balance is disrupted, the result is tear film instability, which may lead to symptoms of dryness, irritation, and visual fluctuation.

Body Mass Index (BMI), a measure of body fat based on height and weight, has been increasingly studied for its influence on ocular physiology. Obesity and overweight states are known to trigger systemic inflammatory processes, hormonal imbalances, and metabolic changes, which may extend to ocular tissues, including the lacrimal and meibomian glands. Conversely, underweight individuals may also experience tear film compromise due to nutritional deficiencies or reduced lipid production.

This study therefore sought to investigate the relationship between BMI and tear film stability among students visiting the Optometry Clinic at the University of Benin. The parameters assessed were BMI, Fluorescein Tear Break-Up Time (FTBUT), Tear Meniscus Height (TMH), and Ocular Surface Disease Index (OSDI) score. The discussion that follows interprets the study's findings in relation to previous research, highlighting areas of agreement and divergence.

The results are organized into sections based on demographic information, descriptive statistics of key variables, tests of normality, and the relationships between body mass index (BMI) and ocular surface parameters, including Ocular Surface Disease Index (OSDI) score, tear meniscus height, and tear break-up time (TBUT).

The study population consisted primarily of young adults aged 18–27 years, with the majority (50.8%) between 21–23 years and a mean age of 22.65 ± 2.24 years. Females represented a slightly higher proportion (55.8%) compared to males (44.2%).

Age is an important determinant of tear function: previous studies such as Tummanapalli *et al.,* (2020) found that substance P and CGRP levels, as well as corneal nerve fibre density, decline with increasing age, potentially influencing tear film homeostasis. However, since participants in this study were mostly young adults, the impact of age-related neurotrophic changes on tear stability is expected to be negligible.

Approximately half of the participants (48.3%) reported wearing spectacles, whereas only 15.0% wore contact lenses. Nichols *et al.,*(2005) demonstrated that contact lens wear alters lipid layer structure and reduces tear break-up time, while Uchino *et al.,* (2018) linked prolonged lens use to evaporative dry eye. Lens use is an important ocular variable, as contact lenses can mechanically disrupt tear film stability and contribute to increased OSDI scores. Therefore, the minimal lens wear rate in this study supports the assumption that most participants had baseline ocular surface integrity unaffected by mechanical or material-related stressors.

The mean BMI was 24.57 ± 5.40 kg/m², spanning from 16.6 to 39.6 kg/m². This suggests that while most participants were within the normal range, a considerable fraction were overweight or obese. The mean TBUT of 11.97 ± 4.09 s indicates generally stable tear films, as values above 10 s are usually regarded as physiologically normal (Bron *et al.,* 2004). The mean tear meniscus height (TMH) of 0.22 ± 0.09 mm also falls within the normal clinical range (0.20–0.25 mm), while the average OSDI score of 24.68 ± 15.18 suggests mild symptoms of ocular surface discomfort.

Comparable TBUT and TMH values have been documented in healthy young populations by Idu *et al.,* (2017) at the University of Benin and by Adu *et al.,* (2009), confirming that the present cohort reflects the typical tear physiology of African university students. The relatively high variation in OSDI scores is slightly higher than expected for normal tear stability. This may be due to environmental or behavioural influences such as extended

digital device use, a trend reported by *Idu et al.,*(2023) among Nigerian students, where screen exposure was associated with mild dry eye symptoms despite adequate tear function. It may also be due to environmental humidity, or unreported systemic conditions rather than BMI alone.

Among participants, 51.7% were of normal weight, 20.0% overweight, 16.7% obese, and 11.7% underweight. The dominance of the normal weight category suggests that the sample mirrors general university health trends.

Obesity prevalence (16.7%) corresponds with Adu *et al.,*(2009), who found that about 15–20% of Nigerian students fall within the obese range. This context is vital because tear film physiology may be indirectly influenced by metabolic alterations associated with excess adiposity, such as subclinical inflammation and hormonal imbalance (Pieńczykowska *et al.,* 2025).

The Kruskal–Wallis test showed no statistically significant difference in OSDI ($p = 0.328$), TMH ($p = 0.132$), or TBUT ($p = 0.921$) across BMI categories. Although the obese group showed slightly higher OSDI scores and lower TMH and TBUT medians, these differences were not significant.

This finding indicates that, within the studied population, BMI is not a strong predictor of tear film instability. Similar results were reported by Tummanapalli *et al.,*(2020), who found no significant correlation between BMI and tear neuromediator levels or corneal nerve density, suggesting that tear film regulation may remain intact in young, metabolically healthy individuals. In contrast, Alanazi (2019) observed significantly reduced TBUT and Schirmer scores in obese adults compared to those with normal BMI, proposing that chronic inflammation and meibomian gland dysfunction could explain the association. However, Alanazi's participants were older and had a higher mean BMI (~33 kg/m²) than those in this study (~24.6 kg/m²), which could account for the differing results.

The Mann–Whitney U test revealed a statistically significant difference in OSDI scores between males and females ($p = 0.002$), with females reporting higher symptom scores. No significant differences were found for TMH ($p = 0.273$) or TBUT ($p = 0.195$).

This gender difference in subjective symptoms aligns with prior research by Sullivan *et al.,* (2017), who attributed higher female dry eye prevalence to hormonal modulation of lacrimal and meibomian glands. Similarly, Bron *et al.*(2017) found that oestrogen fluctuations influence tear composition and lipid-layer function, increasing ocular surface discomfort even when objective measures remain normal.

The Kolmogorov–Smirnov and Shapiro–Wilk tests confirmed that key variables—OSDI, TMH, TBUT, and BMI—were not normally distributed ($p < 0.05$). This justified the use of non-parametric tests such as the Kruskal–Wallis and Mann–Whitney U tests for hypothesis testing.

This distribution pattern is typical in biomedical and clinical datasets where interindividual variability, measurement sensitivity, and categorical health factors (e.g., BMI classification) create skewed data distributions (Field, 2013).

Therefore the findings of this research align with studies that report a weak or absent relationship between BMI and ocular surface parameters in non-pathological populations. The trend towards reduced TMH and TBUT with increasing BMI is physiologically plausible but not statistically supported here, likely due to the narrow BMI dispersion and the young age range.

By contrast, several controlled clinical studies (e.g., Alanazi 2019; Masmali 2022) using older or more obese cohorts demonstrated significant differences, implying that the ocular impact of BMI may manifest more clearly at higher levels of adiposity or in the presence of systemic inflammation.

# CHAPTER SIX

# CONCLUSION AND RECOMMENDATIONS

## 6.1 Conclusion

Based on the findings, it can be concluded that BMI does not have a significant direct effect on tear film stability among young adults. Although slight variations were observed; where higher body mass index (BMI) tended to correspond with lower Tear break-up time (TBUT) and Tear meniscus height (TMH) and higher Ocular surface disease index (OSDI) scores, these differences were not statistically significant. This indicates that within a relatively healthy, youthful population, the ocular surface appears resilient to the subtle systemic variations that accompany higher BMI levels and that tear film stability in young individuals is maintained within normal limits across different BMI categories, possibly due to the absence of age-related or systemic metabolic deterioration. Also, while BMI in the normal to mildly overweight range may not directly impair ocular surface function as shown in this study, in comparison with other literature, it can be deduced that the cumulative effects of metabolic imbalance, inflammation, and lifestyle factors (e.g., screen exposure, dehydration, and poor diet) could still contribute to ocular surface stress and subclinical tear film changes over time.

This enforces the need to view tear film instability as a multifactorial condition influenced by systemic health, environment, ocular habits, etc.

## 6.2 Recommendations

1. **Routine Ocular Surface Screening:**

Optometrists should include simple tear film tests such as TBUT and TMH as part of comprehensive eye examinations, especially for overweight patients or those presenting with dryness symptoms.

2. **Holistic Patient Evaluation:**

During case history taking, clinicians should consider lifestyle factors (diet, screen time, sleep pattern) and systemic conditions that may contribute to ocular surface instability alongside BMI.

3. **Early Patient Education:**

Educate young adults on modifiable habits that support ocular surface health; adequate hydration, reduced digital exposure, and maintaining a balanced diet.

4. **Health Promotion Programmes:**

The University Health Services and Optometry Clinic should collaborate to promote periodic health and vision screening programmes that include both metabolic (BMI) and ocular assessments.

5. **Further Research**

Future studies should adopt;

1. A larger, more diverse population including older adults and individuals with metabolic or endocrine disorders to better capture BMI-related ocular changes.
2. Incorporate additional tear assessment parameters such as lipid-layer interferometry, meibography, and tear osmolarity to provide a more detailed evaluation of tear film physiology.
3. Conduct longitudinal studies to track changes in tear film stability with progressive BMI increase or weight reduction.
4. Investigate biochemical markers such as inflammatory cytokines and adipokines in tears to elucidate the mechanistic links between obesity and ocular surface inflammation.

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# APPENDIX

## Appendix 1

**Ethical approval and clinic approval**

**Appendix 2**

# Ocular Surface Disease Index (OSDI) Questionnaire

**Instructions:**

***For the following questions, please mark the number that best represents how frequently you have experienced the following in the past week.***

**Use this scale:**

**0 = None of the time**

**1 = Some of the time**

**2 = Half of the time**

**3 = Most of the time**

**4 = All of the time**

**A. Ocular Symptoms**

1. **Eyes that are sensitive to light**
2. **Eyes that feel gritty**
3. **Painful or sore eyes**
4. **Blurred vision**
5. **Poor vision**

**B. Visual Functioning (Impact on Activities)**

1. **Difficulty reading**

2. **Difficulty driving at night**
3. **Difficulty working with a computer or ATM**
4. **Difficulty watching TV**

**C. Environmental Triggers**

1. **Eyes uncomfortable in windy conditions**
2. **Eyes uncomfortable in places with low humidity (e.g., air-conditioned room)**
3. **Eyes uncomfortable in areas with air movement (e.g., fan, open window)**

**Data collection sheet**

| Age | Gender | Height | Weight | Body mass index | Tear break-up time | Tear Meniscus Height | OSDI score |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

# Ocular Surface Disease Index (OSDI)

*My name is Chinelo Ikeli, a 6th-year student of the Faculty of Optometry, University of Benin.*

*This questionnaire asks about eye symptoms in the **last week** and is part of my research study on **"The relationship between tear film stability and body mass index among students visiting the Optometry Teaching Clinic, University of Benin".***

*Participation is voluntary, and all responses will remain confidential. By completing this questionnaire, you consent to the use of your data for academic research purposes only. Kindly answer honestly based on your experiences over the **past week(last 7 days); choose 'N/A' if a situation doesn't apply.**.*

I have read and understood the information above, and I agree to participate in this research. *

- ◯ Yes
- ◯ No

**Appendix 3**

**Appendix 3.1: Comparison of Ocular Surface Parameters between Male and Female Respondents**

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of OSDI Score is the same across categories of Gender. | Independent-Samples Mann-Whitney U Test | .002 | Reject the null hypothesis. |
| 2 | The distribution of Tear Meniscus Height (mm) is the same across categories of Gender. | Independent-Samples Mann-Whitney U Test | .273 | Retain the null hypothesis. |
| 3 | The distribution of Tear Break up time (secs) is the same across categories of Gender. | Independent-Samples Mann-Whitney U Test | .195 | Retain the null hypothesis. |

The Mann–Whitney U test revealed a statistically significant difference in OSDI scores between genders ($p = 0.002$), with females exhibiting higher symptom scores, indicating greater dry eye symptoms compared to males. However, differences in tear meniscus height ($p = 0.273$) and TBUT ($p = 0.195$) were not significant.

**Appendix 3.1.2: OSDI Score across Gender – Test Statistics**

| | |
|---|---|
| Total N | 120 |
| Mann-Whitney U | 1182.000 |
| Wilcoxon W | 2613.000 |
| Test Statistic | 1182.000 |
| Standard Error | 189.099 |
| Standardized Test Statistic | -3.139 |
| Asymptotic Sig.(2-sided test) | .002 |

**Appendix 3.1.3: Tear Meniscus Height (mm) across Gender – Test Statistics**

| | |
|---|---|
| Total N | 120 |
| Mann-Whitney U | 1981.000 |
| Wilcoxon W | 3412.000 |
| Test Statistic | 1981.000 |
| Standard Error | 187.505 |
| Standardized Test Statistic | 1.096 |
| Asymptotic Sig.(2-sided test) | .273 |

**Appendix 3.1.4: Tear Break up time (secs) across Gender – Test Statistics**

| | |
|---|---|
| Total N | 120 |
| Mann-Whitney U | 2020.500 |
| Wilcoxon W | 3451.500 |
| Test Statistic | 2020.500 |
| Standard Error | 189.042 |
| Standardized Test Statistic | 1.296 |
| Asymptotic Sig.(2-sided test) | .195 |

Appendix 3.2: Tests of Normality for Key Variables

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | **Statistic** | **df** | **Sig.** | **Statistic** | **df** | **Sig.** |
| OSDI Score | .100 | 120 | .005 | .961 | 120 | .002 |
| Tear Meniscus Height (mm) | .124 | 120 | .000 | .937 | 120 | .000 |
| Tear Break up time (secs) | .109 | 120 | .001 | .949 | 120 | .000 |
| Body mass Index(BMI in kg/m2) | .114 | 120 | .001 | .939 | 120 | .000 |

The Kolmogorov–Smirnov and Shapiro–Wilk tests indicated significant results ($p < 0.05$) for all key variables—OSDI, TMH, TBUT, and BMI—demonstrating that the data were not normally distributed.

**Appendix 3.3: OSDI Score across Body mass index categories -Test Statistics**

| | |
|---|---|
| Total N | 120 |
| Test Statistic | 3.447 |
| Degree Of Freedom | 3 |
| Asymptotic Sig.(2-sided test) | .328 |

**Appendix 3.4: Tear Meniscus Height (mm) across Body mass index categories -Test Statistics**

| | |
|---|---|
| Total N | 120 |
| Test Statistic | 5.618 |
| Degree Of Freedom | 3 |
| Asymptotic Sig.(2-sided test) | .132 |

**Appendix 3.5: Tear Break up time (secs) across Body mass index categories**

**-Test Statistics**

| | |
|---|---|
| Total N | 120 |
| Test Statistic | .492 |
| Degree Of Freedom | 3 |
| Asymptotic Sig.(2-sided test) | .921 |