THE EFFECT OF INCREASE IN HUMIDITY ON TEAR BREAK-UP TIME

BY

FAGBUYI ELIJAH OLUWAPELUMI

LSC1906512

FACULTY OF OPTOMETRY,

DEPARTMENT OF OPTOMETRY,

UNIVERSITY OF BENIN

NOVEMBER, 2025

THE EFFECT OF INCREASE IN HUMIDITY ON TEAR BREAK-UP TIME

BY

FAGBUYI ELIJAH OLUWAPELUMI

LSC1906512

A THESIS SUBMITTED TO THE DEPARTMENT OF OPTOMETRY.

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 AND APPROVAL

This is to certify that this research project titled "**EFFECT OF INCREASE IN HUMIDITY ON TEAR BREAK-UP TIME"** was carried out by **FAGBUYI ELIJAH OLUWAPELUMI** in the Department of Optometry, Faculty of Optometry, University of Benin in partial fulfillment of the requirement for the Doctor of Optometry degree in the 2024/2025 academic session.

____________________ ____________________

PROF. MRS. G.O. GEORGE **DATE**

(THESIS SUPERVISOR)

____________________ ____________________

DR MRS J.O. OKUPON **DATE**

(THESIS COORDINATOR)

____________________ ____________________

PROF. MRS. E. OGHRE **DATE**

(DEAN OF FACULTY)

____________________ ____________________

EXTERNAL SUPERVISOR **DATE**

DEDICATION

This project is dedicated to my parents, Mr. and Mrs. Fagbuyi, and my siblings, Enoch Fagbuyi and Mrs. Hellen Olarufus. I also want to dedicate this project to my mentor, Dr. Uzzi Aiososa, who has been of immense support during the period of carrying out this project.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my friends and lecturers who have supported and assisted me throughout my research journey.

First and foremost, I would like to extend my heartfelt thanks to my project supervisor, Prof. Mrs. G.O. George, and Dr. Mrs. Shuaibu for their mentorship and encouragement. Their knowledge and expertise have been instrumental in helping me navigate the complexities of my research, and I am grateful for their guidance.

I would also like to thank Dr. Uzzi Aisosa for his advice and guidance throughout the School of Optometry; his mentorship yielded a good seed in me.

Their insights and suggestions were crucial to me during the course of this project, and I am extremely grateful for their support.

I would also like to thank my uncle, Mr. Ayodele Omoniyi, for his support, Mrs. Abiola, Mrs. Hellen Olarufus, and my brother, Fagbuyi Enoch.

I would like to express my gratitude to my family and loved ones for their unwavering support and encouragement. Their belief in me has been a constant source of motivation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Background: Tear break up is an important indicator of tear film stability, representing the interval between a complete blink and the first appearance of a dry spot on the corneal surface. Humidity plays a crucial role in tear film dynamics. Increase humidity decelerate evaporative water loss from the tear film, increasing tear break up time (TBUT) and alleviate ocular discomfort. **Objective:** This study investigated the effect of increased humidity on tear breakup time (TBUT) amid fifty (50) participants attending University of Benin Optometry teaching clinic. Studies have shown that increased humidity leads to a significant increase in tear break up time (TBUT), resulting in increased ocular comfort. Therefore, in this study we investigated the effect of increased humidity on TBUT**.** **Method:** Close observation on fifty (50) participants with convenient sampling design. Data on age, gender was carried out, an ocular surface disease index (OSDI) questionnaire was used to grade the participants into normal, mild, moderate and severe tear dry eye , they were then exposed to ideal humidity and increased humidity level, after 10 minutes of acclimatization in each humidity condition, non-invasive tear break up time (NITBUT) was measured in both conditions and findings were recorded. **Result:** Increase in humidity between 50% and 70% relative humidity (RH) were statistically significant ($p < 0.001$), with large effect sizes (r = 0.80-0.95), participants with normal, mild and severe ocular surface disorder index (OSDI) score all showed significant increase in tear break up time (TBUT) and increased ocular comfort. **Conclusion:** Result demonstrates that increase in humidity level markedly improved tear film stability from all groups regardless of age, gender, ocular surface health (normal or dry eye). The results of this study confirmed that humidity is a critical environmental factor that influences ocular surface health. The study also revealed that controlled increase in humidity level yielded statistically significant tear film stability ($p<0.001$) in all groups.

KEYWORDS: relative humidity, tear break-up time, tear film stability, ocular health.

CHAPTER ONE

1.0 INTRODUCTION

The tear film is a dynamic, multi-layered structure critical to maintaining the health and function of the ocular surface. It serves several essential roles, including providing a smooth optical surface, supplying nutrients, flushing away debris, and forming a barrier against microbial invasion (Craig *et al.,* 2017). Comprised of lipid, aqueous, and mucin layers, the tear film undergoes continuous turnover and renewal through blinking and secretion from the lacrimal and meibomian glands. One of the key clinical indicators used to evaluate the integrity and stability of the tear film is the tear breakup time (TBUT), which measures the interval between a blink and the first appearance of a dry spot on the cornea (Sullivan *et al.,* 2017). A shorter tear breakup time (TBUT) is indicative of an unstable tear film and is a hallmark sign of dry eye disease (DED).

Environmental conditions are among the major external factors influencing the stability of the tear film. In Ambient relative humidity plays a critical role in modulating the rate of tear evaporation. Under low humidity conditions, the evaporation rate of the aqueous layer increases significantly, which can destabilize the tear film, leading to quicker tear breakup, discomfort, and visual disturbances (Abusharha and Pearce, 2013). Such environments are common in modern indoor settings, such as air-conditioned offices, aircraft cabins, or heated indoor spaces during winter months. In contrast, high humidity conditions may help preserve tear film stability by slowing down evaporation and supporting longer tear breakup time (TBUT) values.

The prevalence of dry eye symptoms has been increasing globally, partly due to environmental changes and prolonged exposure to screen-based digital devices, which are often associated with reduced blink rate and incomplete blinking (Stapleton *et al*., 2017). Individuals with pre-existing ocular surface disorders, the elderly, and contact lens users are particularly susceptible to the adverse effects of tear film instability. For contact lens wearers, in particular, environmental dryness can exacerbate discomfort and reduce wearing time, as contact lenses disrupt the natural distribution of the tear film and may further enhance evaporation (Korb *et al.*, 2002).

Despite growing awareness of environmental contributions to ocular surface discomfort, there is limited empirical research specifically addressing how varying humidity levels quantitatively influence TBUT. While some studies have assessed subjective symptoms under different environmental conditions, objective data linking humidity to tear film breakup are relatively scarce. Understanding this relationship is essential for clinicians in tailoring management strategies for patients with dry eye, as well as for improving guidelines for optimal indoor environmental conditions.

Therefore, this study investigated the effect of increase humidity on tear breakup time in human subjects. By evaluating tear breakup time (TBUT) across ideal and high humidity levels, this research provides insights into how environmental factors influence tear film stability and contribute to evidence-based recommendations for dry eye management and ocular comfort.

Environmentally induced dry eye (DE) affects otherwise symptom-free individuals under specific circumstances, such as using computers in overheated or air-conditioned workplaces and exposure to low-humidity conditions (Wolffsohn *et al.,* 2017).

The most common ocular complaints associated with these environments are burning, dryness, stinging, and grittiness. (Norns *et al*, 2009). The desiccation stress that triggers these symptoms is thought to originate in large part due to an increased tear evaporation rate (TER) at low humidity's. The negative alterations in tear film physiology that arise in such environments are typically managed with the use of lubricant eye drops.

These artificial tear formulations usually contain a viscous polymer in an aqueous solution to hydrate and protect the dry ocular surface; some also include emulsified lipids specifically intended to reduce tear evaporation. This type of emulsion eye drop has proven to be a particularly effective therapeutic option for managing environmentally induced dry eye.

Previous studies of the use of eye drops of various formulations have shown improvements in tear physiology in mild to moderate dry eye (DE) patients with their use in both acute and chronic application protocols. (Yazdani *et al,* 2020).

The stability and integrity of the tear film play a crucial role in maintaining ocular surface health and visual acuity. Tear break-up time (TBUT), defined as the interval between a complete blink and the appearance of the first dry spot on the corneal surface, serves as a fundamental diagnostic parameter for assessing tear film stability and dry eye syndrome (Tsubota, 2018). A tear breakup time (TBUT) under 10 seconds is considered abnormal, making it a critical clinical measurement for diagnosing evaporative dry eye disease.

1.1 BACKGROUND INFORMATION

Environmental factors, particularly humidity levels, significantly influence tear film dynamics and ocular comfort. Research has demonstrated that evaporation rate, tear lipid layer thickness (LLT), ocular comfort, tear stability, and production were adversely affected by low RH (relative humidity), with the tear film parameters observed after exposure to a desiccating environment for one hour, were like those of the dry eye patient (Abusharha and Pearce, 2013). This outcome emphasizes the clinical significance of understanding how humidity affects tear breakup time (TBUT) within the context of dry eye pathophysiology and management strategies.

The human eye demonstrates remarkable sensitivity to environmental changes, with the ocular surface serving as the primary interface between internal eye structures and the external environment. Studies conducted in high-altitude environments, where humidity levels are naturally low, have provided valuable insights into this relationship. In elevated regions, patients often experience eye irritation, redness, and a sensation of a foreign body, indicating tear film instability caused by low humidity and windy environmental conditions (Gupta *et al.,* 2016).

Research findings indicated that there were 24% individuals with tear breakup time (TBUT) of < 5 seconds, 30% between 6-10 seconds, and 46% with tear breakup time (TBUT) of > 10 seconds in these populations, demonstrating the direct impact of environmental humidity on tear film stability.

The relationship between environmental conditions and tear film stability is further supported by evidence showing that lower humidity also results in increased tear film evaporation, with dry eye symptoms exacerbated in windy situations (Gupta *et al.,* 2009). Additionally, environmental influences. This includes low humidity, high altitude, pollution, wind, dust, and allergens, all of which compromise the ocular surface (Vitale, 2023).

1.1.1 TEAR FILM AND OCULAR SURFACE

The tear film is a complex structure composed of multiple layers, including the lipid, aqueous, and mucin layers (Holly *et al.*, 1977). The tear film plays a crucial role in maintaining ocular surface health and comfort. It provides lubrication, protection, and optical clarity to the ocular surface. Disruptions to the tear film can lead to dry eye symptoms, discomfort, and vision problems (Lemp, 2007). Tear breakup time (TBUT) is a widely used clinical measure to assess the stability of the tear film.

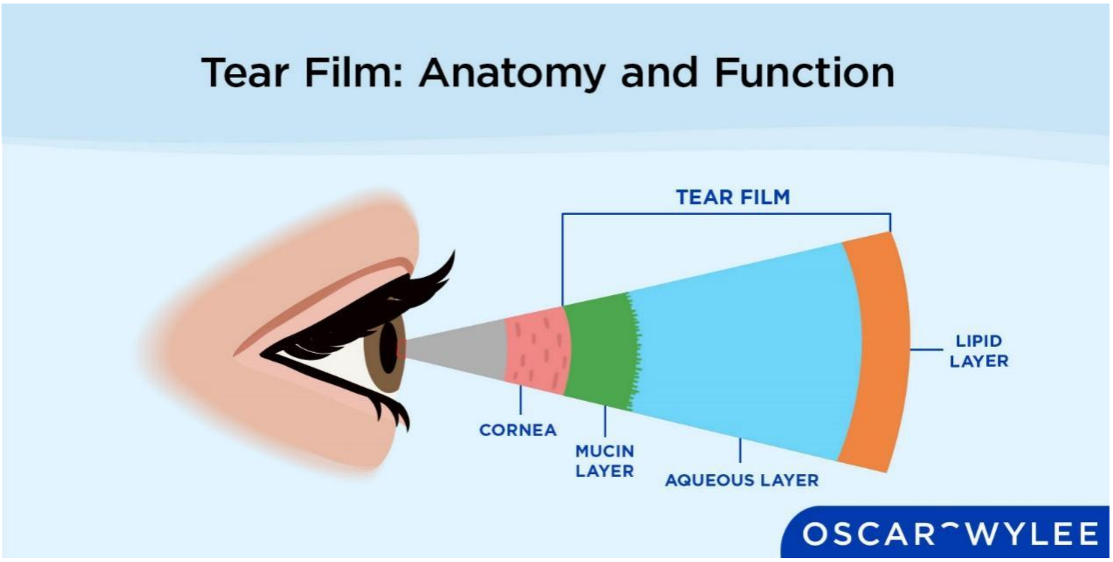

Figure 1.1: showing the Layers of the tear film. Adapted from Tear film and Anatomy by Oscar Wylee.

1.1.2 HUMIDITY AND TEAR FILM STABILITY

Humidity plays a crucial role in maintaining the stability of the tear film. Low-humidity environments can accelerate tear evaporation, leading to decreased tear breakup time (TBUT) and increased risk of dry eye symptoms (McCulley *et al.*, 2006). Conversely, high-humidity environments may help maintain tear film stability by reducing evaporation rates (Abusharha and Pearce, 2013).

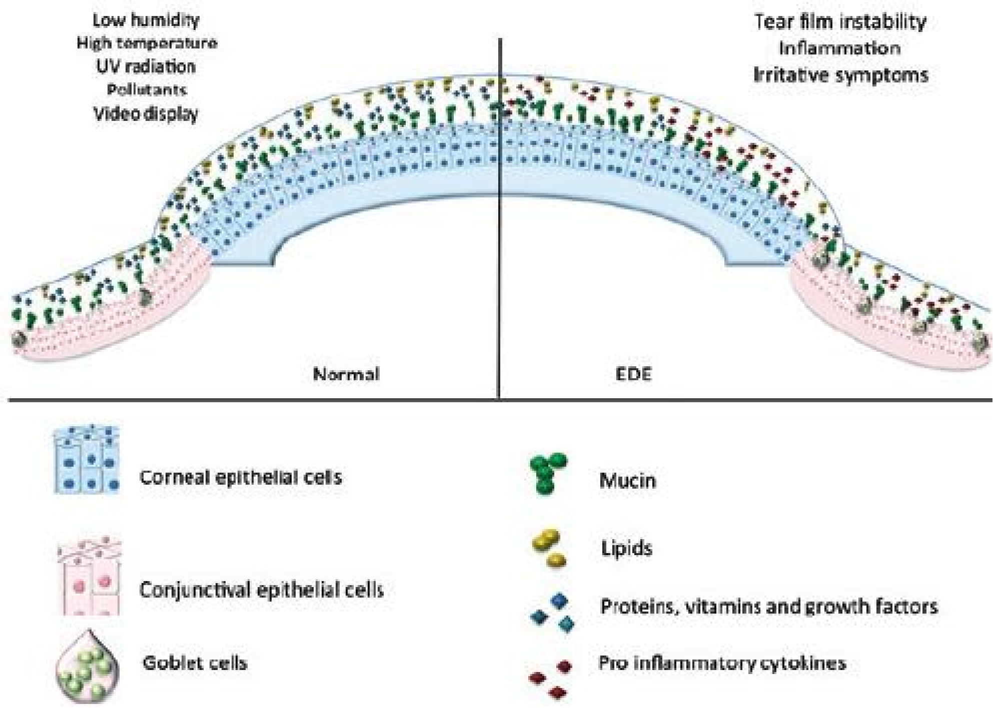

Figure 1.2: showing functions of tear film: Adapted from Researchgate.net

1.1.3 IDEAL HUMIDITY CONDITIONS

Environmental conditions, including humidity, have a substantial effect on tear film stability and overall eye comfort. Ideal humidity conditions for ocular comfort are generally considered to be between 40 to 60% relative humidity (McCulley *et al*., 2006). Within this range, the tear film can maintain its stability, and ocular comfort is optimized.

1.1.4 INCREASED HUMIDITY USING HUMIDIFIERS

Humidifiers can increase the humidity levels in a given environment, potentially benefiting individuals with dry eye symptoms (Nilsson & Andersson, 1986). By maintaining a more stable tear film, humidifiers may help reduce symptoms of dryness, irritation, and discomfort. Tear break-up time (TBUT) is used to assess tear film instability, defined as the time between the completion of a full blink and the emergence of the first break in the tear film (Wolffsohn *et al*., 2017; Sweeney *et al.,* 2013).

The initial tear breakup time (TBUT) method, referred to as fluorescein break-up time (fBUT), was introduced by Norn in 1969. He suggested instilling sodium fluorescein dye into the tear film to identify break-up areas using a slit lamp biomicroscope and cobalt blue light.

The "magic" number 10s would indicate the cut-off between normal and abnormal tear film (Norn *et al.,* 1969). Notwithstanding the clinical fortune of fluorescein break-up time (fBUT) which became the most common test for tear film assessment (Vingrys *et al*., 2013). It has been largely recognised for its poor reliability (Vanley, *et al*.1977), (mainly linked to fluorescein invasiveness) (Mengher, *et al*. 1985). Several modifications to the fluorescein break-up time (fBUT) procedure have been suggested to enhance its reliability, including reducing and standardizing the amount of sodium fluorescein applied (Craig *et al*., 2017) or conducting multiple measurements (Cho *et al*., 1991) across different sessions (Nichols *et al*., 2004), etc. However, the best way to measure the stability of the tear film should be to use a non-invasive approach that should avoid altering the tear film (e.g., by increasing the temperature and/or causing reflex blinking with the illumination systems, instilling fluorescein, forcing blinking, etc.) (Uchino *et al.,* 2014). The non-invasive break-up time (NIBUT) is determined as the interval of time that elapses between the end of a complete blink and the appearance of a discontinuity or break in the image of a mire or a grid pattern (keratometer mire or Placido disc) reflected on the anterior tear film surface. (Backman *et al,* 2014). Such an approach also allows for the detection of early changes in the tear film that precede actual break-up; for instance, distortion in grid patterns may indicate tear film thinning, which can be employed to assess tear breakup time. (Ousler *et al*., 2007).

1.1.5 GOBLET CELL DISTRIBUTION AND FUNCTION

Structurally, the bulbar conjunctiva consists of a stratified squamous epithelium with interspersed goblet cells that secrete mucins essential for tear film composition. Goblet cells within the conjunctival epithelium are specialized cells that secrete mucins onto the surface of the eye (Dartt, 2017). Research has shown that a high density of goblet cells should be expected for the healthy human conjunctiva, with a tendency toward higher values in samples taken from normally covered locations (inferior and superior bulbar conjunctiva) of the open eye (at 973 +/- 789 cells/ mm^2) (Doughty, 2012).

The mucins secreted by these goblet cells form the innermost layer of the tear film, providing the hydrophilic foundation that allows the aqueous layer to spread evenly across the corneal surface. The ocular surface, including the cornea, conjunctiva, and its overlying tear film, is the first tissue of the eye to interact with the external environment (Blalock *et al.,* 2007), making the proper functioning of conjunctival goblet cells crucial for maintaining tear film stability.

1.1.6 MUCIN PRODUCTION AND TEAR FILM STABILITY

The relationship between goblet cell function and tear film stability is well-established in the literature. A mucus covering provides support for the overlying tear film, helping to keep the ocular surface moist and lubricated (Doughty, 2012). Furthermore, Conjunctival goblet cells (CGCs) are specialized cells that produce and secrete soluble mucins to the tear film that bathes the ocular surface (Dartt & Masli, 2019).

The role of the mucous layer in tear film stability is important in the context of blinking mechanics. Research indicates that the blink reflex removes up to 70% of the surface aqueous–

mucous layer, while the remaining 30–40% thick mucus layer in contact with the cornea is not wiped away on blinking. Instead, it is thinned by blinking and may take 30 minutes to reconstitute itself (ScienceDirect, 2023). This finding demonstrates the critical role of conjunctival goblet cell secretions in maintaining continuous tear film coverage between blinks.

1.1.7 ENVIRONMENTAL IMPACT ON BULBAR CONJUNCTIVAL FUNCTION

The bulbar conjunctiva's response to changes in environmental humidity is mediated through several mechanisms. The tissue contains numerous sensory nerve endings that respond to environmental stimuli, including changes in humidity and temperature. When humidity levels fluctuate, these mechanoreceptors and chemoreceptors initiate reflex pathways that regulate blinking frequency and tear production.

Reduced tear film break-up time in dry eye disorders of various types, therefore reflecting a disturbance in tear mucin/aqueous protein interaction, which can be directly influenced by environmental humidity levels affecting goblet cell function. Their secreted mucins contribute to the tear film by maintaining a smooth ocular surface (Scientific Reports, 2023), making the understanding of humidity's effects on bulbar conjunctival goblet cells essential for comprehending tear breakup time (TBUT) variations.

The interaction between the bulbar conjunctiva and varying humidity conditions becomes particularly relevant when considering the pathophysiology of evaporative dry eye. As humidity increases, the rate of tear evaporation may decrease, potentially allowing for improved tear film stability and longer tear break-up times. Conversely, the bulbar conjunctival goblet cells may need to adjust their mucin production in response to these environmental changes to maintain optimal tear film composition and stability.

This relationship between humidity, bulbar conjunctival function, and tear break-up time forms the foundation for understanding how environmental factors influence ocular surface health, providing the rationale for investigating the specific effects of humidity variations on tear film stability parameters.

1.1.8 RELATIONSHIP BETWEEN HUMIDITY, EVAPORATION AND TEMPERATURE

The interaction between humidity, evaporation, and temperature directly affects tear film stability and break-up time through well-established physical principles that govern moisture loss from the ocular surface.

Temperature and Tear Evaporation

Temperature has a direct exponential relationship with tear evaporation rates. Research demonstrates that ambient temperatures significantly affect tear film, with researchers observing a threefold increase in tear evaporation rate as ambient temperature increased to 25°C, resulting in a mean evaporation rate of 0.056 µL/min (Healio, 2017). This occurs because higher temperatures provide more energy for water molecules to transition from liquid to vapor phase, increasing the driving force for evaporation from the tear film surface.

Humidity's Effect on Tear Evaporation

Relative humidity (RH) directly controls the evaporation rate by affecting the moisture gradient between the tear film and the surrounding air. Evaporation rate, tear lipid layer thickness (LLT), ocular comfort, tear stability, and production were adversely affected by low relative humidity (RH), with tear film parameters observed after exposure to a desiccating environment for 1 hour being like those of dry eye patients (Abusharha & Pearce, 2013).

When humidity is low, there is a substantial difference between the moisture content of the tear film and the dry air, resulting in rapid evaporation. When humidity increases, this difference decreases, slowing down tear evaporation and potentially extending tear break-up time.

Vapor Pressure Deficit: The Key Factor

The key concept connecting humidity and temperature to tear evaporation is vapor pressure deficit (VPD), which refers to the gap between the maximum moisture the air can hold at a given temperature and the actual amount of moisture present.

VPD has a simple, nearly straight-line relationship to the rate of evapotranspiration and other measures of evaporation (Wikipedia, 2025).

This relationship explains why temperature and humidity must be considered together. For example, when the relative humidity is 70% at 60°F, VPD is 0.55 kPa. But if the temperature rises to 90°F with the same humidity level, the VPD changes to 1.45 kPa (Emerald Harvest, 2024), making evaporation much more likely despite the same relative humidity.

1.1.9 CLINICAL SIGNIFICANCE FOR TEAR BREAK-UP TIME

These correlations carry direct clinical significance for tear film stability; individuals exposed to low humidity conditions show markedly higher symptom scores and tear osmolarity, whereas those in low temperature environments present with elevated symptom scores and increased ocular staining (PMC, 2023). This confirms that both factors independently affect tear film parameters.

When humidity increases:

The vapor pressure deficit decreases

Less driving force exists for tear evaporation

Tear break-up time potentially increases

The effect depends on the concurrent temperature

Temperature-Humidity Interaction

The benefit of increased humidity on tear break-up time is not constant but varies with temperature. At higher temperatures, air can hold much more moisture, so the same relative humidity represents a much larger absolute amount of water vapor. This means that increasing humidity at higher temperatures may have a greater protective effect against tear evaporation than the same humidity changes at lower temperatures.

Understanding this relationship is crucial for interpreting how environmental changes in humidity affect tear film stability and break-up time measurements.

1.2 STATEMENT OF THE PROBLEM

The lack of understanding about the relationship between humidity and tear breakup time makes it challenging to develop effective strategies for promoting ocular comfort in various environmental conditions. This research investigated how different humidity levels influence tear breakup time (TBUT), offering important insights into tear film stability and the potential therapeutic benefits of regulated humidity conditions. While humidifiers are often used to improve ocular comfort. There are limited reported studies on the specific effects of varying humidity levels on tear breakup time (TBUT) and the underlying mechanisms that govern tear film stability in different atmospheric conditions. This knowledge gap hinders the development of evidence-based environmental interventions for maintaining optimal tear film function and ocular surface health across diverse humidity settings. Therefore, this research study investigated how different humidity levels influence tear breakup time (TBUT), offering important insights into tear film stability and the potential therapeutic benefits of regulated humidity conditions.

1.3 AIM AND OBJECTIVES

1.3.1 AIM OF STUDY

This study investigated the effects of an increase in environmental humidity on tear breakup time (TBUT) among individuals attending University of Benin Optometry Teaching Clinic.

1.3.2 OBJECTIVES

1. To determine the effects of ideal humidity conditions (40-60% RH) on tear breakup time.

2. To determine the effects of increased humidity (>70% RH) using a humidifier on tear breakup time.

3. To compare the differences in tear breakup time between ideal humidity conditions and increased humidity conditions.

4. To determine the potential benefits of using humidifiers in homes and the workplace in unfavorable environmental conditions.

1.4 NULL HYPOTHESIS/RESEARCH QUESTION

NULL HYPOTHESIS

1. Null hypothesis: There is no significant difference in tear breakup time between varying humidity levels.

1.5 RESEARCH QUESTIONS

1. Primary question: What are the effects of varying humidity levels on tear breakup time in individuals?

2. Specific question 1: Does the use of a humidifier improve tear breakup time in low-humidity environments?

3. Specific question 2: What is the optimal humidity range for maintaining stable tear breakup time and ocular comfort?

4. Comparative question: Compare the tear breakup time between ideal humidity conditions (40-60% RH) and increased humidity conditions (60-80%) using a humidifier?

1.6 SIGNIFICANCE OF THE STUDY

This study on the effects of varying humidity on tear breakup time is significant for several reasons:

1. Ocular comfort prevalence: Ocular discomfort and tear film instability are common conditions affecting millions of people worldwide. Understanding the impact of humidity on tear film stability can help enhance overall ocular comfort and visual quality.

2. Environmental factors: Humidity is a crucial environmental factor influencing tear film stability and ocular surface health. This study offers insights into the optimal humidity conditions for maintaining ocular comfort and preventing tear film instability.

3. Humidifier use: Humidifiers are often used to improve ocular comfort and maintain tear film stability. This study investigated the effectiveness of humidifiers in preserving optimal tear film parameters and enhancing ocular surface comfort.

4. Harmattan season: In regions experiencing the Harmattan season, such as West Africa, the dry and cold winds can significantly compromise ocular comfort and tear film stability. This study provided valuable insights into maintaining optimal ocular surface conditions during this challenging environmental period.

5. Clinical applications: This study provided valuable insights into the relationship between humidity and tear film stability. The findings have implications for optimizing environmental conditions to enhance ocular comfort, improve tear film quality, and help the therapeutic use of humidifiers in various eco-friendly settings for maintaining healthy ocular surface function.

1.6.1 POTENTIAL BENEFITS

The findings of this study may offer several key benefits:

1. Enhanced Management of Ocular Discomfort: A clearer understanding of the relationship between humidity and tear breakup time (TBUT) supports more effective strategies for managing ocular surface discomfort.

2. Optimization of Environmental Conditions: Identifying ideal humidity levels may help in creating indoor environments that reduce symptoms of ocular irritation and enhance visual comfort.

3. Guided Humidifier Use: Insights from this study could inform the use of humidifiers in homes, offices, and healthcare settings to alleviate symptoms associated with ocular discomfort.

4. Seasonal Symptom Relief: The findings may support targeted approaches for managing ocular discomfort during periods of harsh environmental conditions, such as the Harmattan season.

1.6.2 CONTRIBUTION TO EXISTING KNOWLEDGE

This study will contribute to the existing body of research on tear film stability and ocular surface health by:

1. Expanding the Understanding of Humidity's Role: The research will provide new insights into how varying ambient humidity levels influence tear breakup time and ocular surface integrity.

2. Informing Clinical and Environmental Recommendations: Results may guide clinicians and public health professionals in recommending optimal environmental conditions for individuals experiencing ocular discomfort.

3. Providing Region-Specific Insights: By focusing on the Harmattan season, the study addresses a regional gap in the literature and offers context-specific findings relevant to populations exposed to dry, dusty atmospheric conditions.

1.6.3 POTENTIAL IMPACT

The potential impact of this research includes:

1. Improved Quality of Life: A better understanding of how humidity affects TBUT may help individuals experiencing ocular discomfort to achieve greater visual comfort and ocular health.

2. Evidence-Based Decision-Making: The findings can support informed choices by individuals, eye care professionals, and organizations seeking to optimize indoor environments for ocular surface protection.

3. Regional Public Health Relevance: The study's emphasis on environmentally driven ocular discomfort, particularly during the Harmattan season, can provide practical solutions for those living in affected regions**.**

CHAPTER TWO

2.0 LITERATURE REVIEW

In a study by Abusharha *et al.,* (2013), a controlled environment chamber was used to create two different environmental conditions. Close temperature was steady in both conditions, while the relative humidity was maintained at 40% in the normal condition and at 5% in the low humidity condition. Tear evaporation, noninvasive tear break-up time, lipid layer thickness (LLT), osmolarity, ocular comfort, tear production, and ocular surface temperature were measured in normal humidity and across 60 minutes in the dry environment. To observe the changes in tear film dynamics during the influence of a dry surrounding, tear film parameters were observed at 20-minute intervals for 1 hour, starting from the baseline assessment at 0 minutes (0, 20, 40, and 60 minutes). At a sane relative humidity, only one observation was made after 15-minute equilibration. The other visit was to expose the tear film to a desiccating environment and then assess the tear film parameters. The visits were arranged in an alternating manner. Twelve healthy normal subjects (10 men, 2 women) with no symptoms of dry eye were enrolled in this study. Evaporation magnitude relation, tear LLT, extraocular coziness, tearfilm stability, and refreshing rate are unfavourably altered by low RH. The tear film indicators observed after exposure to an excisccate environment for 1 hour were in relation to those observed in individuals with dry eyes.

Sun-Hee *et al*., (2023) researched the effects of humidity changes on the eyes. A total of 48 adult men and women in their 20s (21.1±1.56 years old) were surveyed with ocular surface disorder index (OSDI) questionnaire. Tearfilm breakup time was measured under varying humidity (40%, 60%, 80%), while controlled reactions and controlled fine waves were measured through tactile tests. As a result of the ocular surface disorder index (OSDI) questionnaire, 10 subjects were classified as having no sign of dry eye, 8 presented with mild dry eyes, 1 presented with moderate dry eyes, and 5 presented with severe dry eyes. The initial tear film breakup time was 7.34±4.67 seconds at 40% humidity,8.99±4.75 seconds at 60% humidity, and 10.26±4.52 seconds at 80% humidity, and the average tear film break up time was 9.51±4.07 seconds at 40% humidity, 10.99±3.82 seconds at 60% humidity, and 12.05±3.42 seconds at 80% humidity. The accommodative response was –0.41~1.79D at 40% humidity, -0.34~1.79D at 60% humidity, and –0.30~2.01D at 80% humidity. The accommodative microwave was measured as 56.39~63.43dB when it was 40%, 56.41~62.64dB when it was 60%, and 55.96 ~61.13dB when it was 80%, as the humidity (40~80%) increased, the tear break-up time increased,

Another study by McCulley *et al.,* (2006) reported that tear break-up time (TBUT) was significantly longer in environments with higher humidity levels. In a prospective experimental research, ocular surface vapourization was measured with the aid of evaporometry and evaluated for both RH conditions, 25% to 35%, and 35% to 45% in an irregular study population. Mean evaporative magnitude in the high humidity condition was within 0.029 ± 0.009 and 0.043 ± 0.016 µl/cm2/min. At low humidity, the limit was between 0.044 ± 0.013 through 0.058 ± 0.018 µl/cm2/min. Discrepancy in the related evaporative magnitude was statistically significant (ranging from $P < .003$ to $P < .043$); a decrease of 10% RH resulted in an average discrepancy of 28.33% and a 59.42% increase in evaporation. The increase in evaporation at lower humidity has significant clinical implications for patients with aqueous-deficient dry eyes, and possibly, those undergoing laser-assisted in situ keratomileusis (LASIK).

Vaughan *et al.* (2024) conducted a study to assess the ocular effects of contact lens wear in a low-humidity environment, comparing conditions of normal humidity (RH: 45%) with those of low humidity (RH: 5%). It was found that exposure to a low-humidity environment increases the blinking rate, which is a result of tear film instability. Environmental factors include humidity, temperature, air velocity, air instability, and ocular discomfort.

Gao *et al.* (2018) conducted a cross-sectional experimental study to evaluate the effect of different relative humidity (RH) levels on tear film stability. The study involved a sample size of 209 healthy young adults, who were randomly assigned to three groups based on exposure to varying humidity environments: low (<40% RH), medium (40–70% RH), and high (>70% RH). The procedure involved exposing participants to controlled humidity environments and subsequently measuring their TBUT using standardized clinical methods. The results showed that higher RH was significantly associated with increased tear break-up time (TBUT), indicating that elevated humidity levels help maintain tear film stability. The study concluded that increasing ambient humidity may be an effective environmental strategy for promoting ocular surface health and alleviating dry eye symptoms, particularly in individuals frequently exposed to low-humidity conditions.

In a related longitudinal study, Onwubiko *et al.* (2019) assessed the seasonal variation in tear break-up time (TBUT) and tear secretion among adult participants in Enugu, Nigeria. A total of 50 adults were recruited and followed across the dry and rainy seasons, representing low- and high-humidity environmental conditions, respectively. Tear secretion was assessed using the Schirmer test, while tear film stability was evaluated through tear break-up time (TBUT) measurements. The procedure involved taking these measurements during both seasons under similar clinical settings. Findings revealed that the mean tear break-up time (TBUT) during the rainy season was 30.0 ± 18.3 seconds, compared to 15.6 ± 9.5 seconds in the dry season. These results suggest that natural increases in environmental humidity, such as those occurring during the rainy season, have a positive effect on tear film stability. The authors concluded that humidity is a critical environmental factor that should be considered in the diagnosis and management of dry eye, particularly in tropical regions with marked seasonal changes.

Both studies collectively reinforce the hypothesis that increased humidity leads to a longer tear break-up time (TBUT), thereby reducing the risk of tear film instability and dry eye symptoms. These findings provide a strong foundation for further experimental studies examining humidity as a modifiable factor in ocular surface health.

González-García *et al.* (2007) exposed minimally symptomatic contact lens wearers to a controlled adverse environment (~22 °C; ~19% RH) for 2 hours and compared the outcome with a more typical indoor environment (~24 °C; ~35% RH). Even in participants with only mild baseline complaints, the low-humidity CAE produced significant decrements in non-invasive tear break-up time (NIBUT), increased conjunctival hyperemia, changes in short thread wetting (phenol red), and reduced subjective comfort. Some alterations were magnified when lenses were worn. Most changes reversed after recovery, indicating that transient environmental desiccation can acutely destabilize the tear film and provoke ocular discomfort, particularly in individuals who wear contact lenses.

Tesón *et al.* (2013) simulated an aircraft cabin environment- a setting known for very low relative humidity in individuals with ocular surface disease. Exposure to the low-humidity, airflow-controlled chamber aggravated signs and symptoms, including reduced tear break-up time (TBUT) and increased ocular surface staining, compared with baseline indoor conditions. The study highlighted commercial air travel as a real-world desiccating challenge and reinforces the need for preventive strategies (lubrication, protective eyewear, humidification) for voyagers with pre-existing ocular surface vulnerability.

In a related study by Buckmaster *et al*., (2016) To determine the effects of humidity on tests of tear production, all experiments took place within a controlled environment chamber at a range of 5% to 95% relative humidity (RH). In vitro testing submerges Schirmer strips at a depth of 5 mm in water within 5 minutes. In vivo tests were carried out using the standardized clinical technique. All experiments were carried out using both standard Schirmer strips and Schirmer strips encased in a plastic film to prevent the possible effects of evaporation. Invitro results revealed a distinct decrease in Schirmer wetting dimension as RH was reduced. Schirmer test strips that were encased within a plastic protection covering were less affected by dynamic RH. As well as wetting dimension, the magnitude of wetting of Schirmer strips was also altered by changes in RH. In vivo data revealed that Schirmer results in subjects with severe dry eye disease were less altered by changes in RH than those of "normal" participants. This study established that patients with severe dry eye syndrome manifest Schirmer test results that are unaltered by environmental humidity. However, participants with moderate Schirmer wetting dimension may be incorrectly diagnosed with dry eye disease if their test is carried out in a low-humidity condition.

Madden *et al*., (2013) carried out a study on effect of humidity variations in a controlled environment chamber on tear evaporation after dry eye therapy, in first study A pilot study on tear evaporative rate (TER) adaptation time was determined by exposing 3 normal and 3 DE subjects to RH of 40% at 72°F for 0, 5, 10, 15, 20, and 25 minutes, the difference in noninvasive tear breakup time (NITBUT) and TER responses between DE and normal subjects were determined at various RH from 5% to 70% (at 72°F) for 20 subjects (10 normal subjects; 10 DE subjects). Study 2—The efficiency of the emulsion eyedrop was assessed. 20 participants were put under four times per day for 7 days using a drop containing emulsified castor oil and reevaluated, pilot study—Evaporation at 40% RH revealed an upper limit (around 5 minutes) followed by a decrease to a stable level within 10 minutes. Dry eye participants manifest higher evaporation than normal participants at 40% and 5% RH but not at 70%, where TER decreased to zero in both groups. No significant change in NITBUT was established in either group for the various exposure times of the test period ($P>0.05$). Study 1 shows TER was high in DE in relation with normal participants at 5% or 40% RH, nonetheless, it was reduced to almost zero in both test groups at 70% RH. A substantial change in NITBUT was found between the DE and normal groups at each humidity ($P<0.05$). Study 2 shows an emulsion-based drop effectively reduced the TER, especially in DE patients. For NITBUT, a substantial improvement in both healthy and DE participants was found at 5% and 40% but not at 70% RH levels, pilot study—TER assessment takes at least 10 minutes in the test room to obtain a stable-state TER with no substantial change to NITBUT. Study 1—TER has an inverse correlation with environmental humidity in the range of 5% to 70%, with TER decreasing to zero at 70% RH. DE participants had an increased TER at all RH levels below 70%, and NITBUT is substantially different between DE and healthy subjects at all humidities. Study 2—Emulsion-based drops decreased TER in DE participants by a magnitude proportionate to that obtained by increasing environmental humidity by 30%. Noninvasive tear breakup time was better in both normal and DE subjects at reduced RH levels.

Willmann *et al*., (2014) Investigated effect of exposure to high altitude on tear film osmolarity and breakup time, this study assess the quality of the tear film during high altitude exposure in healthy subjects using tear film osmolarity (TFO), tear film breakup time (TBUT), and Schirmer I and II were used to assess tear film properties under standardized conditions in 14 healthy subjects on day 1, 2, and 4 during exposure to high altitude at the Capanna Margherita (CM; 4559 m, Italy) compared to baseline measurements in Tübingen (341 m, Germany) before (BL1) and after (BL2) exposure. This study established a significant increase subjects on reaching CM in their intra-individual TFO (309.1±19.3, 332.2±24.1, 335.5±28.7, 329.7±19.0, and 308.5±15.3 mOsms/L at BL1, day1, 2, 4, and BL2, respectively) and a substantial reduction of TBUT (11.2±5.2, 7.3±5.2, 7.2±11.6, 4.5±2.3, and 8.7±4.6 seconds at BL1, day1, 2, 4, and BL2, respectively) were established. Schirmer test changes at high altitude stayed statistically nonsubstantial compared to baseline. Similitude of parameters among BL1 and BL2 established no statistically substantial discripancy and recordings of right and left eyes for TBUT and Schirmer did not differ substantially on any day assessed. This study established that high altitude exposure result in an an altered tear film, resulting in an increased TFO and a reduced TBUT.

Song MS *et al*. (2023) investigated the effects of humidity and temperature on dry eye disease (DED). A retrospective, clinical study was carried out on DED patients using dry eye treatment.

Patients were monitored at least twice, and signs and symptoms were evaluated using the Symptoms Assessment Questionnaire in Dry Eye (SANDE) score, tear secretion, tear film breakup time (TBUT), ocular staining score, and tear osmolarity. Mean humidity and temperature figures for 1 week before ocular examinations were used as the environmental exposure level. The relationship between humidity and temperature, with DED clinical parameters was analyzed in single- and multi-environmental factor models, result reveal the low humidity group presented with significantly higher SANDE scores ($p = 0.023$) and tear osmolarity ($p = 0.008$), and the low temperature group had higher SANDE scores ($p = 0.004$), ocular staining scores ($p = 0.036$), and tear osmolarity ($p < 0.001$). In the linear mixed model, single factor analysis showed that an increase in humidity resulted in decreased SANDE scores ($p = 0.043$), and an increase in temperature led to a decrease in SANDE score ($p = 0.007$), ocular staining score ($p = 0.007$), and tear osmolarity ($p = 0.012$). In the multifactor analysis, changes in humidity had no significant effect on dry eye parameters, but an increase in temperature was significantly correlated with decreased SANDE score ($p = 0.026$), ocular staining score ($p = 0.024$), and tear osmolarity ($p = 0.002$). this study established lower temperature led to aggravated symptoms and signs of DED and the effect of temperature on DED was more pronounced than humidity. Tear osmolarity was the most sensitive clinical parameter to be affected by climate factors in DED patients.

Kanoko *et al.,* (2023) carryout a study on effect of low humidity on eye discomfort in soft contact lens (SCL) and non-CL wearers in relation to subjective sensations, physiological parameters related to eye discomfort including tear-film parameters and blink patterns were comparatively evaluated between relative humidities of 10% and 45% at 23°C. For both the SCL and non-CL wearer groups, low humidity had a significant effect on some of the measured physiological parameters. The SCL group showed lower ocular surface temperature and larger temperature differential after blinking at 10% relative humidity (RH) than that at 45% RH, indicating faster tear evaporation. Furthermore, their tear films tended to be thinner and have a shorter break-up time at 10% RH than at 45% RH. The non-CL group showed a significantly higher blink frequency and longer eye-closure time at 10% RH than at 45% RH, presumably as a compensatory response to the disturbance of the tear film due to low humidity. These results suggest the importance of humidity control in indoor spaces in terms of tear-film quality, which contributes to eye discomfort.

Abusharha *et al.,* (2016) investigated the effect of ambient temperature on the human tear film

A controlled environment was used to create different ambient temperatures (5, 10, 15, 20, and 25°C) at a constant relative humidity of 40%. Subjects attended for two separate visits and were exposed to 25, 20, and 15°C at one visit and to 10 and 5°C at the other visit. The subjects were exposed to each room temperature for 10 min before investigating tear film parameters. The order of the visits was random. Tear physiology parameters assessed were tear evaporation rate, noninvasive tear break-up time (NITBUT), lipid layer thickness (LLT), and ocular surface temperature (OST). Each parameter was assessed under each condition.

Result:

A threefold increase in tear evaporation rate was observed as ambient temperature increased to 25°C (P=0.00). The mean evaporation rate increased from 0.056 µL/min at 5°C to 0.17 µL/min at 25°C. The mean NITBUT increased from 7.31 sec at 5°C to 12.35 sec at 25°C (P=0.01). A significant change in LLT was also observed (P=0.00), LLT median ranged between 20 and 40 nm at 5 and 10°C and increased to 40 and 90 nm at 15, 20, and 25°C. Mean reduction of 4°C

OST was observed as ambient temperature decreased from 25 to 5°C.The study established ambient temperature has a considerable effect on human tear film characteristics. Tear evaporation rate, tear LLT, tear stability, and OST were considerably affected by ambient temperature. Chronic exposure to low ambient temperature would likely result in symptoms of dry eye and ultimately ocular surface disorders.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

-Hygrometer (model: HTC-1, manufacturer: ACUUD)

- Keratometer (model: 71-21-35, manufacturer: Bausch and Lomb)

-Stop clock (model: HS-80TW, manufacturer: Casio)

-writing material

-humidifier (model: HKFedEx-IE, manufacturer: Shenzhen Huiqimei technology Co., Ltd.)

- Ocular surface disorder index (OSDI) questionnaire

3.2 STUDY DESIGN

This study employed a prospective, experimental design to investigate the effects of increased humidity on tear breakup time (TBUT). The study was conducted in contact lens examination room, University of Benin Optometry Teaching Clinic, where fifty (50) participants were exposed to two different humidity levels, during the research study.

Participants

The study recruited fifty (50) participants

3.3 INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria:

- Subjects within the age of 18-35 years

-Subjects without lid malformations e.g. ectropion

- Subjects who are not habitual Contact lens wearers

- Subjects without History of recent surgery.

Exclusion criteria:

- Age below 18 and above 35 years

-Subjects with lid malformations e.g. ectropion

- Subjects who are habitual Contact lens wearers

- Subjects with History of recent surgery.

Humidity Conditions

Participants will be exposed to different humidity conditions:

1. Ideal humidity (50%RH)

2. High humidity (70% RH)

3.4 OCULAR SURFACE DISORDER INDEX (OSDI) QUESTIONNAIRE GRADING

Ocular surface disorder index (OSDI) questionnaire was used to categorize the subjects into groups and the results was compared, the groups are; Normal (0-12), Mild (13-22), Moderate (23-32), or Severe (33-100)

3.5 NON-INVASIVE TEAR BREAKUP TIME (NIBUT) MEASUREMENT

Non-invasive tear break-up time (NIBUT) was measured using a Keratometer (Bausch and Lomb) equipped with placido disc rings or grid projection capability. The participants were positioned comfortably on the keratometer with their chin on the chin rest and forehead against the headrest. The instrument was aligned to focus on the corneal surface, projecting a regular pattern of concentric rings or grid lines onto the tear film.

The participants were instructed to blink normally once to refresh the tear film, then keep their eyes open without blinking while looking straight ahead at the fixation target within the keratometer. The examiner observed the reflected ring pattern or grid on the corneal surface through the keratometer's viewing system.

The measurement begins immediately after the complete blink, and the examiner monitors the regularity and continuity of the reflected pattern. The non-invasive tear break-up time (NIBUT) was recorded as the time interval from the complete blink until the first distortion, break, or discontinuity appears in the reflected ring pattern or grid lines, indicating the initial breakdown of the tear film. This distortion typically appeared as a dark area, irregular reflection, or break in the otherwise smooth and regular pattern.

The procedure was repeated three times for each eye to ensure accuracy, with a brief interval between measurements to allow tear film recovery. The average of the three measurements was calculated and recorded as the final non-invasive tear break up time (NIBUT) value. This non-invasive method eliminates the potential disruption to the tear film caused by fluorescein instillation while providing reliable and repeatable measurements of tear film stability.

3.6 PROCEDURE

Participants were seated comfortably in the room with the humidity level set to one of the two conditions. After 10 minutes of acclimation in the ideal humidity, non-invasive tear break-up time (NIBUT) was measured in each eye. The participant was then exposed to the next humidity condition after 10 minutes, and the non-invasive tear break up time (NIBUT) measurement was recorded.

3.7 EXPECTED OUTCOMES

This study provided valuable insights into the relationship between increased humidity using a humidifier and assessing tear stability using tear break up time (TBUT). The findings alleviated ocular discomfort as well as ocular health and the use of humidifiers in various environmental conditions and workplaces.

3.8 ETHICAL CONSIDERATIONS

Ethical clearance was obtained from the Research and Ethical Committee of the Faculty of Optometry, University of Benin, Benin City, in accordance with the tenets of the Declaration of Helsinki.

3.9 STUDY LOCATION

The study was conducted at the University of Benin Optometry Teaching Clinic, Contact Lens Examination room.

3.10 SAMPLE SIZE

The sample size for this study was calculated using Fisher's formula:

N = sample size

Z = Z statistic level of confidence of 95% (1.96)

P = maximum reported prevalence (of awareness) of 75%

D = Precision desired (assuming a different precision or adjusting the formula to fit the desired sample size)

$N = 1.96^2 \times 0.75(0.25)/0.088^2$

$N \approx 50$

Attrition factor is 5% of n (approx. 2.5), total sample size $N = 52.5 \approx 53$

STUDY POPULATION

The study population consists of healthy Subjects without ocular surface malformations.

3.11 SAMPLING METHODS

subjects were recruited using a convenience sampling method, from a screening exercise carried out across various Faculties and departments, where interested Participants were screened and selection were made based on inclusion criteria.

3.12 LIMITATIONS OF THE STUDY

Limitations of the study include:

2. Variability in individual responses to humidity changes.

3. Bias in Subjects selection.

3.13 DATA ANALYSIS AND PRESENTATION

The data were analyzed using a repeated-measures ANOVA on the statistical package for the social sciences (SPSS version 26) to compare the tear break up time (TBUT) values in ideal and increased humidity conditions. A *p-value* < 0.05 was considered statistically significant. Descriptive statistics and inferential statistics (e.g., paired t-tests) were used to summarize and compare the data. Results were presented in tables, figures, and graphs to facilitate understanding and interpretation.

CHAPTER FOUR

4.0 RESULTS

Table 4.1a: Descriptive Statistics of Categorical Variables

		Frequency	Percent	Cumulative Percent
Gender	Male	26	52.0	52.0
	Female	24	48.0	100.0
	Total	50	100.0	
OSDI severity	Normal ocular surface (0-12)	20	40.0	40.0
	Mild dry eye disease (13-22)	16	32.0	72.0
	Moderate dry eye disease (23-32)	4	8.0	80.0
	Severe dry eye disease (33-100)	10	20.0	100.0
	Total	50	100.0	

Out of the 50 participants, 26 (52.0%) were male, while 24 (48.0%) were female, indicating a nearly balanced gender representation with a slight male predominance. 20 participants (40.0%) had a normal ocular surface (score 0–12). 16 participants (32.0%) had mild dry eye disease (score 13–22). 4 participants (8.0%) had moderate dry eye disease (score 23–32) based on the ocular surface disease index questionnaire. 10 participants (20.0%) had severe dry eye disease (score 33–100).

Table 4.1b: Descriptive Statistics of Categorical Variables Cont'd

		Frequency	Percent	Cumulative Percent
TBUT category at 50% RH	Normal (>10seconds)	46	92.0	92.0
	Marginal (5-10seconds)	3	6.0	98.0
	Low(<5seconds)	1	2.0	100.0
	Total	50	100.0	
TBUT category at 70% RH	Normal (>10seconds)	49	98.0	98.0
	Marginal (5-10seconds)	1	2.0	100.0
	Total	50	100.0	

The tear break-up time measured at 50% relative humidity showed that 46 (92%) participants had TBUT within normal range (>10 seconds), 3 (6%) participants had marginal TBUT and 1 (2%) participant had low TBUT (<5 seconds). At 70% relative humidity, the TBUT of participants had significantly improved across all categories with 49 (98%) participants recorded to have TBUT of greater than 10 seconds (normal) leaving only one participant at the marginal category (5-10 seconds).

Tables 4.2a &4.2b: Shows the Effects Of ideal and Increased Humidity on TBUT

Tables 4.2a: Mean rank and sum of ranks for TBUT at 50% vs 70% RH

		N	Mean Rank	Sum of Ranks
Average TBUT at 70% RH - Average TBUT at 50% RH	Negative Ranks	2[a]	49.50	99.00
	Positive Ranks	48[b]	24.50	1176.00
	Ties	0[c]		
	Total	50		
TBUT for OD at 70% RH - TBUT for OD at 50% RH	Negative Ranks	0[d]	.00	.00
	Positive Ranks	50[e]	25.50	1275.00
	Ties	0[f]		
	Total	50		
TBUT for OS at 70% RH - TBUT for OS at 50% RH	Negative Ranks	1[g]	2.00	2.00
	Positive Ranks	49[h]	25.98	1273.00
	Ties	0[i]		
	Total	50		

Table 4.2a shows how many participants had an increase in TBUT (Positive Ranks), across both relative humidity conditions (i.e 50% and 70% RH) a decrease (Negative Ranks), or no change (Ties), the average of those rank of those increases and decreases and the sum of those ranks. The table depicts that when the average TBUT of both eyes at 70% RH was compared to the average TBUT of both eyes at 50% RH, 48 participants had an increase in TBUT. When the TBUT of OD at 70% RH was compared to the TBUT of OD at 50% RH all the participants (i.e 50 individuals) had an increase in TBUT while 49 participants had an increase in TBUT for OS.

Table 4.2b: Wilcoxon signed-rank test results for TBUT at 50% vs 70% RH

	Average TBUT at 70% RH - Average TBUT at 50% RH	TBUT for OD at 70% RH - TBUT for OD at 50% RH	TBUT for OS at 70% RH - TBUT for OS at 50% RH
Z	-5.213[b]	-6.154[b]	-6.135[b]
Asymp. Sig. (2-tailed)	.000	.000	.000
Effect size (r)	.80	.95	.95

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Table 4.2b is the results table and it contains the conclusive output of the test statistic for the Wilcoxon signed-rank test (i.e the Z-value). The table determines the final test statistic(z). The Asymp. Sig. (i.e the p-value) shows that the observed change (from 50% to 70%) is statistically significant. The Wilcoxon Signed-Rank test showed that tear breakup time (TBUT) was statistically significantly higher in both the right eye and left eye after using a humidifier to increase humidity to 70% RH compared to the 50% RH condition, $Z = -6.135$, $p < .001$ for OS, $Z = -6.154$, $p < .001$ for OD and $Z = -5.213$, $p < .001$ when the average TBUT for both eyes were taken across two relative humidity levels. The "average TBUT at 70% RH" as shown in the table above is the mean TBUT of both eyes (OD and OS) at 70%RH while the "average TBUT at 50% RH" is the mean TBUT of both eyes (OD and OS) at 50%RH.

Table 4.3a-4.3b shows the correlation between average TBUT and OSDI score at different humidity levels

Table 4.3a: Correlation between TBUT at 50% RH and OSDI score

			Average TBUT at 50% RH	OSDI score
Spearman's rho	Average TBUT at 50% RH	Correlation Coefficient	1.000	-.461**
		Sig. (2-tailed)	.	.001
		N	50	50
	OSDI score	Correlation Coefficient	-.461**	1.000
		Sig. (2-tailed)	.001	.
		N	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

A Spearman's rho correlation showed a statistically significant moderate negative correlation between average TBUT at 50% RH and OSDI score, $\rho(50) = -0.461$, $p = .001$. This indicates that lower TBUT at 50% RH was associated with higher symptom severity on OSDI. The "average TBUT at 50% RH" as shown in the table above is the mean TBUT of both eyes (OD and OS) at 50%RH.

Table 4.3b: Correlation between TBUT at 70% RH and OSDI score

			Average TBUT at 70% RH	OSDI score
Spearman's rho	Average TBUT at 70% RH	Correlation Coefficient	1.000	-.304*
		Sig. (2-tailed)	.	.032
		N	50	50
	OSDI score	Correlation Coefficient	-.304*	1.000
		Sig. (2-tailed)	.032	.
		N	50	50

*. Correlation is significant at the 0.05 level (2-tailed).

A Spearman's rho correlation revealed a statistically significant weak-to-moderate negative correlation between average TBUT at 70% RH and OSDI score, $\rho(50) = -0.304$, $p = 0.032$. This suggests that as TBUT increases at higher humidity (70% RH), OSDI scores tend to decrease, reflecting reduced symptoms. Higher OSDI scores were associated with smaller TBUT improvements (Spearman's rho = −0.32, $p = 0.001$), suggesting participants with more severe symptoms benefited less from increased humidity. The "average TBUT at 70% RH" as shown in the table above is the mean TBUT of both eyes (OD and OS) at 70%RH.

Table 4.3c: Correlation between Average Change in TBUT and OSDI score

			Average change in TBUT	OSDI score
Spearman's rho	Average change in TBUT	Correlation Coefficient	1.000	.324*
		Sig. (2-tailed)	.	.022
		N	50	50
	OSDI score	Correlation Coefficient	.324*	1.000
		Sig. (2-tailed)	.022	.
		N	50	50

*. Correlation is significant at the 0.05 level (2-tailed).

A Spearman's rho correlation showed a statistically significant moderate positive correlation between the average change in TBUT (70% – 50%) and OSDI score, $\rho(50) = 0.324$, $p = .022$. This means that participants with greater improvements in TBUT when humidity increased have a greater chance of reporting higher symptom relief on OSDI. The "average change in TBUT" shown in the table above was derived by recording the difference between the average TBUT at 50% RH (mean TBUT of OU at 50%RH) and average TBUT at 70% RH (mean TBUT of OU at 70%RH).

Tables 4.4a-4.4d Determines if gender affects OSDI scores, severity of dry eyes among participants and TBUT

Table 4.4a shows Mann-Whiney U Test to determine the relationship between gender of participants and OSDI scores and dry eye severity.

	OSDI score	OSDI severity
Mann-Whitney U	156.500	192.000
Wilcoxon W	507.500	543.000
Z	-3.028	-2.463
Asymp. Sig. (2-tailed)	.002	.014

a. Grouping Variable: Gender

A Mann–Whitney U test was conducted to examine gender differences in OSDI outcomes. It was found that for OSDI score, there was a statistically significant difference between males and females, U = 156.500, Z = -3.03, p = .002. This suggests that OSDI scores differed significantly by gender. For OSDI severity category, there was also a statistically significant difference between genders, U = 192.000, Z = -2.46, p = .014. This indicates that the distribution of severity categories varied between males and females. These findings suggest that gender plays a role in symptom severity and self-reported ocular surface disease, with differences observed both in raw OSDI scores and categorical severity levels.

Table 4.5b: Shows Mann-Whiney U Test to Determine the Relationship Between Gender and Change in Tear Break up Time.

	Average change in TBUT	Change in TBUT for OD	Change in TBUT for OS
Mann-Whitney U	272.000	306.000	283.500
Wilcoxon W	623.000	606.000	634.500
Z	-.787	-.120	-.559
. Sig. (2-tailed)	.431	.905	.576

a. Grouping Variable: Gender

A Mann–Whitney U test was conducted to investigate whether gender had an effect on tear break-up time (TBUT) changes between 50% and 70% relative humidity. Results indicate that there were no statistically significant differences in TBUT changes between males and females. For average change in TBUT, the difference was not significant (U = 272.000, Z = -0.79, p = .431). Similarly, for right eye (OD) TBUT change, the difference was not significant (U = 306.000, Z = -0.12, p = .905), and for left eye (OS) TBUT change, the difference was also not significant (U = 283.500, Z = -0.56, p = .576). These results suggest that gender does not significantly influence the change in TBUT when humidity is increased from 50% to 70% RH.

Table 4.5c: Shows the Ranks for Friedman's Test Comparing Tear Break-Up Time (TBUT) Across Eyes and Humidity Conditions (50% vs. 70% RH)

	Mean Rank
TBUT for OD at 50% RH	1.56
TBUT for OS at 50% RH	1.80
TBUT for OD at 70% RH	3.14
TBUT for OS at 70% RH	3.50

A Friedman's test was conducted to compare tear break-up time (TBUT) across four related conditions: right eye (OD) at 50% relative humidity (RH), left eye (OS) at 50% RH, right eye at 70% RH, and left eye at 70% RH.

Table 4.5d: Shows the Test Statistics for Friedman's Test Comparing Tear Break-Up Time (TBUT) Across Eyes and Humidity Conditions (50% vs. 70% RH)

N	50
Kendall's W[a]	.559
Chi-Square	83.831
Df	3
Asymp. Sig.	.000

a. Kendall's Coefficient of Concordance

The Friedman's test results indicated a statistically significant difference in TBUT across the four conditions, $\chi^2(3) = 83.83$, $p < .001$, with a moderate-to-strong effect size (Kendall's W = .559). Inspection of the mean ranks showed that TBUT was lowest at 50% RH (OD = 1.56; OS = 1.80) and highest at 70% RH (OD = 3.14; OS = 3.50). This suggests that increasing humidity from 50% to 70% RH significantly improved tear film stability in both eyes. These findings confirm that humidity has a significant effect on TBUT, with better tear film performance observed under higher humidity conditions.

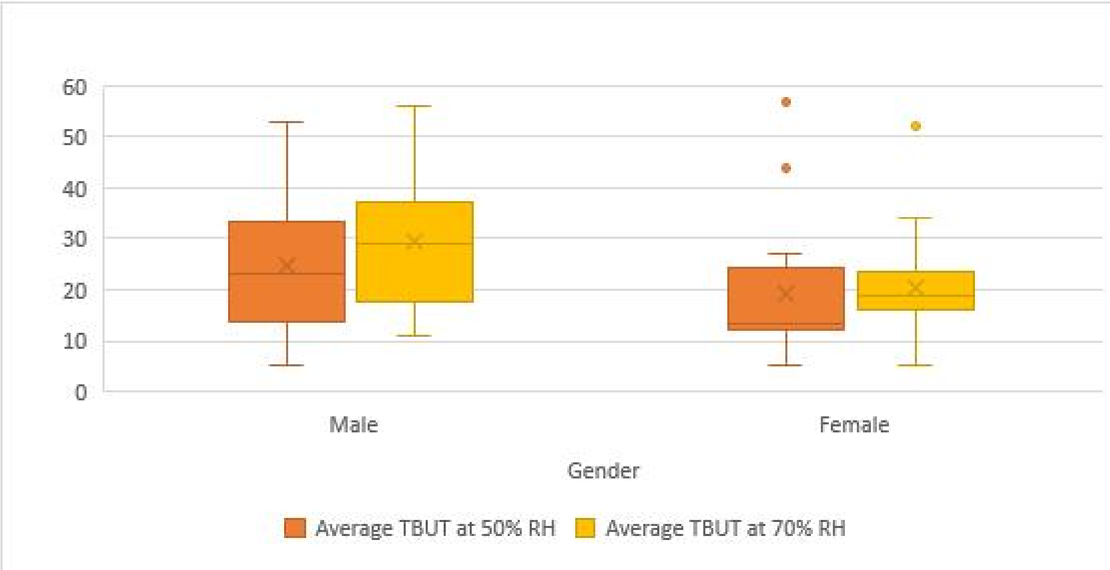

Figure 4.1: Boxplot of Average TBUT at 50% and 70% Relative Humidity by Gender

Figure 1 illustrates the distribution of average tear breakup time (TBUT) at 50% and 70% relative humidity (RH) stratified by gender. Both male and female participants demonstrated an increase in TBUT when humidity was raised from 50% to 70% RH. Among males, the median TBUT increased from approximately 25 seconds at 50% RH to nearly 30 seconds at 70% RH, with a wider interquartile range at higher humidity, indicating variability in responsiveness. Similarly, females showed a median TBUT increase, though with slightly lower overall values compared to males. A few outliers were observed among females at 70% RH, reflecting participants who experienced particularly high TBUT improvement. Overall, these results suggest that both genders benefit from increased humidity, with males showing slightly higher average TBUT values.

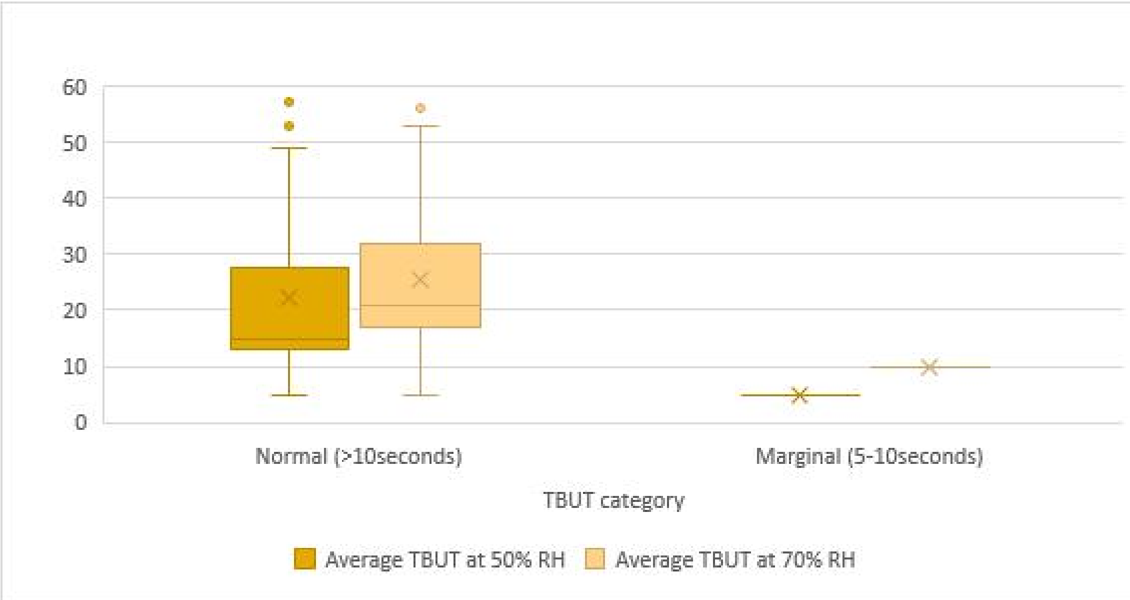

Figure 4.2: Boxplot of Average TBUT at 50% and 70% Relative Humidity by TBUT Category

Figure 4.2 compares average TBUT at 50% and 70% RH across two baseline TBUT categories: normal (>10 seconds) and marginal (5–10 seconds). Participants in both categories exhibited improvements in TBUT with increased humidity. In the normal TBUT group, the median rose from about 25 seconds at 50% RH to nearly 30 seconds at 70% RH, though some outliers indicated very high TBUT values. For the marginal TBUT group, the improvement was smaller but still evident, with median values increasing from below 10 seconds at 50% RH to just above 10 seconds at 70% RH. This finding highlights that while both normal and marginal TBUT groups respond positively to higher humidity, the magnitude of improvement is greater among those with initially normal tear film stability.

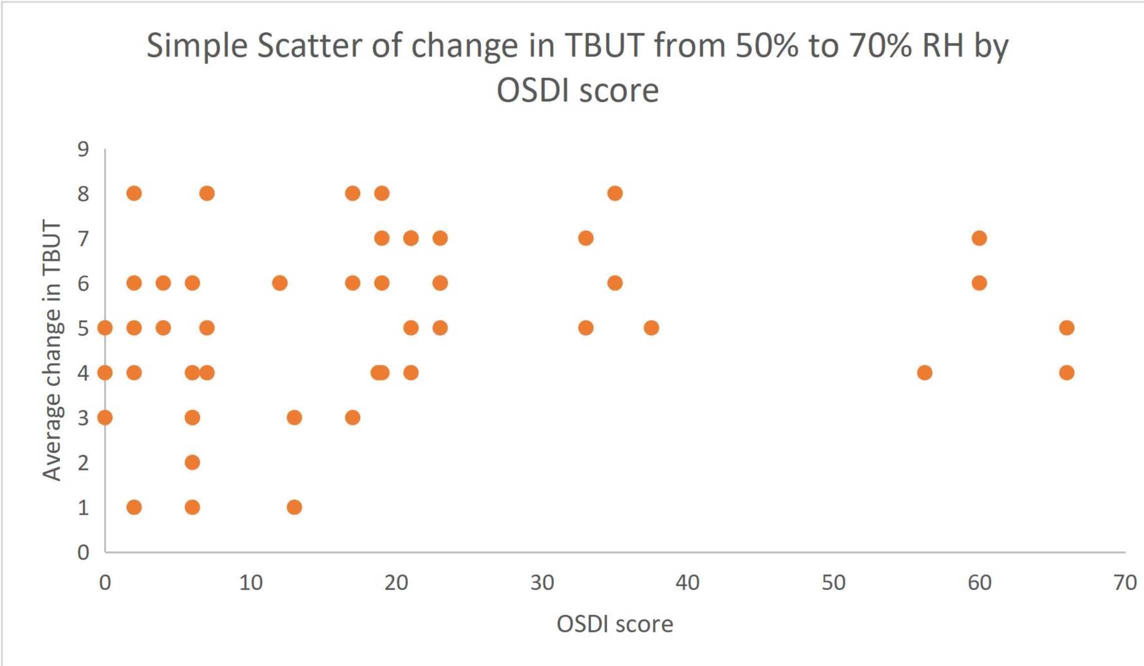

Figure 4.3: Scatterplot of Change in TBUT from 50% to 70% Relative Humidity by OSDI Score

Figure 4.3 shows the relationship between the change in tear breakup time (TBUT) from 50% to 70% relative humidity (RH) and the Ocular Surface Disease Index (OSDI) score. The distribution of data points suggests no strong linear trend between OSDI scores and the magnitude of TBUT change, although individuals with lower OSDI scores (<20, indicating normal to mild dry eye) tended to demonstrate a wider range of TBUT changes. Conversely, participants with higher OSDI scores exhibited relatively smaller TBUT improvements, suggesting that disease severity may attenuate the positive effect of increased humidity on tear stability.

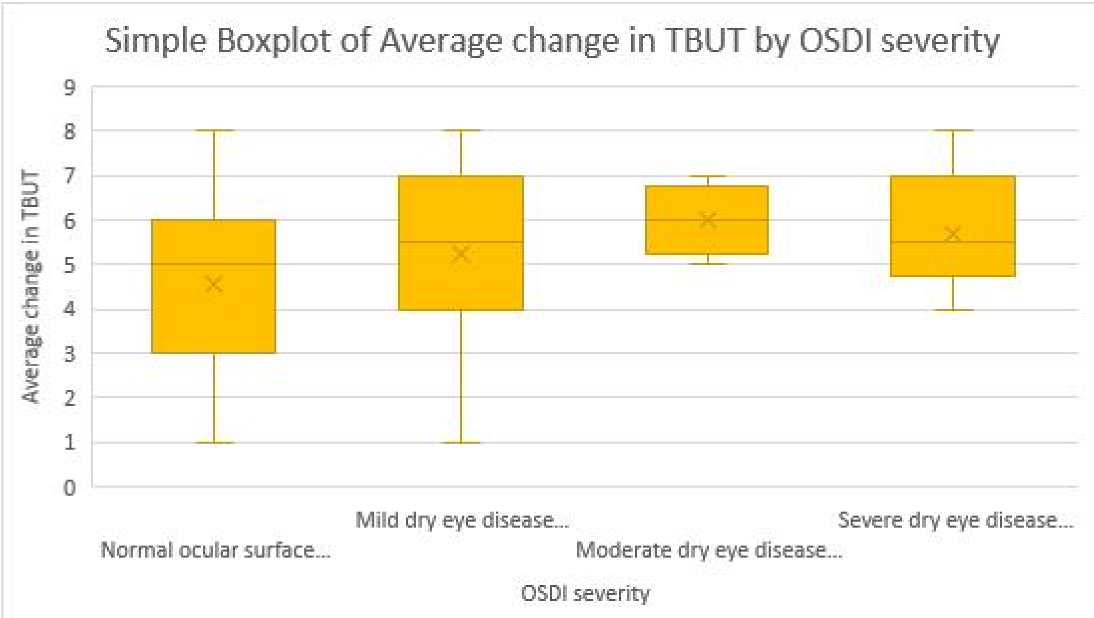

Figure 4.4: Boxplot of Average Change in TBUT Across OSDI Severity Categories

Figure 4.4 presents a boxplot of the average change in TBUT stratified by OSDI severity (normal ocular surface, mild, moderate, and severe dry eye disease). Median TBUT change was higher in participants with mild and moderate dry eye compared to those with severe dry eye. The spread of values was relatively consistent across groups, though severe dry eye participants showed slightly lower interquartile ranges. The results suggest that individuals with less severe disease experience greater improvement in TBUT with increased environmental humidity, while those with severe dry eye may exhibit reduced responsiveness.

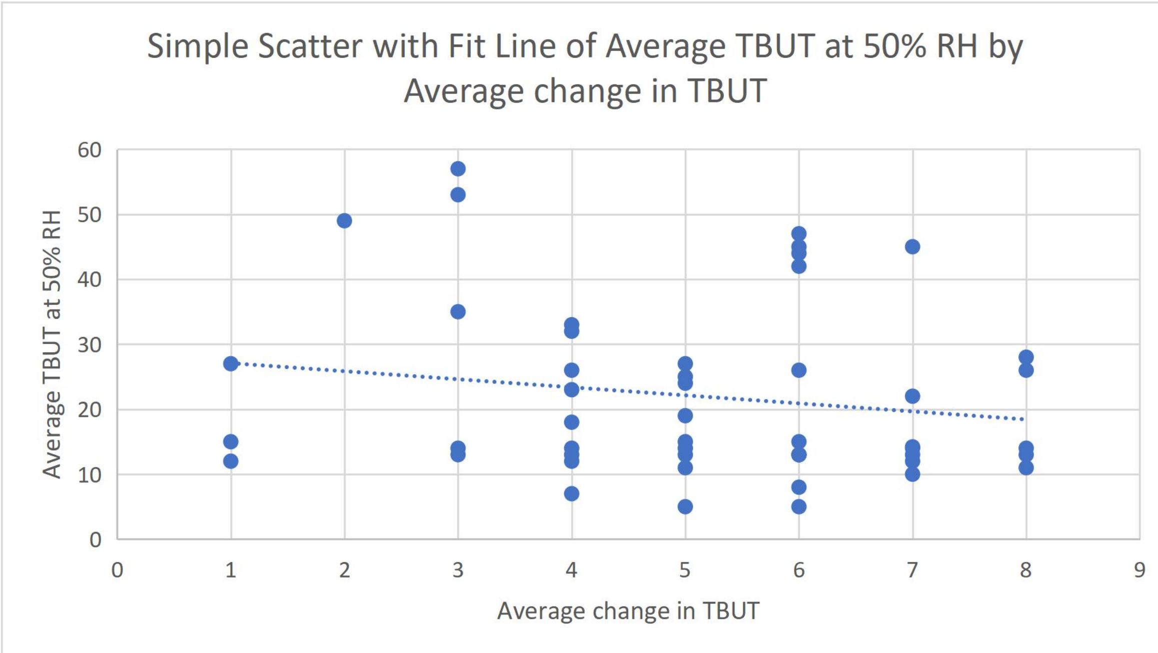

Figure 4.5: Scatterplot with Regression Line of Average TBUT at 50% RH by Average Change in TBUT

Figure 4.5 depicts the association between average TBUT at 50% RH and the average change in TBUT following exposure to 70% RH. A slight negative trend is observed, as indicated by the regression line, suggesting that participants with higher baseline TBUT at 50% RH tended to show smaller improvements when humidity increased. This implies that individuals with initially more stable tear films are less influenced by environmental changes in humidity compared to those with more unstable tear films.

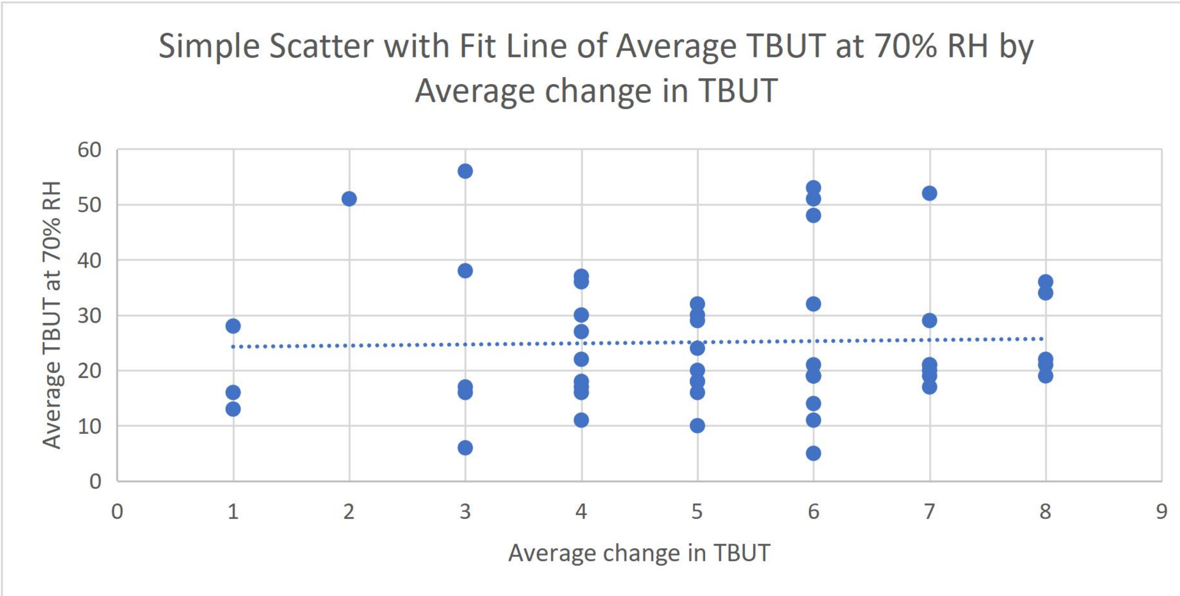

Figure 4.6: Scatterplot with Regression Line of Average TBUT at 70% RH by Average Change in TBUT

Figure 4.6 demonstrates the relationship between average TBUT at 70% RH and the average change in TBUT. In contrast to Figure 3, the regression line suggests a weakly positive association, though the trend is minimal. This indicates that at higher humidity levels, participants with greater changes in TBUT tended to achieve slightly higher average TBUT values overall. The finding reinforces the role of humidity as a beneficial factor for tear film stability, particularly among individuals with lower baseline TBUT values.

CHAPTER FIVE

5.0 DISCUSSION

This study investigated the effect of increased humidity on tear breakup time (TBUT) in fifty (50) healthy Subjects exposed to 50% relative humidity (RH) and 70% RH. The results consistently demonstrated that higher humidity significantly improved TBUT in both eyes across all Subjects. There were reduced symptoms severity as measured by Ocular Surface Disease Index (OSDI), and measurable ocular comfort. These findings are discussed in relation to prior literature.

5.1 GENERAL TBUT CHANGES WITH HUMIDITY

The data revealed that the mean TBUT increased from 21.98 ±1.91 seconds at 50% RH to 25.10 ±1.79 seconds at 70% RH across participants. Both eyes showed consistent improvements, with maximum TBUT values reaching 36 ±1.95 seconds at higher humidity. This improvement agrees with the findings of Buckmaster and Pearce (2016), who observed that environmental humidity strongly influences tear production and test outcomes. In their study, Schirmer wetting length was markedly reduced at low RH due to faster evaporation. Similarly, our results suggest that at 70% RH, reduced evaporation allowing the tear film to maintain stability for longer duration, thereby increasing TBUT.

The results of this study is also consistent with Jha (2009), who reported that individuals in high-altitude, low-humidity environments exhibited TBUT abnormalities (<5 seconds in 24% of subjects), accompanied by ocular irritation and redness. In contrast, our data indicate that higher humidity provides a protective effect, confirming that environmental moisture levels are directly linked to tear film stability.

5.2 OSDI SEVERITY AND TBUT CATEGORIES

Table 4.1a and Table 4.1b showed that at 50% RH, 92% of participants had normal TBUT (>10 seconds), but 8% fell into marginal or low categories. At 70% RH, 98% had normal TBUT, showing that even borderline cases improved with humidity. This echoes the findings of Harp (2024), who reported that higher humidity levels were associated with significantly lower SANDE symptom scores (Symptom Assessment in Dry Eye), lower tear osmolarity, and reduced ocular surface staining among dry eye patients. The strong overlap suggests that TBUT improvement translates into measurable symptom relief.

Moreover, the fact that all severe OSDI participants experienced some degree of relief with increased humidity suggests that humidity interventions could be beneficial across the disease spectrum, though less pronounced in severe cases, as also highlighted by Buckmaster and Pearce (2016), who found that patients with advanced dry eye showed less variability in response to humidity changes.

5.3 STATISTICAL SIGNIFICANCE OF TBUT CHANGES

Tables 4.2a and 4.2b (Wilcoxon signed-rank test) confirmed that the improvements in TBUT between 50% and 70% RH were statistically significant ($p < 0.001$), with large effect sizes ($r = 0.80-0.95$). This aligns with Song *et al.,* (2023), who demonstrated that low-humidity groups showed higher symptom severity, osmolarity, and ocular staining, whereas increases in humidity corresponded with symptom improvement. Although Song *et al.* found temperature to be a stronger determinant of DED outcomes, my findings emphasize that humidity alone exerts a substantial positive influence on TBUT, particularly in young, otherwise healthy participants.

5.4 CORRELATION BETWEEN TBUT AND SYMPTOMS

Tables 4.3a and 4.3b showed significant negative correlations between TBUT and OSDI scores at both humidity levels. At 50% RH, lower TBUT was moderately associated with worse symptoms ($\rho = -0.461$, $p = 0.001$), while at 70% RH, the correlation weakened ($\rho = -0.304$, $p = 0.032$). This finding suggests that humidity attenuates the relationship between tear instability and symptom severity.

Table 4.3c further revealed a positive correlation ($\rho = 0.324$, $p = 0.022$) between improvement in TBUT and reduction in OSDI scores, confirming that participants who gained more tear stability also reported greater relief. This reflects Harp (2024), who reported that each 1% rise in humidity was associated with reduced SANDE symptom scores and osmolarity. Taken together, these results underscore the dual clinical and subjective benefits of increased humidity.

5.5 GENDER DIFFERENCES

Table 4.4a indicated that OSDI scores and severity varied significantly by gender, with females reporting higher discomfort ($p = 0.002$, $p = 0.014$). This corresponds with epidemiological findings that women are more susceptible to DED due to hormonal influences (Song *et al.,* 2023). However, Table 4.4b showed that TBUT improvements with increased humidity did not differ significantly between genders, suggesting that the physiological tear film response to humidity is consistent across sexes, even though subjective symptoms may vary.

5.6 EYE AND CONDITION COMPARISONS

The Friedman's test (Tables 4.4c and 4.4d) confirmed significant differences across humidity conditions, with mean ranks highest at 70% RH in both eyes ($\chi^2 = 83.83$, $p < 0.001$). These findings strongly corroborate Jha (2009), who emphasized the destabilizing effect of low humidity, and extend the evidence by demonstrating that controlled humidity elevation reliably enhances tear stability in all participants.

5.7 INTERPRETATION OF FIGURES

Figure 1 (Gender differences): Both males and females benefited from increased humidity, though males exhibited slightly higher TBUT medians. This reflects Song *et al.* (2023), who reported greater symptom severity in females but noted that both sexes showed environmental sensitivity.

Figure 2 (TBUT category comparison): Marginal TBUT participants improved into the normal range at 70% RH, supporting Buckmaster & Pearce (2016), who warned that low humidity can lead to false diagnoses of dry eye.

Figure 3 and 4 (TBUT vs OSDI): Participants with lower severity showed greater improvements, consistent with Harp (2024), who noted that mild-to-moderate cases benefit most from environmental improvements.

Figure 5 (Baseline vs change): Participants with low TBUT at 50% RH improved the most, reflecting Jha (2009), who documented profound tear instability in low-humidity conditions.

Figure 6 (TBUT at 70% RH vs change): Showed overall stability at higher humidity, reinforcing Song *et al.* (2023), who noted that environmental improvements directly influence tear physiology and symptomatology.

Overall, the results of this study strongly confirm that humidity is a key determinant of tear film stability and ocular comfort. While severe dry eye patients may show less variability, young healthy participants benefited substantially from elevated RH. These findings corroborate earlier studies (Buckmaster and Pearce, 2016; Song *et al.,* 2023; Jha, 2009; Harp, 2024) and extend knowledge by providing controlled experimental evidence within a West African setting.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This study demonstrated that:

1. The data revealed that the mean TBUT increased from 21.98 ±1.91 seconds at 50% RH to 21.0 ±1.79 seconds at 70% RH across participants.
2. Symptom relief paralleled TBUT improvement. Subjects with greater TBUT also reported greater OSDI reductions (Tables 4.3a–c).
3. Gender differences exist in symptom reporting, not physiological. Females reported higher OSDI scores, but both sexes experienced equal TBUT gains (Tables 4.4a–b).
4. Severity of dry eye affects responsiveness. Mild-to-moderate cases improved more than severe cases (Figure 4), aligning with previous findings that advanced disease may show reduced environmental sensitivity.

These results confirm that humidity is a critical environmental factor influencing ocular surface health. The study extends prior research by demonstrating that controlled humidity elevation yields statistically and clinically significant benefits.

6.1.1 IMPLICATIONS

Clinical Practice: Humidifiers should be recommended as supportive therapy for dry eye patients, especially in low-humidity climates and during Harmattan seasons.

Environmental Health: Maintaining indoor RH between 50–70% may optimize tear stability and reduce discomfort in workplaces and homes.

Diagnostic Accuracy: Low-humidity environments may contribute to false-positive diagnoses of dry eye in borderline patients (Buckmaster & Pearce, 2016).

6.1.2 LIMITATIONS

1. Restricted to young healthy participants; results may differ in elderly or diseased populations.
2. Short-term exposure assessed; long-term adaptation remains untested.
3. Symptom–sign mismatch persisted in some participants

6.2 RECOMMENDATIONS FOR FUTURE RESEARCH

1. Replicate findings in older populations, contact lens wearers, and dry eye patients.
2. Conduct longitudinal studies to determine sustained effects of humidification.
3. Explore combined effects of humidity, temperature, and pollutants (Harp, 2024).
4. Investigate humidity's role in preventing ocular complications in extreme environments (e.g., high altitude, aviation, Harmattan).

REFEERNCE

Abelson M.B., Ousler G.W., Nally L.A., Welch D. and Krenzer K. (2002). Alternative reference values for tear film break-up time in normal and dry eye populations. *Advances in Experimental Medicine and Biology*, 506: 1121-1125.

Abusharha A.A. and Pearce E.I. (2013). The effect of low humidity on the human tear film', *Cornea*. 32(4): 429-434.

Abusharha, Ali A. Ph.D.; Pearce, E. Ian. (2016). Fagehi, Raied Ph.D.. Effect of Ambient Temperature on the Human Tear Film. *Eye & Contact Lens: Science & Clinical Practice*. 42(5): p 308-312,. | DOI: 10.1097/ICL.0000000000000210

Backman H. and Haghighat F. (1999). Indoor-air quality and ocular discomfort. *Journal of the American Optometric Association*. 70: 309-316.

Blalock T.D., Spurr-Michaud S.J., Tisdale A.S., Heimer S.R., Gilmore, M.S. and Ramesh V. (2007). Functions of MUC16 in corneal epithelial cells. *Experimental Eye Research.* 85(2): 137-148.

Bron A.J., de Paiva C.S., Chauhan S.K., Bonini S., Gabison E.E., Jain S., Knop E., Markoulli M., Ogawa Y., Perez V., Uchino Y., Yokoi N., Zoukhri D. and Sullivan D.A. (2017). 'TFOS DEWS II pathophysiology report. *The Ocular Surface.* 15(3): 438-510.

Buckmaster F., and Pearce, E.I. (2016). Effects of humidity on tests of tear production. *Cornea*. 35(6): 778–782.

Buckmaster, Fiona; Pearce, E. Ian., (2016). Effects of Humidity on Tests of Tear Production. *Cornea*. 35(6): p 754-758. | DOI: 10.1097/ICO.0000000000000818

Cardona G., Seres C., Quevedo L. and Gispets J. (2011). Knowledge and use of tear film evaluation tests by Spanish practitioners. *Optometry and Vision Science*, 88(9): 1106-1111.

Cho P. (1991). Stability of the precorneal tear film: A review', Clinical and Experimental Optometry, 74(1): 19-25.

Craig J.P., Nichols K.K., Akpek E.K., Caffery B., Dua H.S., Joo C.K., Liu Z., Nelson J.D., Nichols J.J., Tsubota K., and Stapleton F. (2017). TFOS DEWS II definition and classification report. *The Ocular Surface*. 15(3): pp. 276-283.

Dartt, D.A. (2017). Goblet cells of the conjunctiva: A review of recent findings. *Progress in Retinal and Eye Research.* 57: pp. 26-42.

Dartt, D.A. and Masli, S. (2019). Conjunctival goblet cells: Ocular surface functions, disorders that affect them, and the potential for their regeneration. *The Ocular Surface*. 17(4): pp. 777-787.

Doughty, M.J. (2012). Goblet cells of the normal human bulbar conjunctiva and their assessment by impression cytology sampling. *The Ocular Surface.* 10(3): pp. 149-169.

Downie, L.E., Keller, P.R. and Vingrys, A.J. (2013). An evidence-based analysis of Australian optometrists' dry eye practices. *Optometry and Vision Science*. 90(12): pp. 1385-1395.

Emerald Harvest (2024). Vapor pressure deficit: The key to optimizing plant growth.

Foulks, G.N. and Bron, A.J. (2007). The epidemiology of dry eye disease: Report of the Epidemiology Subcommittee of the International Dry Eye Workshop. *The Ocular Surface*. 5(2): pp. 93-107.

Gao, Y., Zhang, L., Wang, H., Chen, M. and Liu, P. (2018). Effects of relative humidity on tear film stability in young adults. *Clinical Journal of Medicine.* 15(3): pp. 124-131. Available at: https://www.c-jcm.com.

González-García, M.J., González-Sáiz, A., López-Miguel, A., Enríquez-de-Salamanca, A., García-Vázquez, C., Fernández, I. and González-González, M. (2007). Exposure to a controlled adverse environment impairs the ocular surface of subjects with minimally symptomatic dry eye. *Investigative Ophthalmology & Visual Science.* 48(9): pp. 4026-4032.

Gupta, N., Prasad, I., Himashree, G. and D'Souza, P. (2009). Tear break-up time in high altitude areas. *Indian Journal of Ophthalmology*. 57(6): pp. 461-464.

Gupta, N., Prasad, I., Himashree, G. and D'Souza, P. (2016). Tear break-up time in high altitude areas. *Delhi Journal of Ophthalmology*. 27(1): pp. 91-94.

Harp, M.D. (2024). Study looks at the correlation of humidity, temperature, and air pollutants on dry eye disease patients. *Ophthalmology News.*

Healio. (2017). Environmental temperature affects tear film parameters. *Ophthalmology Times.*

Holly, F.J., Lemp, M.A. and Iwata, S. (1977). The precorneal tear film: factors in spreading and maintaining a continuous tear film over the corneal surface. *Archives of Ophthalmology*. 95(1): pp. 89-94.

Jha, K.N. (2009). Tear break-up time in high altitude areas. *Medical Journal Armed Forces India*. 65(1): pp.2–3. https://doi.org/10.1016/S0377-1237(09)80042-7

Khanal, S., Simmons, P.A., Pearce, E.I. and Tomlinson, A. (2008). Effect of artificial tears on tear stress test. *Optometry and Vision Science*. 85(8): pp. 732-739.

Khanal, S., Tomlinson, A., Pearce, E.I. and Simmons, P.A. (2007). Effect of an oil-in-water emulsion on the tear physiology of patients with mild to moderate dry eye. *Cornea*. 26(2): pp. 175-181.

Korb, D.R., Greiner, J.V. and Herman, J. (2001). Comparison of fluorescein break-up time measurement reproducibility using standard fluorescein strips versus the dry eye test (DET) method. *Cornea*. 20(8): pp. 811-815.

Korb, D.R., Greiner, J.V., Herman, J.P., Hebert, E.M. and Finnemore, V.M. (2002). Lid wiper epitheliopathy and dry eye symptoms in contact lens wearers. *Eye and Contact Lens*. 28(4): pp. 211-216.

Lee, J.H. and Kee, C.W. (1988). The significance of tear film break-up time in the diagnosis of dry eye syndrome. *Korean Journal of Ophthalmology*. 2(2): pp. 69-71.

Lemp, M.A., Baudouin, C., Baum, J., Dogru, M., Foulks, G.N., Kinoshita, S., Laibson, P., McCulley, J., Murube, J., Pflugfelder, S.C., Rolando, M. and Toda, I. (2007). The definition and classification of dry eye disease: Report of the Definition and Classification Subcommittee of the International Dry Eye WorkShop. *Ocular Surface*. 5(2): pp. 75-92.

Mathers, W.D., Binarao, G. and Petroll, M. (1993). Ocular water evaporation and the dry eye. A new measuring device. *Cornea*. 12(4): pp. 335-340.

Mathers, W.D. and Daley, T.E. (1996). Tear flow and evaporation in patients with and without dry eye. *Ophthalmology.* 103(4): pp. 664-669.

McCulley, J.P., Aronowicz, J.D., Uchiyama, E., Shine, W.E. and Butovich, I.A. (2006). Correlations in a change in aqueous tear evaporation with a change in relative humidity and the impact. *American Journal of Ophthalmology.* 141(4): pp. 758-760.

Mengher, L.S., Bron, A.J., Tonge, S.R. and Gilbert, D.J. (1985). Effect of fluorescein instillation on the pre-corneal tear film stability. *Current Eye Research*. 4(1): pp. 9-12.

Mooi, J.K., Wang, M.T.M., Lim, J., Müller, A. and Craig, J.P. (2017). Minimizing instilled volume reduces the impact of fluorescein on clinical measurements of tear film stability. *Contact Lens and Anterior Eye.* 40(3): pp. 170-174.

Nichols, K.K., Mitchell, G.L. and Zadnik, K. (2004). The repeatability of clinical measurements of dry eye. *Cornea*. 23(3): pp. 272-285.

Nilsson, S.E. and Andersson, L. (1986). Contact lens wear in dry environments. *Acta Ophthalmologica*. 64(2): pp. 221-225.

Norn, M.S. (1969). Desiccation of the precorneal film. *Acta Ophthalmologica*. 47(4), pp. 865-880.

Onwubiko, S.N., Eze, B.I., Udeh, N.N. and Arinze, O.C. (2019). Seasonal variation in tear secretion and tear film break-up time in adults in Enugu. *Herald Open Access*. 2(1): pp. 15-22. Available at: https://www.heraldopenaccess.us (Accessed: 3 May 2025).

Ousler, G.W., Abelson, M.B., Nally, L.A. and Welch, D. (2002). Evaluation of the time to "natural compensation" in normal and dry eye subject populations during exposure to a controlled adverse environment', Advances in Experimental Medicine and Biology. 506(Pt B): pp. 1057-1063.

Ousler, G.W., Wilcox, K.A., Gupta, G., Abelson, M.B. and Fink, K. (2007). An evaluation of tear film breakup time extension and ocular protection index scores among three marketed lubricant eye drops', *Cornea.* 26(8): pp. 949-952.

PMC (2023) Environmental factors affecting tear film stability. PubMed Central. Available at: https://pmc.ncbi.nlm.nih.gov (Accessed: 3 May 2025).

Pult, H. and Riede-Pult, B.H. (2012). A new modified fluorescein strip: Its repeatability and usefulness in tear film break-up time analysis. *Contact Lens and Anterior Eye.* 35(1): pp. 35-38.

Schlote, T., Kadner, G. and Freudenthaler, N. (2004). Marked reduction and distinct patterns of eye blinking in patients with moderately dry eyes during video display terminal use', *Graefe's Archive for Clinical and Experimental Ophthalmology* 242(4): pp. 306-312.

ScienceDirect Topics (2023). Tear film - An overview. Available at: https://www.sciencedirect.com/topics/neuroscience/tear-film (Accessed: 3 May 2025).

Song, M.S., Lee, Y., Paik, H.J. and Kim, D.H., (2023). A comprehensive analysis of the influence of temperature and humidity on dry eye disease. *Korean Journal of Ophthalmology,* 37(6): pp.501–509. https://doi.org/10.3341/kjo.2023.0077

Stapleton, F., Alves, M., Bunya, V.Y., Jalbert, I., Lekhanont, K., Malet, F., Na, K.S., Schaumberg, D., Uchino, M., Vehof, J., Viso, E., Vitale, S., and Jones, L., (2017). TFOS DEWS II epidemiology report. *The Ocular Surface*. 15(3): pp. 334-365.

Sullivan, B.D., Crews, L.A., Messmer, E.M., Foulks, G.N., Nichols, K.K., Baenninger, P., Geerling, G., Figueiredo, F., and Lemp, M.A. (2017). Correlations between commonly used objective signs and symptoms for the diagnosis of dry eye disease: Clinical implications. *Acta Ophthalmological.* 92(3): pp. 161-166.

Sun-Hee, K., Min-Jung, L., Soo-Young, P. and Hyun-Sook, C. (2023). Effects of humidity changes on the eyes. *Journal of Environmental Health*. 45(3): pp. 124-131.

Sweeney, D.F., Millar, T.J. and Raju, S.R. (2013). Tear film stability: *A review', Experimental Eye Research*. 117: pp. 28-38.

Tesón, M., González-García, M.J., López-Miguel, A., Enríquez-de-Salamanca, A., Martín-Montañez, V., Benito, M.J., Mateo, M.E., Stern, M.E., González, M.J., Calonge, M. and González-González, M. (2013). Influence of a controlled environment simulating an in-flight airplane cabin on dry eye disease. *Investigative Ophthalmology & Visual Science*. 54(3): pp. 2093-2099.

Tsubota, K. (2018). Short tear film breakup time-type dry eye. *Investigative Ophthalmology & Visual Science*. 59(14): pp. DES64-DES70.

Turner, A.W., Layton, C.J. and Bron, A.J. (2005). Survey of eye practitioners' attitudes towards diagnostic tests and therapies for dry eye disease. *Clinical and Experimental Ophthalmology*. 33(4): pp. 351-355.

Uchino, M., Schaumberg, D.A., Dogru, M., Uchino, Y., Fukagawa, K., Shimmura, S., Satoh, T., Takebayashi, T., and Tsubota, K. (2008). Prevalence of dry eye disease among Japanese visual display terminal users. *Ophthalmology*. 115(11): pp. 1982-1988.

Uchino, M., Yokoi, N., Uchino, Y., Dogru, M., Kawashima, M., Komuro, A. and Tsubota, K. (2014). Dry eye disease and work productivity loss in visual display users: the Osaka study. *American Journal of Ophthalmology*. 157(2): pp. 294-300.

Vanley, G.T., Leopold, I.H. and Gregg, T.H. (1977). Interpretation of tear film breakup. *Archives of Ophthalmology.* 95(3): pp. 445-448.

Vaughan, W., Smith, R.J., Johnson, M.K. and Brown, L.S. (2024). Ocular effects of exposure to low-humidity environment with contact lens wear. *Contact Lens & Anterior Eye*. 47(1): pp. 78-86.

Vingrys, A.J., Robinson, S.R., Vessey, K.A., Schmid, K.L. and Downie, L.E. (2013). Optometric management of early-stage AMD: Translating evidence to practice. *Clinical and Experimental Optometry*. 96(1): pp. 4-14.

Vitale, S. (2023). Understanding the tear film. *Review of Contact Lenses*. 20(2): pp. 28-32.

Wikipedia (2025). Vapor pressure deficit. Available at: https://en.wikipedia.org (Accessed: 3 May 2025).

Wolffsohn, J.S., Arita, R., Chalmers, R., Djalilian, A., Dogru, M., Dumbleton, K., Gupta, P.K., Karpecki, P., Lazreg, S., Pult, H., Sullivan, B.D., Tomlinson, A., Tong, L., Villani, E., Yoon, K.C., Jones, L. and Craig, J.P. (2017). TFOS DEWS II diagnostic methodology report. *The Ocular Surface*. 15(3): pp. 539-574.

Xue, A.L., Downie, L.E., Ormonde, S.E. and Craig, J.P. (2017). A comparison of the self-reported dry eye practices of New Zealand optometrists and ophthalmologists. *Ophthalmic and Physiological Optics*. 37(2): pp. 191-201.

Yazdani, M., Fiskadal, J., Chen, X., Aakre, B.M. and Dartt, D.A. (2021). Tear film break-up time and dry eye disease severity in a large Norwegian cohort. *Acta Ophthalmologica*. 99(5): pp. 503-510

Ocular Surface Disease Index© (OSDI©)[2]

Ask your patients the following 12 questions, and circle the number in the box that best represents each answer. Then, fill in boxes A, B, C, D, and E according to the instructions beside each.

Have you experienced any of the following *during the last week*?	All of the time	Most of the time	Half of the time	Some of the time	None of the time
1. Eyes that are sensitive to light? . .	4	3	2	1	0
2. Eyes that feel gritty?	4	3	2	1	0
3. Painful or sore eyes?	4	3	2	1	0
4. Blurred vision?	4	3	2	1	0
5. Poor vision?	4	3	2	1	0

Subtotal score for answers 1 to 5 (A)

Have problems with your eyes limited you in performing any of the following *during the last week*?	All of the time	Most of the time	Half of the time	Some of the time	None of the time	N/A
6. Reading?	4	3	2	1	0	N/A
7. Driving at night?	4	3	2	1	0	N/A
8. Working with a computer or bank machine (ATM)?	4	3	2	1	0	N/A
9. Watching TV?	4	3	2	1	0	N/A

Subtotal score for answers 6 to 9 (B)

Have your eyes felt uncomfortable in any of the following situations *during the last week*?	All of the time	Most of the time	Half of the time	Some of the time	None of the time	N/A
10. Windy conditions?	4	3	2	1	0	N/A
11. Places or areas with low humidity (very dry)?	4	3	2	1	0	N/A
12. Areas that are air conditioned? . . .	4	3	2	1	0	N/A

Subtotal score for answers 10 to 12 (C)

Add subtotals A, B, and C to obtain D (D = sum of scores for all questions answered) (D)

Total number of questions answered (do not include questions answered N/A) (E)

Please turn over the questionnaire to calculate the patient's final OSDI® score.

APPENDIX I

APPENDIX II

	Std. Error of Mean	Std. Deviation	Minimum	Maximum	Percentiles		
					25	50	75
Gender	.071	.505	1	2	1.00	1.00	2.00
OSDI score	2.483	17.557	0	66	6.00	17.00	23.00
OSDI severity	.161	1.140	1	4	1.00	2.00	3.00
TBUT for OD at 50% RH	1.815	12.837	5	53	12.10	15.32	26.99
TBUT for OS at 50% RH	2.030	14.353	4	60	12.98	15.13	30.92
TBUT for OD at 70% RH	1.825	12.905	10	59	17.25	21.33	31.36
TBUT for OS at 70% RH	1.953	13.811	11	60	17.96	21.38	36.17
TBUT category at 50% RH	.052	.364	1	3	1.00	1.00	1.00
TBUT category at 70% RH	.020	.141	1	2	1.00	1.00	1.00

	Std. Error of Mean	Std. Deviation	Minimum	Maximum	Percentiles		
					25	50	75
Change in TBUT for OD	.259	1.828	0	9	4.00	6.00	6.00
Change in TBUT for OS	.295	2.083	1	9	4.00	5.00	7.00
Average TBUT at 50% RH	1.907	13.481	5	57	13.00	15.00	27.25
Average TBUT at 70% RH	1.785	12.619	5	56	17.00	21.00	32.00
Average change in TBUT	.263	1.859	1	8	4.00	5.00	6.25

Ranks

	Gender	N	Mean Rank	Sum of Ranks
Average change in TBUT	Male	26	23.96	623.00
	Female	24	27.17	652.00
	Total	50		
Change in TBUT for OD	Male	26	25.73	669.00
	Female	24	25.25	606.00
	Total	50		
Change in TBUT for OS	Male	26	24.40	634.50
	Female	24	26.69	640.50
	Total	50		

Ranks

		N	Mean Rank	Sum of Ranks
Average TBUT at 70% RH - Average TBUT at 50% RH	Negative Ranks	2[a]	49.50	99.00
	Positive Ranks	48[b]	24.50	1176.00
	Ties	0[c]		
	Total	50		

a. Average TBUT at 70% RH < Average TBUT at 50% RH

b. Average TBUT at 70% RH > Average TBUT at 50% RH

c. Average TBUT at 70% RH = Average TBUT at 50% RH

		N	Mean Rank	Sum of Ranks
TBUT for OD at 70% RH - TBUT for OD at 50% RH	Negative Ranks	0[a]	.00	.00
	Positive Ranks	50[b]	25.50	1275.00
	Ties	0[c]		
	Total	50		
TBUT for OS at 70% RH - TBUT for OS at 50% RH	Negative Ranks	1[d]	2.00	2.00
	Positive Ranks	49[e]	25.98	1273.00
	Ties	0[f]		
	Total	50		
Average TBUT at 70% RH - Average TBUT at 50% RH	Negative Ranks	2[g]	49.50	99.00
	Positive Ranks	48[h]	24.50	1176.00
	Ties	0[i]		
	Total	50		

a. TBUT for OD at 70% RH < TBUT for OD at 50% RH
b. TBUT for OD at 70% RH > TBUT for OD at 50% RH
c. TBUT for OD at 70% RH = TBUT for OD at 50% RH
d. TBUT for OS at 70% RH < TBUT for OS at 50% RH
e. TBUT for OS at 70% RH > TBUT for OS at 50% RH
f. TBUT for OS at 70% RH = TBUT for OS at 50% RH
g. Average TBUT at 70% RH < Average TBUT at 50% RH
h. Average TBUT at 70% RH > Average TBUT at 50% RH

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Interval by Interval	Pearson's R	-.370	.116	-2.758	.008[c]
Ordinal by Ordinal	Spearman Correlation	-.336	.128	-2.473	.017[c]
N of Valid Cases		50			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Interval by Interval	Pearson's R	-.381	.094	-2.853	.006[c]
Ordinal by Ordinal	Spearman Correlation	-.366	.132	-2.727	.009[c]
N of Valid Cases		50			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Interval by Interval	Pearson's R	-.226	.138	-1.607	.115[c]
Ordinal by Ordinal	Spearman Correlation	-.286	.134	-2.066	.044[c]
N of Valid Cases		50			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Interval by Interval	Pearson's R	.255	.110	1.830	.073[c]
Ordinal by Ordinal	Spearman Correlation	.259	.123	1.859	.069[c]
N of Valid Cases		50			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.