INVESTIGATING GENDER DIFFERENCES IN HAEMTOLOGICAL INDICES OF YOUNG ADULTS IN UNIVERSITY OF BENIN

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DEDICATION

I dedicate this work to God Almighty for His love, strength, wisdom and Grace to carry through. And to my amazing parents and family, for their constant prayers, encouragement and support so far, and their financial support in making this study a success.

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I am most thankful to GOD Almighty for the wisdom, strength, grace, knowledge he provided me throughout the time span of this project.

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May God bless you all and grant you all success

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Hematological indices are essential for evaluation of blood composition and overall health. They are a set of measurements and values obtained from a complete blood count (CBC) test. They include: Red blood cell count, total and differential white blood cell count, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), platelets count etc. This study aims to measure and compare the values of RBCs, Total and Differential WBCs, MCV, MCH, MCHC and Platelets between young male and female human adults. A Questionnaire was given to collect demographic and a little clinical data from the participants to ensure they met the criteria for participation. The participants constituted two (2) groups – males and females, with each group having 20 individuals between ages 18-30. Blood samples were collected. The data obtained from the groups were presented as Mean ± S.E.M (Standard Error of Mean), (n=20) in each group and analyzed for statistical significant at ($p \leq 0.05$). The statistical software used includes R and WPS sheets. The results for RBC count, MCV, MCH and MCHC were significantly higher (**$p \leq 0.05$**) in males than in females, while the values of total WBC count, each of the differential WBC count and the platelet count, were significantly higher (**$p \leq 0.05$**) in females compared to males. In conclusion, the results of this study highlights and buttress that there are significant differences between the selected hematological parameters of males and females. These variations are most likely due to physiological factors like the testosterone on erythropoiesis and the potential differences in body composition and metabolism.

CHAPTER ONE

INTRODUCTION

1.1 Blood

Blood is a specialized body fluid present in most living things. In humans, it flows through specialised vessels called arteries and the veins. It has three main cellular components: red blood cells (RBCs), white blood cells (WBCs), and platelets and a liquid component called: plasma with a specific gravity of 1.052 to 1.061 (Mathew *et al*., 2023). It also contains a mixture of cellular elements, colloids and crystalloids like glucose, albumin, etc. (Rudloff, and Hopper, 2021). Circulating blood in the average human adult is about 5L of which plasma contributes 60% indicating an average plasma volume of about 3L, while the cellular compartment contributes about 40%, though women tend to have low blood volume than men. A woman's blood volume can increase by 50% during pregnancy (Sharma and Sharma, 2023).

1.1.1 Haematological or Blood Indices

Haematological indices are a set of measurements obtained from a complete blood count (CBC) that provide valuable information about the cellular components of blood. They are essential tools for diagnosing and monitoring various haematological conditions. They include: Red Blood Cell (RBC) Indices like RBC Count, Haemoglobin (Hb), Haematocrit (Hct), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), Red Cell Distribution

Width (RDW), White Blood Cell (WBC) Count and Differential WBC Count and Platelet Indices such as Platelet Count, Mean Platelet Volume (MPV) (Seo and Lee, 2022; El Brihi and Pathak, 2025).

1.2 Plasma

Blood plasma serves as the liquid base for whole blood. It is a light-yellowish or straw colored fluid and contains about 91%-92% of water and other contents including fibrinogen, albumin, globulin, electrolytes and immunoglobulins, which constitutes 8% to 9% (Mathew *et al*., 2023). The total plasma protein levels range from 6.0 to 8.0 g dl^{-1}. Levels of each protein found in the plasma includes: albumin (3.5–5.0 g dl^{-1}) and constitutes about 55% of total plasma protein levels (Moman *et al*, 2022), globulin (2.6–4.6 g dl^{-1}) and constitutes about 38% (Wilson, 2012), normal fibrinogen (0.2–0.45 g dl^{-1}) and constitutes about 7% (Kaur and Jain, 2023).

Synthesis of plasma in Embryos, it is carried out the mesenchymal cells, beginning with albumin, followed by globulin and other plasma proteins. Meanwhile, in adults, the reticuloendothelial cells of the liver, bone marrow, degenerating blood cells and spleen all play contributing roles to the formation of plasma proteins (Mathew *et al*., 2023). The plasma plays a major role in coagulation, nutrition, defense, transport of hormones, etc. (Mathew *et al*., 2023).

1.3 Red Blood Cells (RBC)

Red Blood Cells, also known as erythrocytes, are the functional component of blood responsible for transporting gases and nutrients throughout the human body (Barbalato and Pillarisetty, 2019). It was first observed under a microscope in 1658 by a Dutch naturalist, Jan Swammerdam (Hajdu, 2003). They are biconcave and discoid in shape and have no nucleus (anucleated), which provides an increased surface area that supports sufficient gas exchange allowing the cell to carry out its function and gives it the flexibility needed to navigate through blood vessels and the cardiovascular system (Barbalato and Pillarisetty, 2019).

The lifespan of RBCs is 120 days after which they are phagocytised by reticuloendothelial macrophages (Thiagarajan *et al.*, 2021). The formation of RBCs occurs primarily and mostly in bone marrow at birth and throughout life and in other secondary sites like the liver, spleen, lymph nodes, thymus, while it occurs in the yolk sac and liver for foetus (Parravicini, 2005; Mirza, 2020), they originate from hematopoietic stem cells (HSCs), which are capable of developing into multiple cell types. The process of becoming a mature red blood cell involves several distinct physical changes. HSCs first produce multipotent progenitors, which then differentiate into precursors specifically destined to become red blood cells. These precursors then undergo terminal erythropoiesis, a process where they mature into functional red blood cells and also reduces its surface area by

20–30%. This final maturation stage is characterized by the ejection of the nucleus and the elimination of membrane-bound organelles like the Golgi apparatus, endoplasmic reticulum, mitochondria, and ribosomes (Janeway *et al*., 2001; Moras *et al*., 2017). RBC formation (erythropoiesis) is controlled by the natural hormone erythropoietin (EPO), which is a globular 165 amino acid glycoproteins primarily produced by interstitial fibroblasts in the kidney. Burst forming units-erythroid (BFU-E), which is one of the earliest erythroid progenitors, increases the expression of erythropoietin receptors. The increased receptor-hormone interaction, induces the differentiation of these progenitors to form colony forming units-erythroid (CFU-E), which further differentiates into proerythroblast and erythroblasts (Sinclair, 2013).

1.3.1 Haemoglobin (Hb)

Haemoglobin is an oxygen-binding protein found in the red blood cells and they play a vital role in the transportation of oxygen from the lungs to all the tissues and organs of the body to ensure proper functioning (Farid *et al*., 2025). Siimilarly, haemoglobin also play a role in transporting carbon dioxide from the tissues and organs to the lungs to get expelled (Doyle and Cooper, 2025). There are different types of haemoglobin, the most common being haemoglobin A (HbA), found in adults and Fetal haemoglobin (HbF) present in fetuses and newborns. The HbF has a higher affinity for oxygen than HbA, which helps ensure that the fetus receives enough oxygen from the mother's blood (Farid *et al.*, 2025)

1.3.2 Hematocrit (Hct)

This is a blood test that measures the percentage of the total blood volume that red blood cells occupy and it is expressed in percentage. Hematocrit can be determined using a glass tube and a centrifuge, which separates the blood into three layers: red blood cells at the bottom, white blood cells and platelets in the middle, and plasma at the top. The hematocrit is determined by measuring the height of the packed red blood cell layer and dividing it by the total height of the blood column (red blood cells, white blood cells/platelets, and plasma). This ratio, multiplied by 100, gives the hematocrit value, expressed as a percentage (Mondal and Zubair, 2025).

1.3.3 Mean Corpuscular Volume (MCV)

Mean Corpuscular Volume is a value that measures the average size and volume of circulatory red blood cells and it is expressed in femtoliters (fL) (El Brihi, and Pathak, 2025; Mao and Wu, 2020; Maner *et al*., 2025). The Mean Corpuscular Volume (MCV) is calculated by dividing the hematocrit percentage by the erythrocyte count, and the result is multiplied by 10, mathematically it is expressed as: MCV (fL) = (Hematocrit %)/ (RBC count × 10^12/L) × 10 (El Brihi, and Pathak, 2025; Maner *et al*., 2025). The MCV value is used to categorize anemias into microcytic, normocytic, and macrocytic classifications. MCV also exhibits a gradual increase with age, specifically observed in two linear patterns in patients aged 1 to 25 and 26 to 88 (Maner *et al*., 2025).

1.3.4 Mean Corpuscular Hemoglobin (MCH)

Mean Corpuscular Haemoglobin (MCH) is a haematological index that tells the average amount of haemoglobin per red blood cell. It gives information on how much haemoglobin is found in each red blood cell. It is measured in picograms (pg) and is calculated by dividing hemoglobin by red blood cell count, which mathematically expressed as: Hb (g/dL) × 10/RBC count (million/μL) (Naeim *et al*., 2008; El Brihi, and Pathak, 2025).

1.3.5 Mean Corpuscular Haemoglobin Concentration (MCHC)

Mean Corpuscular Haemoglobin Concentration (MCHC) represents the average concentration of haemoglobin within red blood cells. Simply put, it shows the concentration of haemoglobin that is packed into a given volume of red blood cells (Peng *et al*., 2023). It is measured in grams per deciliter (g/dL) and calculated using the formula: Hb (g/dL) × 100/Hct (%) (Naeim *et al*., 2008; El Brihi, and Pathak, 2025). The difference between MCHC and MCH is that; MCH quantifies the amount of haemoglobin while MCHC indicates the hemoglobin density in each red cell (El Brihi, and Pathak, 2025).

1.4 White Blood Cells (WBC)

White blood cells, also known as leukocytes, are primarily responsible for immunity of the body (Janeway *et al*., 2001). There are five types of WBCs, namely: neutrophils, eosinophils, and basophils, monocytes and lymphocytes and they are further classified as granulocytes and agranulocytes based on the

presence or absence of microscopic granules in their cytoplasm, which can be seen when stained with Giemsa or Leishman stains (Kutlu *et al*., 2020; Tigner *et al*., 2020). WBCs make up about 1% of the blood cells in a healthy person and each WBC play different roles in immunity responses, for example, neutrophils and monocytes/macrophages help in carrying out phagocytic reactions, Eosinophils and Basophils are involved in allergic reactions and parasitic defense, lymphocytes are responsible for acquired immunity, they recognise and target particular pathogens that the body has been previously sensitized to, while the rest of the white blood cells are responsible for innate immunity, the body's first line of defense against infection (Janeway *et al*., 2001; Monie, 2017; Tigner *et al*., 2020).

Belonging to the granulocytes class are the neutrophils, eosinophils, and basophils, while monocytes and lymphocytes belong to the agranulocytes class (Tigner *et al*., 2020). Neutrophils make up the majority of white blood cells in the blood (40-60%), followed by lymphocytes (20-40%). Eosinophils, monocytes, and basophils are present in smaller amounts, with ranges of 1-4%, 2-8%, and 0.5-1%, respectively (Almezhghwi and Serte, 2020). WBCs are also derived from the progenitor or precursor cells, hematopoietic stem cells in the bone marrow. The hematopoietic stem cell (HSC) commits to either the myeloid or lymphoid lineage, which determines the type of WBC being formed. Myeloid stem cells give rise to the majority of white blood cell types, encompassing neutrophils, monocytes

(which mature into macrophages), eosinophils, and basophils. Lymphoid stem cells, on the other hand, are the precursors of lymphocytes, which includes the B cells, T cells, and natural killer (NK) cells (Janeway *et al*., 2001).

1.4.1 Monocytes and Macrophages

Monocytes are the largest type of WBC with a diameter of 12 to 20 µm. They make up about 4% - 8% of the total white blood cells and have large nuclei that are indented or C—C-shaped, which can be laterally placed (Tigner *et al*., 2020; Espinoza and Emmady, 2022). They undergo differentiation to form macrophages when recruited to sites of infection and are the precursor cells for other cells such as osteoclasts, and microglial cells in connective tissue and organs, which all make up the mononuclear phagocytic system (Kapellos *et al*., 2019; Tigner *et al*., 2020).

They are formed from the myeloid precursor of hematopoietic stem cell (HSC), which migrates into the blood stream to differentiate into a monocyte. Differentiation of the precursor cells into monocytes occur through four intermediate maturational stages, which includes: multipotent progenitor (MPP), common myeloid progenitor (CMP), granulocyte-macrophage progenitor (GMP) and macrophage progenitor (MP) (Huber *et al*., 2014).

1.4.2 Lymphocytes

Lymphocytes constitute about 25% of white blood cells, and have a diameter of 9 to 18 µm (Tigner *et al*., 2020). Apart from being found in blood, they are also present in the lymph and lymphoid organs such as the thymus, lymph nodes, spleen, and appendix and are mainly categorized into two: T cells and B cells but also have a third lineage called: Natural killer (NK) cells (Janeway *et al*., 2001; Orakpoghenor *et al*., 2019).

B and T lymphocytes both begin development in the bone marrow. However, while B cells mature in the bone marrow itself, T cells go to the thymus to mature. This difference in maturation location gives them their names: B for bone marrow-derived and T for thymus-derived. After maturing, both B and T cells enter the bloodstream and then move to the peripheral lymphoid organs (Janeway *et al*., 2001; Orakpoghenor *et al*., 2019). Lymphocytes are responsible for immune responses against any foreign antigen due to the presence of a unique variant of a prototype antigen receptor in each matured individual lymphocyte. These receptors are highly diverse in their antigen-binding sites and consists of the B-cell antigen receptors (BCR) and T-cell antigen receptors (TCR) (Janeway *et al*., 2001; Ramesh *et al*., 2022).

1.4.2.1 T cells

T cells originate from hematopoietic stem cells in the fetal liver and subsequently in the bone marrow, where they differentiate into multipotent progenitors. These precursors migrate to the thymus where they undergo

maturation, a process involving positive (selection for cells recognizing self-MHC) and negative (elimination of cells strongly reactive to self-antigens) selection. This process ensures that mature T cells are functional and prevents overactive immune responses and autoimmunity. Mature T cells then leave the thymus and circulate to secondary lymphoid organs (Cano and Lopera, 2013; Thapa and Farber, 2019). Mature T lymphocytes express the T-cell receptor (TCR) and the Pan-T-cell co-receptor CD3, which together recognize antigen-loaded MHC molecules on other cells. Based on additional structural markers, T cells are classified into CD4+ T cells, CD8+ T cells, and regulatory T cells. CD4+ T cells express the CD4 co-receptor, CD8+ T cells express the CD8 co-receptor, and regulatory T cells express both CD4 and CD25 co-receptors (Cano and Lopera, 2013; Saul *et al*., 2018).

1.4.2.2 B cells

The B cells originate and mature in the bone marrow unlike the T cells that migrate to the thymus to get mature (Janeway *et al*., 2001). B cells express unique B-cell receptors (BCRs) on their surface, each capable of recognizing a specific antigen. Upon coming in contact with an antigen, B cells are activated, typically with the help of T helper cells, which triggers the formation of antibodies, which are then secreted into circulation to neutralize pathogens and mark them for destruction (Janeway *et al*., 2001). Some activated B cells differentiate into memory B cells, providing a memory,

which allows for faster and more effective responses upon subsequent encounters with the same antigen (Althwaiqeb *et al*., 2024).

1.4.2.3 Natural killer (NK) Cells

Natural killer (NK) cells do not possess antigen-specific receptors. They are seen circulating in the bloodstream as large lymphocytes and contain distinctive cytotoxic granules. NK cells are capable of identifying and destroying certain abnormal cells and intracellular pathogens, including some tumor cells and virus-infected cells (Janeway *et al*., 2001; Orakpoghenor *et al*., 2019).

1.4.3 Basophils and Mast Cells

Basophils make up less than 1% of all leukocytes and have a diameter of 12 to15 µm. Their nucleus is bi-lobed or S-shaped, and contain cytoplasmic granules stain blue to purple (Tigner *et al*., 2020). Basophils have a similar function to mast cells and play a role in allergic inflammation., autoimmunity, tissue repair, fibrosis and cancer due to their surface expression of the high-affinity IgE receptor (FcεRI), and the release histamine in response to various stimuli (Tigner *et al*., 2020; Miyake *et al*., 2022).

Basophil development originates from hematopoietic stem cell-derived granulocyte-monocyte progenitor cells (GMPs) within the bone marrow. These versatile GMPs possess the potential to differentiate into several cell types, including macrophages, eosinophils, mast cells, and basophils. As

GMPs progress in their maturation, they undergo intermediate commitment stages, giving rise to precursors like mast cell precursors (MCPs), basophil-mast cell precursors (BMCPs), or basophil precursors (BaPs), ultimately leading to the formation of basophils and mast cells. A key distinction between these two cell types is their maturation timeline: mast cells generally leave the bone marrow in an immature state and complete their development in peripheral tissues, while basophils are understood to fully mature within the bone marrow before their release into circulation (Siracusa *et al*., 2013).

1.4.4 Neutrophils

They are the most abundant population of circulating granulocytes and are recognized by their segmented, multi-lobed nuclei joined by thin strands or isthmuses, hence, they are also called polymorphonuclear neutrophils. They comprise 50% to 70% of circulating leukocytes and have a diameter of 12-15 µm and are usually short-lived, surviving only a few days. When activated, they migrate from the bloodstream into tissues by squeezing between cells, after which they undergo apoptosis (programmed cell death) and are then cleared away by macrophages. They are also the most numerous cells to arrive at the site of injury or infection, as they represent the body's first line of defense and carry out antimicrobial activities in the body (Janeway *et al*., 2001; Rosales, 2018; Tigner *et al*., 2020; Burn *et al*., 2021).

Neutrophil development begins with myeloblasts in the bone marrow, the initial committed granulocyte progenitor. Myeloblasts further give rise to three granulocytes lineage, the one for neutrophil being the promyelocytes. Promyelocytes then mature through myelocyte and metamyelocyte stages before becoming fully mature, segmented neutrophils ready to enter circulation (Janeway *et al*., 2001; Tak *et al*., 2013).

1.4.5 Eosinophils

Eosinophils make up about 1 to 4% of the leukocytes on average and have a have bi-lobed nucleus with large cytoplasmic specific granules that stains red/pink (Tigner *et al*., 2020). They help fight against parasitic infection and participate in inflammatory responses and homeostasis due to their possession of receptors for cytokines, chemokines, etc., and they also promote intravascular inflammation and are able to trigger the coagulation cascade. (Ramirez *et al*, 2018; Tigner *et al*., 2020; Wechsler *et al*., 2021). Eosinophils are also formed from myeloid progenitor cells, which then give rise to eosinophil precursors. The maturation process involves several stages, including the promyelocyte, myelocyte, and metamyelocyte stages, similar to other granulocytes. Specific growth factors and cytokines, such as IL-5, IL3 and GM-CSF are crucial for eosinophSil differentiation and maturation (Ramirez *et al*, 2018).

1.4.6 White Blood Cell (WBC) Count

A white blood cell (WBC) count, also known as a leukocyte count, is a fundamental blood test that measures the number of white blood cells in a sample of blood. The WBC count provides valuable information about an individual's health status, often serving as a diagnostic tool or a marker for monitoring disease progression and treatment effectiveness (Hoffman *et al*., 2017). The WBC count typically falls within a normal range. A normal WBC count generally indicates a healthy immune system. However, deviations from this range can suggest various underlying conditions. A high WBC count, known as leukocytosis, can be caused by infections, inflammation, stress, certain medications, or even some cancers (Lee *et al*., 2019). Conversely, a low WBC count, or leukopenia, can be caused by infections, autoimmune disorders, bone marrow disorders, certain medications (like chemotherapy), or nutritional deficiencies (Young and Gertz, 2015).

1.4.7 Differential WBCs Count

The differential white blood cell (WBC) count provides a detailed analysis of the various types of white blood cells circulating in the bloodstream. While the total WBC count offers a general knowledge of the immune system, the differential count breaks down the proportions of each cell type – neutrophils, lymphocytes, monocytes, eosinophils, and basophils – giving a more detailed knowledge and understanding of immune function (Rodak *et al*., 2017).

1.1 Platelets

Platelets are the smallest blood cells, with a diameter of about 2 μm and an average lifespan of 7 to 10 days in humans. They are anucleated but contain other cell organelles like ribonucleic acid, ribosomes, mitochondria, and various granules (α-granules, dense granules and lysosomes) which helps them carry out the physiological function in hemostasis and thrombosis, which was first discovered more than 100 years ago by the Italian pathologist Giulio Bizzozero (Williams and Sergent, 2022).

Platelets are formed from large cells found in the bone marrow called megakaryocytes, that increase in size by replicating their DNA without cell division. Within the megakaryocytes, organelles are arranged into distinct areas that will become individual platelets upon being exposed to the force of circulating blood, which breaks apart their cytoplasm. Circulating platelets normally have a disc-like shape, but due to the action of actin and myosin, they change into compact spheres with branching extensions upon activation, which facilitates adhesion when carrying out their function (Thon and Italiano, 2010; Williams and Sergent, 2022)

1.5 Platelet Count

A platelet count is a blood test that measures the number of platelets in a given volume of blood and provides valuable information about an individual's health status, reflecting the body's ability to form clots and maintain vascular

integrity. A high platelet count, known as thrombocytosis, can increase the risk of thrombosis, the formation of blood clots within blood vessels. Conversely, a low platelet count, known as thrombocytopenia, can increase the risk of bleeding (Periayah *et al*., 2017)

1.5.1 Mean Platelet Volume (MPV)

Mean platelet volume (MPV) refers to the average platelet size, it is measured in femtoliters (González-Sierra *et al*., 2023). It is an indicator of platelet activation and aggregation and is usually associated with several disorders, including inflammatory and cardiovascular diseases (Şenel *et al*., 2017).

1.6 AIM AND OBJECTIVES

The aim of this research is to examine the differences between the haematological indices of both genders and the contributing role gender plays in determining the values of these indices.

1.7 JUSTIFICATION OF THE STUDY

This study investigates the role and contribution of gender in determining the volume, percentage and level of haematological indices because an understanding of gender differences is important in clinical management, accuracy in diagnosis and healthcare.

1.8 STATEMENT OF PROBLEM

This study seeks to investigate and prove the differences in hematological indices between each gender, identify potential underlying physiological mechanisms, and assess the clinical significance of these variations.

1.9 RESEARCH QUESTIONS

- Are there differences in hematological indices of males and females?
- Do differences in genetic, physiological and phenotypic make-up affect haematological indices?

CHAPTER TWO

LITERATURE REVIEW

2.1 Physiological Differences between Genders

There are many physiological differences between genders, males and females differ due to a combination of genetic, variations in chromosomes and hormonal factors, which further brings about a phenotypic or physical difference (Szadvári *et al*., 2023, Lafta *et al*., 2024). Gender differences matter in an individual's health and well-being as it influences various aspects of human biology such as hormones, body composition and metabolism and hematological parameters (Mandala *et al*., 2017; Massey *et al*., 2021).

2.1.1 Hormones

Hormones play a crucial role in shaping physiological characteristics. Studies have established that males typically have higher levels of androgens, primarily testosterone, which promotes the development of male primary and secondary sexual characteristics like the thickening of voice, increases muscle mass, and influences bone density and descent of testes (Nassar and Leslie, 2023; Patel and Zafar, 2023). At birth the presence of anti-mullerian or Mullerian-inhibiting hormones inhibits the development of mullerian structures like the Fallopian tubes, uterus, and upper segment of the vagina and gives room for the development of the Wolffian duct and male internal and external genitalia (Nassar and Leslie, 2023; Patel and Zafar, 2023).

On the other hand, the hormones predominant in the female body are estrogens, progesterone and little of oxytocin. Estrogens are responsible for the development of female primary and secondary sexual organs like breasts, regulation of the menstrual cycle; progesterone is known to support pregnancy and has other effects on the female reproductive system like preparing the uterus for implantation and pregnancy while oxytocin helps in contraction of the uterus during parturition, lactation and copulation (Blanks and Thornton, 2003; World Health Organisation (WHO), 2009; Borrow and Cameron, 2012; Cable and Grider, 2023; Delgazo and Lopez-Ojeda, 2023).

2.1.2 Genetic Factors

Genetic factors play a very important role in determining gender. It is in fact the first determinant and the basis for all other physiological differences seen between genders. The primary genetic determinant of variation is the presence of the Y chromosome in males, which carries the SRY gene responsible for male characteristic development. In contrast, females have two X chromosomes and do not carry the Y chromosome (Gilbert, 2000; Arnold *et al*., 2016; *Gurung et al*., 2023). Similarly, differences in several other genetic factors like hormone-receptor genes, TLR7 (Toll-like receptor 7) etc., also contribute to gender-based variations (Shen *et al*., 2010; Rubtsova *et al*., 2015; Echem and Akamine, 2021).

2.1.3 Body Composition and Metabolism

Body composition varies between men and women, with men typically having a higher lean/muscle mass and women a greater fat mass. This difference in composition also influences metabolic rate, which is generally higher in men (Karastergiou *et al*., 2012; Ethun, 2016; Bredella, 2017).

2.2 Gender-Based Differences in Specific Hematological Indices

2.2.1 Red Blood Cell Count (RBC)

RBC counts are generally higher in adult males with a range value of 4.6 to 6.2 million cells/μL and 4.2 to 5.4 million cells/μL in adult women females (El Brihi and Pathak, 2024). Studies have shown that this could be due to the effect of factors such as hormones, body composition, etc.

Testosterone, a major androgen hormone in men has been found to have an effect in the stimulation of erythropoietin, which facilitates erythropoiesis (production of red blood cells) (Bachman *et al*., 2014; Grau *et al*., 2018). Similarly, it also causes higher muscle mass in men, which increases oxygen demand, prompting the body to produce more red blood cells as a compensatory mechanism (Jensen *et al*., 2001; Ethun, 2016; Bredella, 2017; Green *et al*., 2024).

2.2.2 Mean Corpuscular Volume (MCV)

The normal range for mean corpuscular volume (MCV) is 80 to 100 fL (Seo and Lee, 2022; Maner *et al*., 2024) with slight differences observed between males and females. This slight difference could as a result of the higher

hematocrit and erythrocyte count in males compared to females (Schmetzer and Flörcken, 2012; Sim *et al*., 2018)

2.2.3 Mean Corpuscular Hemoglobin (MCH) and Mean Corpuscular Hemoglobin Concentration (MCHC)

The values of MCH and MCHC are also generally similar between genders with range values of 27.0–33.0 pg and 31.5–37.0 g/dL respectively (Seo and Lee, 2022; El Brihi and Pathak, 2024; Maner *et al*., 2024). This is as a result of the effects of testosterone on hemoglobin and hematocrit; testosterone stimulates the secretion of erythropoietin and reduces ferritin and hepcidin concentrations and also increases the utilization of iron for erythropoiesis (Bachman *et al*., 2014).

Similarly, in a study carried out by Sajjad *et al*., (2018) on the relationship between testosterone and hemoglobin level in healthy men, hemoglobin level was strongly associated with total testosterone.

2.2.4 Total and Differential White Blood Cell Count (WBC)

Although the general reference range of total WBC count in adults is 4,500 to 11,000 cells/μL, with differential counts as follows—lymphocytes (1,000–4,000 cells/μL), monocytes (200–1,000 cells/μL), eosinophils (0–500 cells/μL), basophils (0–200 cells/μL), and neutrophils (1,500–8,000 cells/μL)—several studies have shown that females tend to have higher counts than males over time (Bain, 1996; Grau *et al*., 2018; Seo and Lee, 2022; El brihi and Pathak, 2024). This reason for this is said to be the high

level of estrogen in females (Roved *et al*., 2017). According to a study by Foo *et al*., (2016), estrogen has immunoenhancing effects, although its effects are not uniformed and varies depending on the part of immunity being measured while testosterone has a medium-sized immunosuppressing effect, which would account for the lower levels of MBCs in males. Estrogen impacts the level of circulating antibodies and also modulates T cell function (Harding and Heating, 2022; Sciarra *et al*., 2023)

Further studies show that, an increase in the level of estrogen correlates with an increase in the level of antibodies in females. For example, during pregnancy when estrogen levels are at the peak, there is seen to be elevated antibody levels, improved autoimmune disease symptoms, and increased expression of key immunomodulatory and anti-inflammatory cytokines (Harding and Heating, 2022). Similarly, menopausal females, have been observed to exhibit lower WBC counts, increase in inflammation and the development of chronic conditions in a variety of organ systems, although, these do not solely result from an alteration in the levels of estrogen, it has been agreed that estrogen plays a role (Harding and Heating, 2022).

2.2.5 Platelets Count

Platelets count have also been proven to be higher in females compared to males (Segal and Monterno, 2004; Bonaccio *et al*., 2016). The normal reference range of platelet counts in adults is 150,000 to 400,000/μL or mm^3 (Seo and Lee, 2022; El brihi and Pathak, 2024).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Materials used for the study include:

- EDTA blood collection bottles
- Syringes and needles
- Staining reagents
- Disposable gloves
- Cotton wool
- Methylated spirit
- Automated hematology analyser
- Microscope

3.2 Methods

3.2.1 Study Design

This study is a comparative, cross-sectional analysis of haematological indices in healthy males and females.

3.2.2 Study Setting

The study was conducted at the University of Benin City, which served as the site for participant recruitment and sample collection. Laboratory analyses were carried out at the University’s Teaching Hospital's diagnostic laboratory.

3.2.3 Study Population

The study included a total of 40 persons, which were divided into two groups:

1. 20 male individuals.
2. 20 female individuals

3.2.4 Inclusion Criteria

- Participants aged between 18 – 30 years of age.
- Participants must not have complained of malaria or any other form of disease or sickness within one month prior to the collection of blood samples.
- Participants were not to be asthmatic.
- Participants were either AA or AS genotype.
- Females were not to be on their monthly flow or pregnant.

3.2.5 Study Timeline

The study lasted for about a month.

3.2.6 Sample Collection and Analysis

Venous blood samples were collected into a 5ml EDTA bottles. Laboratory tests included:

- Complete Blood Count (CBC) which further includes:
- Red Blood Cells (RBC) count

- Total White Blood Cell (WBC) count
- Differential White Blood Cell (WBC) count (lymphocytes, monocytes, neutrophils, eosinophils and basophils)
- Mean Corpuscular Volume (MCV)
- Mean Corpuscular Haemoglobin (MCH)
- Mean Corpuscular Haemoglobin Concentration (MCHC)
- Platelet Count

3.2.7 Statistical Analysis

The Haematological data was described using descriptive statistics. Comparative analyses such as Mann-Whitney tests and Kruskal-Wallis test were performed to evaluate differences in the number and amount of Red Blood Cells, Total White Blood Cell, Differential White Blood Cell, Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin, Mean Corpuscular Haemoglobin Concentration and Platelet Count between males and females. A p-value < 0.05 was considered statistically significant. The statistical software used was R.

3.2.8 Ethical Considerations

Ethical approval was obtained from the university's ethics committee. Participants voluntarily consented to participant in the research by filling consent forms.

CHAPTER FOUR

RESULTS

4.1 RBC COUNT

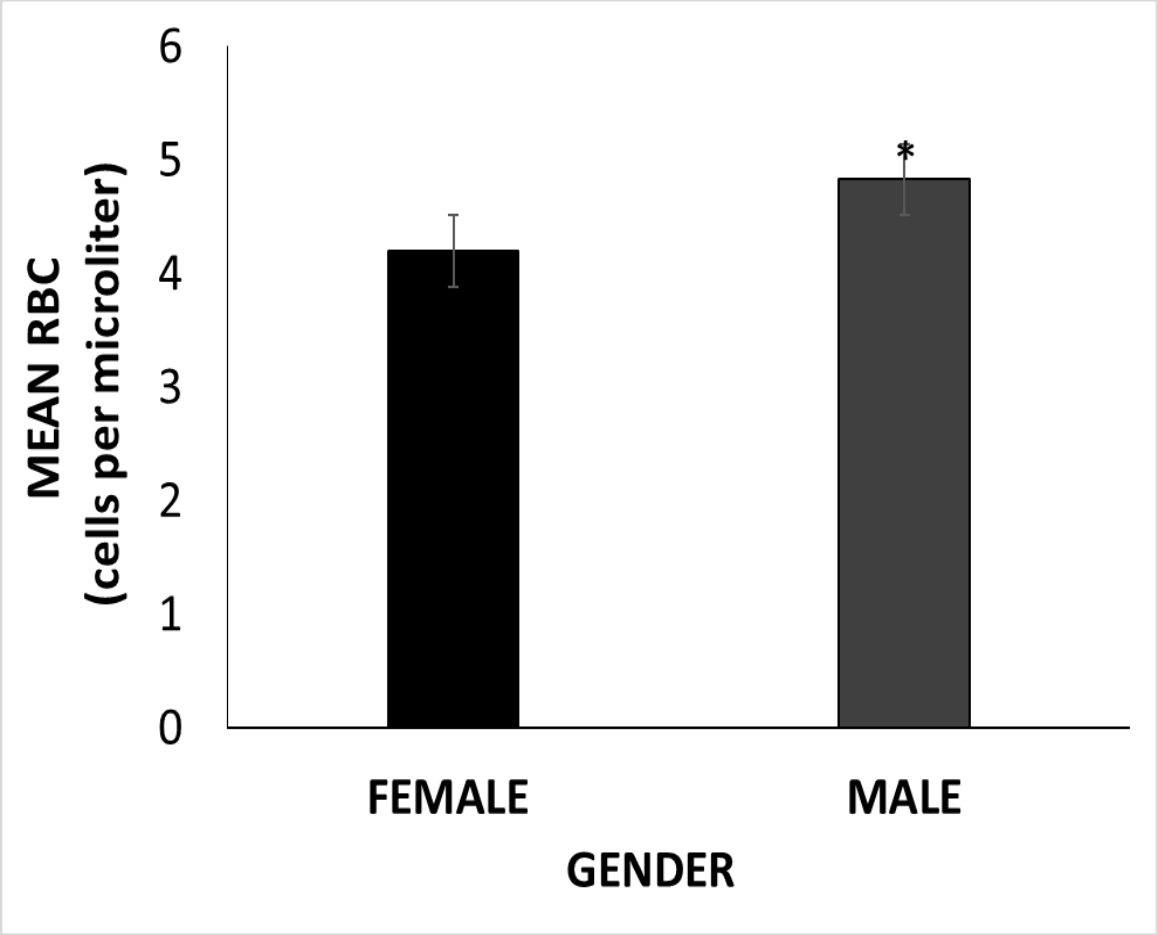

Fig 4.1: Female RBC Count Compared To Male

TABLE 4.1: Descriptive Analysis of Red Blood Cell Of Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	FEMALE	MALE
Mean RBC	4.196 cells per microliter ± 0.089432631	4.8275 cells per microliter ± 0.152050109

* $p \leq 0.05$

4.2 MCV

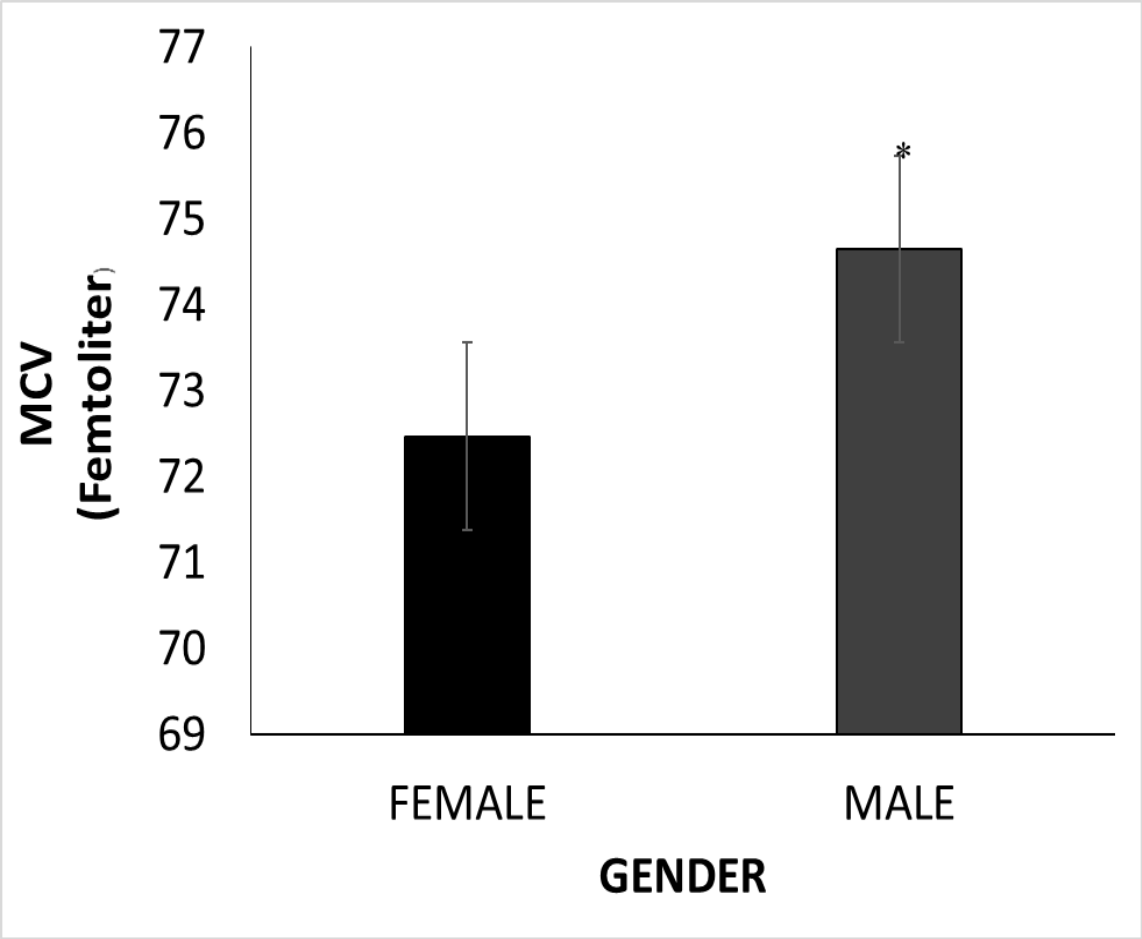

Fig 4.2: Female MCV Count Compared To Male

TABLE 4.2: Descriptive Analysis of MCV between Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	**FEMALE**	**MALE**
MCV Mean	72.47 Femtoliter ± 1.589203864	74.645 Femtoliter ± 1.353163471

*$p \leq 0.05$

4.3 MCH

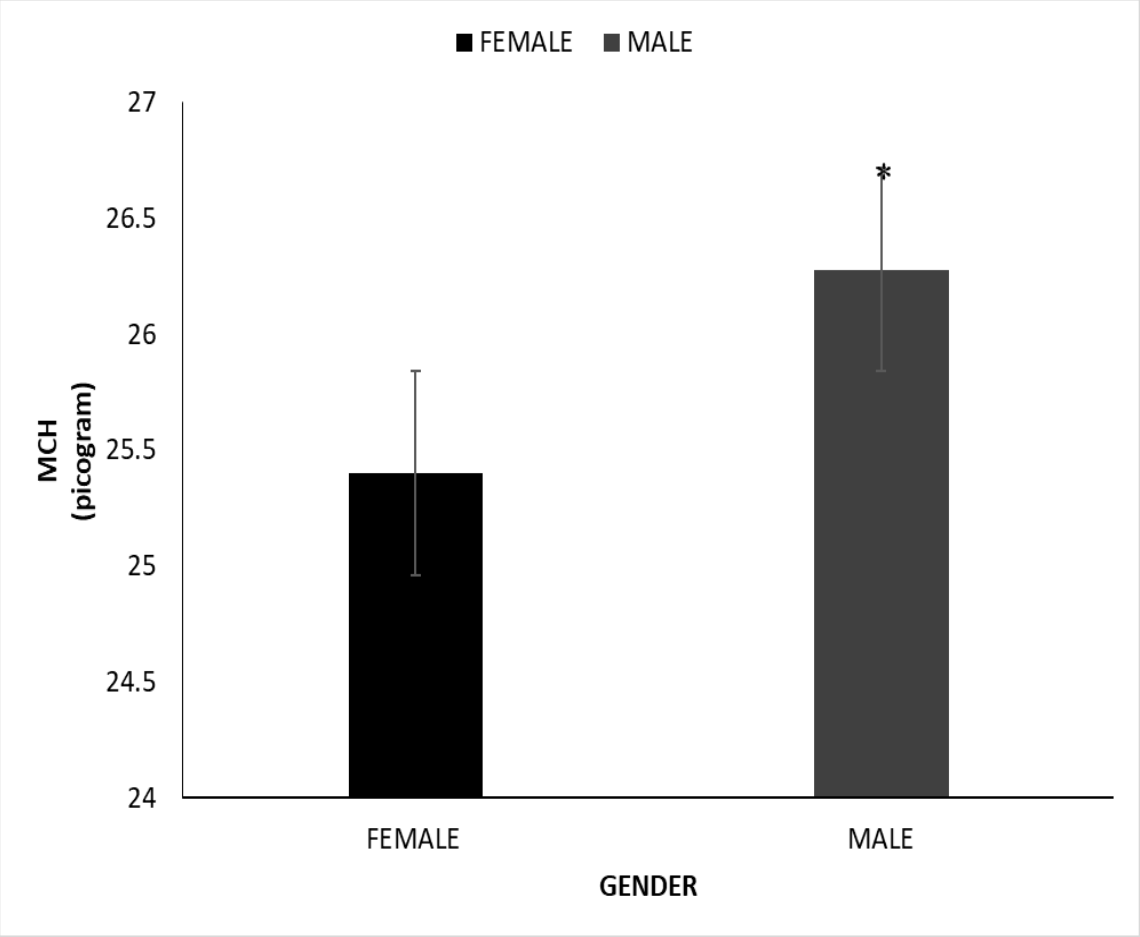

Fig 4.3: Female MCH Count Compared To Male

TABLE 4.3: Descriptive Analysis of MCH between Male And Female Human Adults

GENDER	FEMALE	MALE
MCH Mean	25.4 picogram ± 0.618470909	26.28 picogram ± 0.436010623

*$p \leq 0.05$

4.4 MCHC

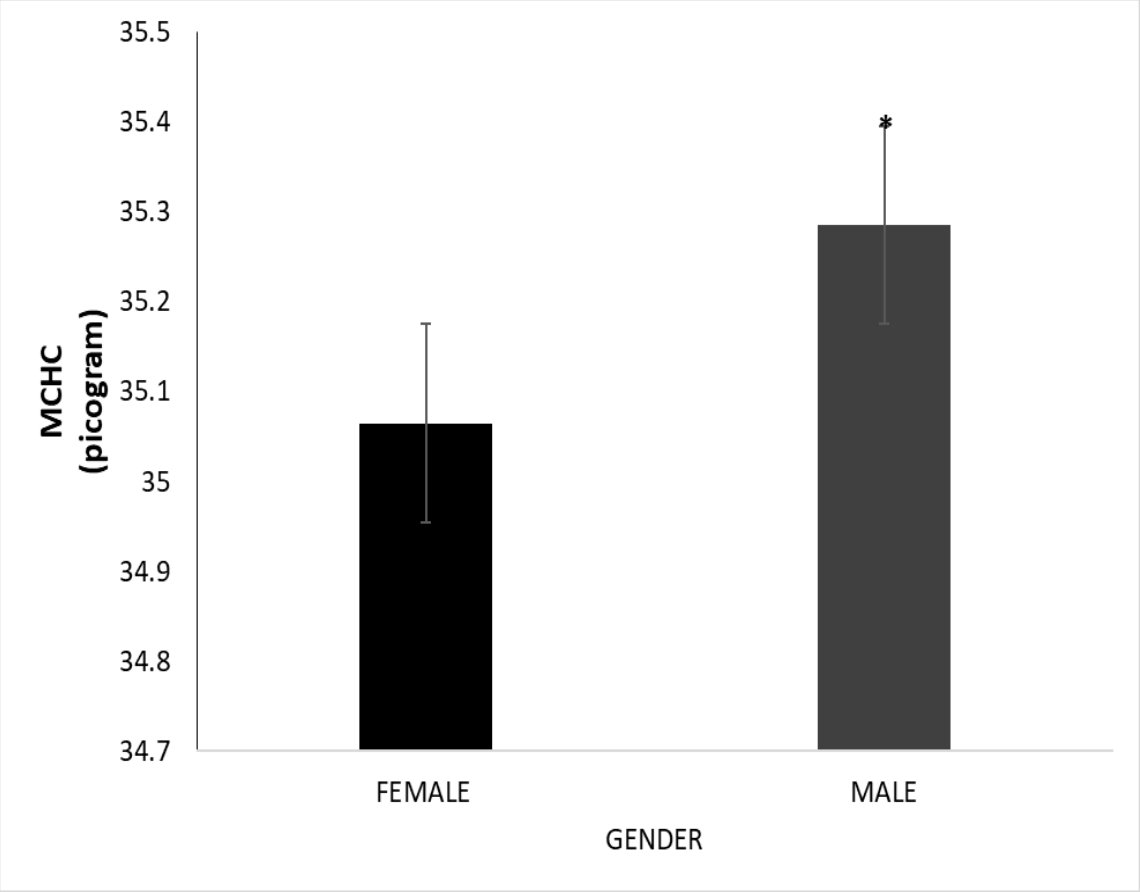

Fig 4.4: Female MCHC Count Compared To Male

TABLE 4.4: Descriptive Analysis of MCHC between Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	**FEMALE**	**MALE**
MCHC Mean	35.065 picograms ± 0.206689505	35.285 picograms ± 0.126505966

***p ≤ 0.05**

4.5 TOTAL WBC COUNT

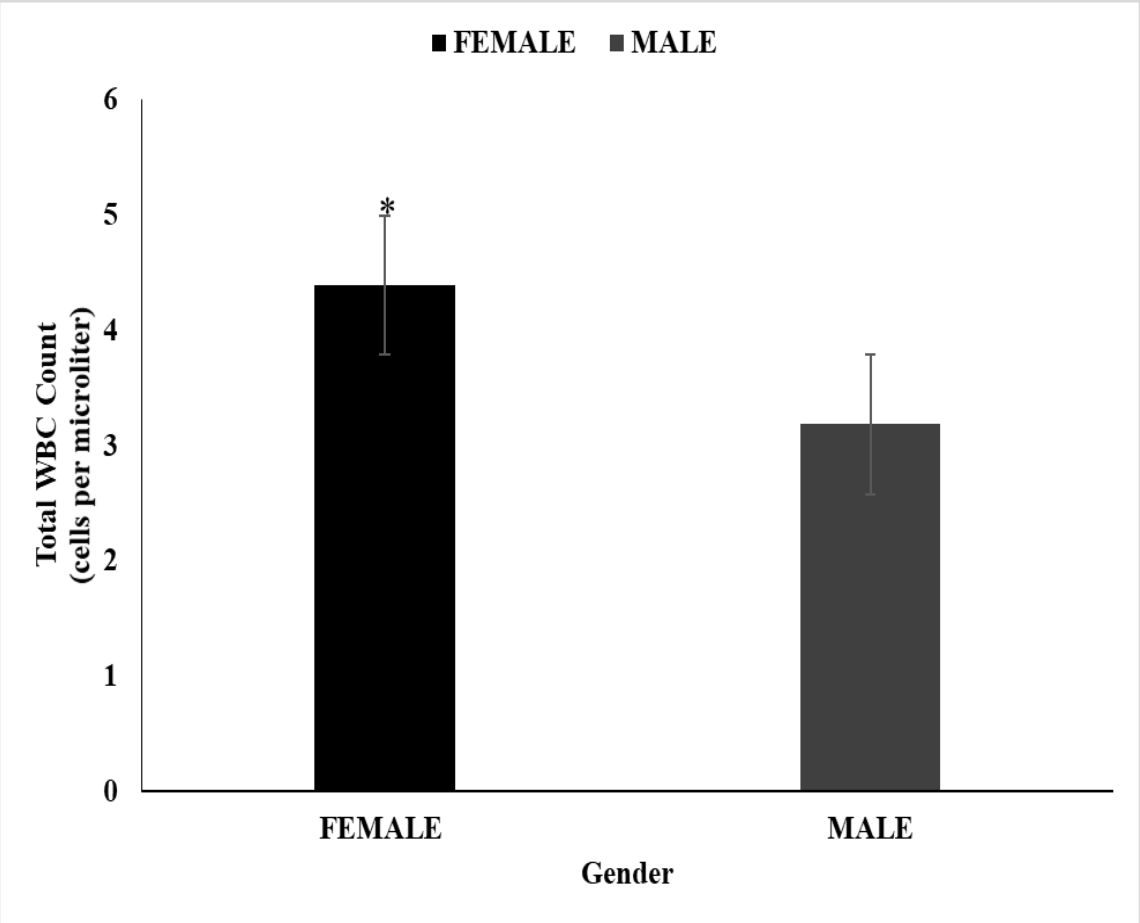

Fig 4.5: Female WBC Count Compared To Male

TABLE 4.5: Descriptive Analysis of Total WBC Count between Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	FEMALE	MALE
Total WBC Mean	4.39 cells per microliter ± 0.244734012	3.185 cells per microliter ± 0.167732183

***p ≤ 0.05**

4.6 DIFFERENTIAL WBC COUNT

4.6.1 LYMPHOCYTE COUNT

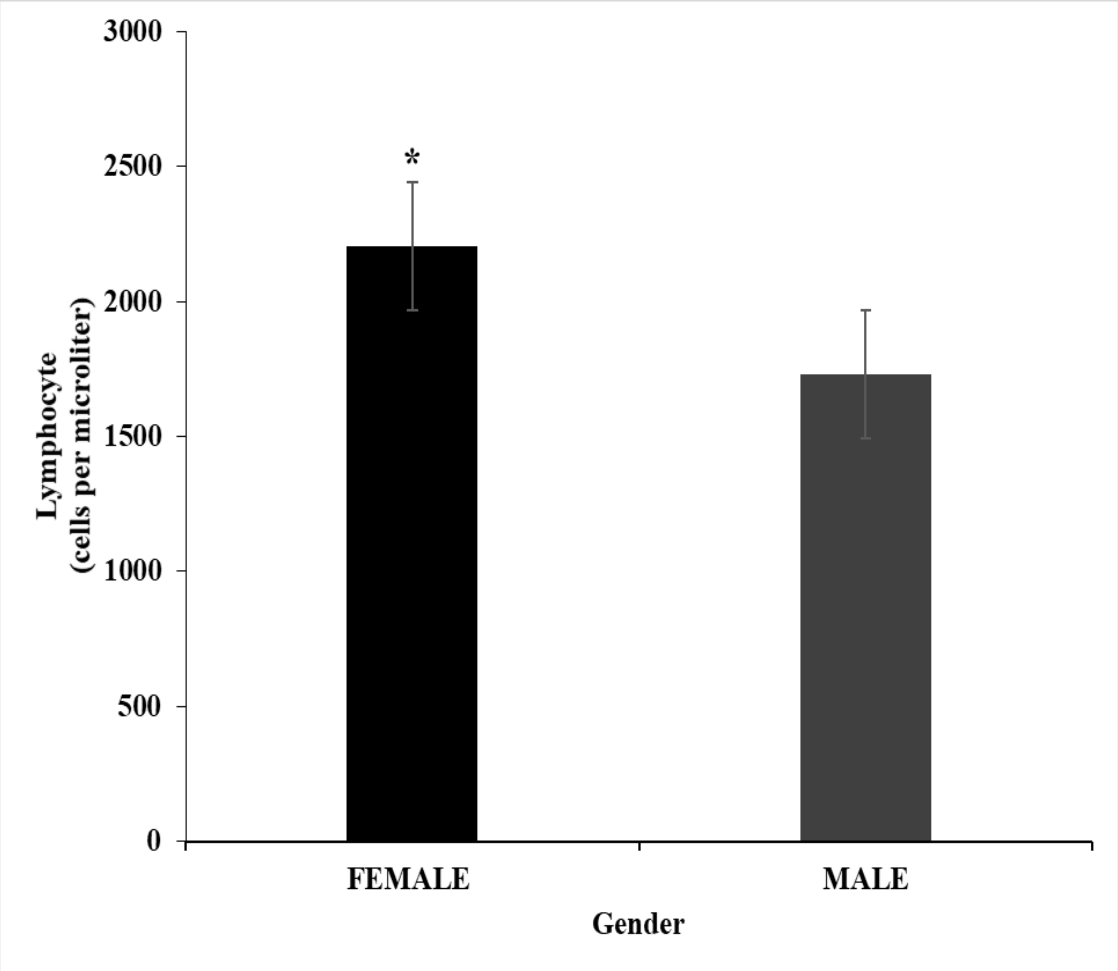

Fig 4.6.1: Female Lymphocyte Count Compared To Male

TABLE 4.6.1: Descriptive Analysis of Lymphocyte Count between Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	FEMALE	MALE
Total Lymphocyte Mean	2203 cells per microliter ± 129.7169565	1728 cells per microliter ± 107.1404017

***p ≤ 0.05**

4.6.2 MONOCYTE

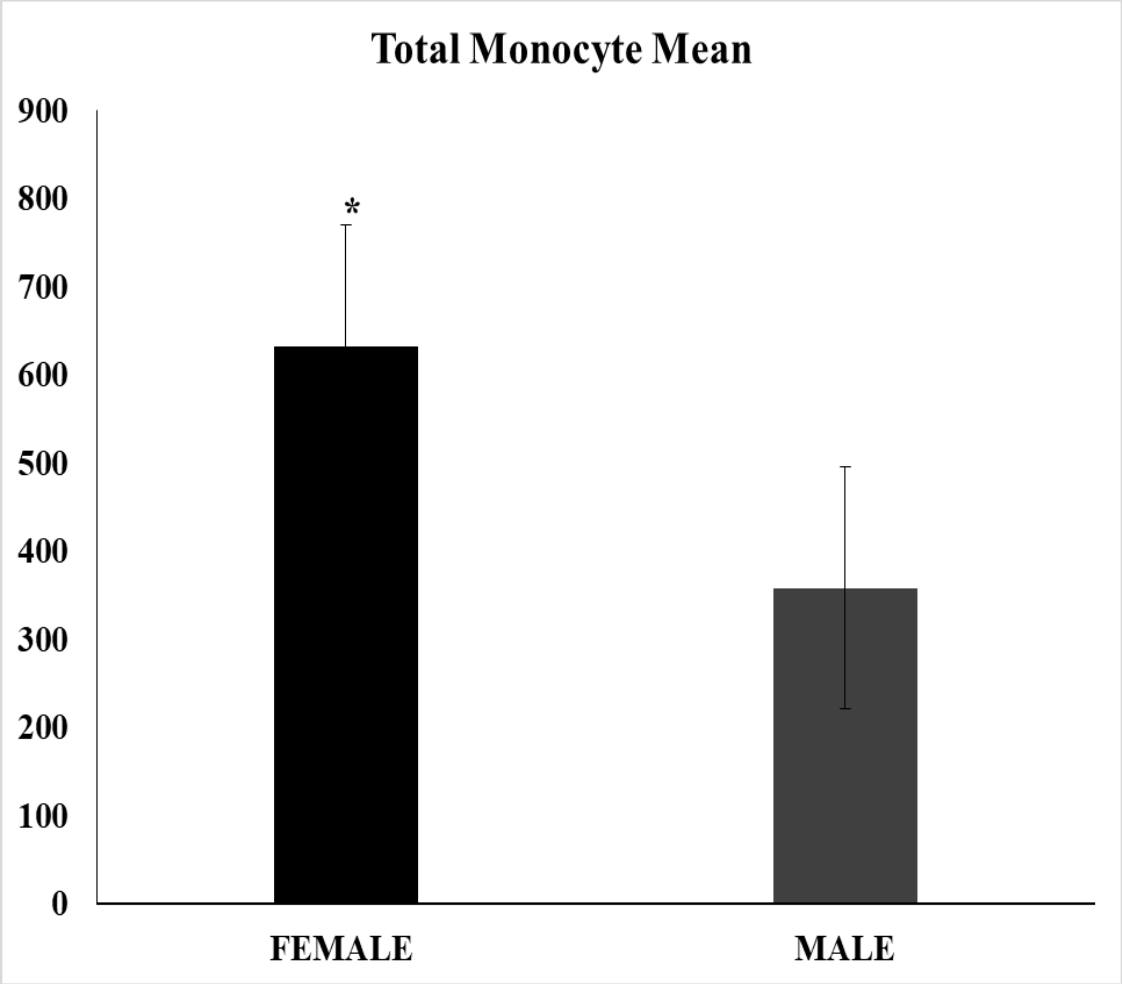

Fig 4.6.2: Female Monocyte Count Compared To Male

TABLE 4.6.2: Descriptive Analysis of Monocyte Count between Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	FEMALE	MALE
Total Monocyte Mean	632 cells per microliter ± 68.43861348	358 cells per microliter ± 38.68714461

***p ≤ 0.05**

4.6.3 NEUTROPHIL

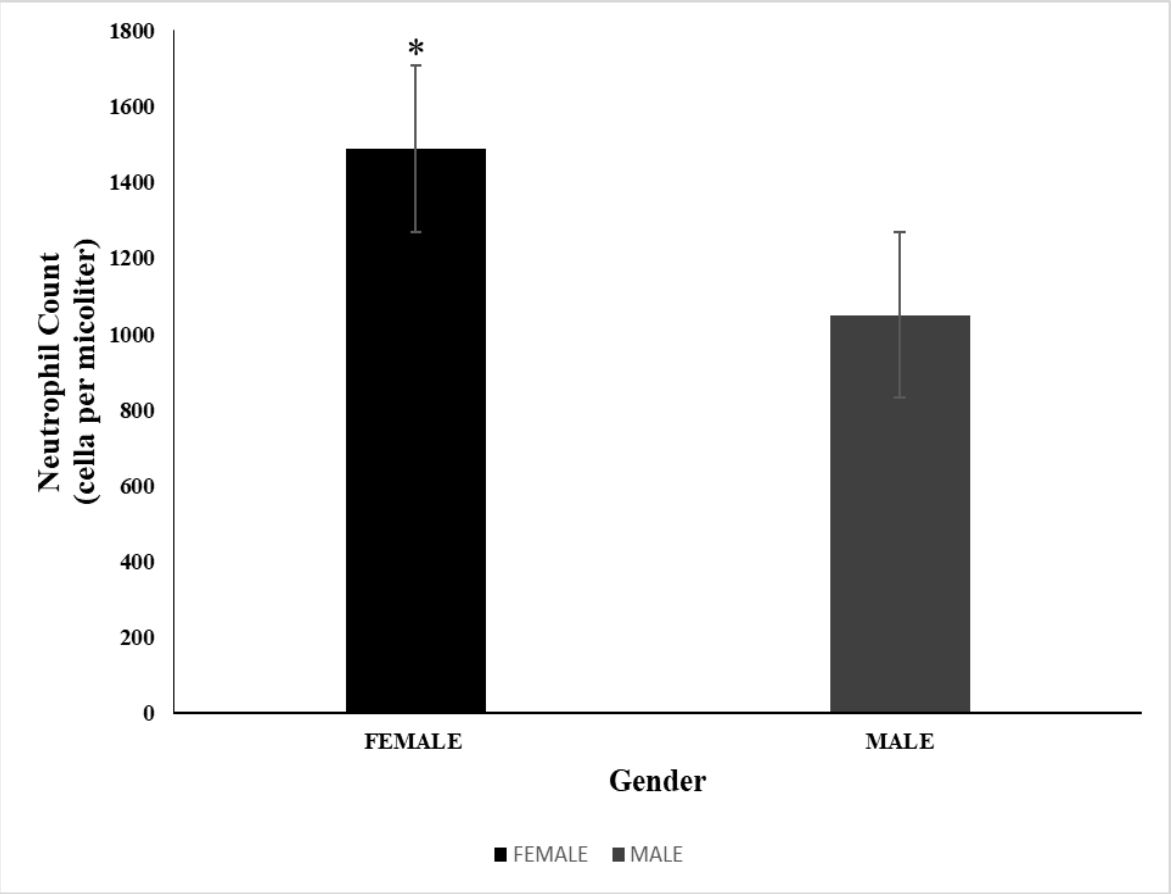

Fig 4.6.3: Female Neutrophil Count Compared To Male

TABLE 4.6.3: Descriptive Analysis of Neutrophil Count between Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	FEMALE	MALE
Total Neutrophil Mean	1488 cells per microliter ± 125.0346942	1050 cells per microliter ± 86.85301431

***p ≤ 0.05**

4.6.4 EOSINOPHIL

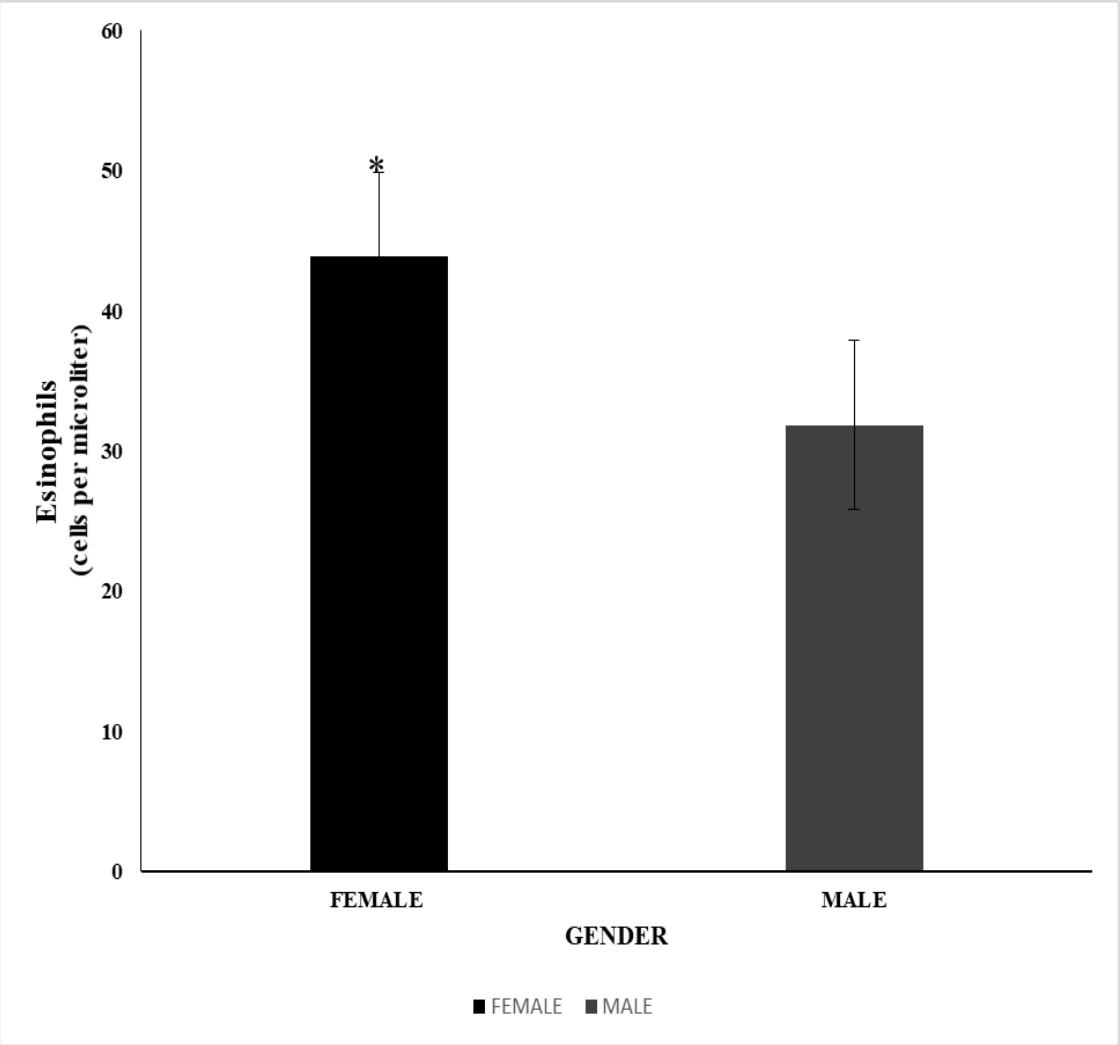

Fig 4.6.4: Female Eosinophil Count Compared To Male

TABLE 4.6.4: Descriptive Analysis of Eosinophil Count between Male And Female Human Adults
Mean ± Standard Error Mean (S.E.M)

GENDER	FEMALE	MALE
Total Esinophil Mean	43.9 cells per microliter ± 2.447340124	31.85 cells per microliter ± 1.67732183

***p ≤ 0.05**

4.6.5 BASOPHIL

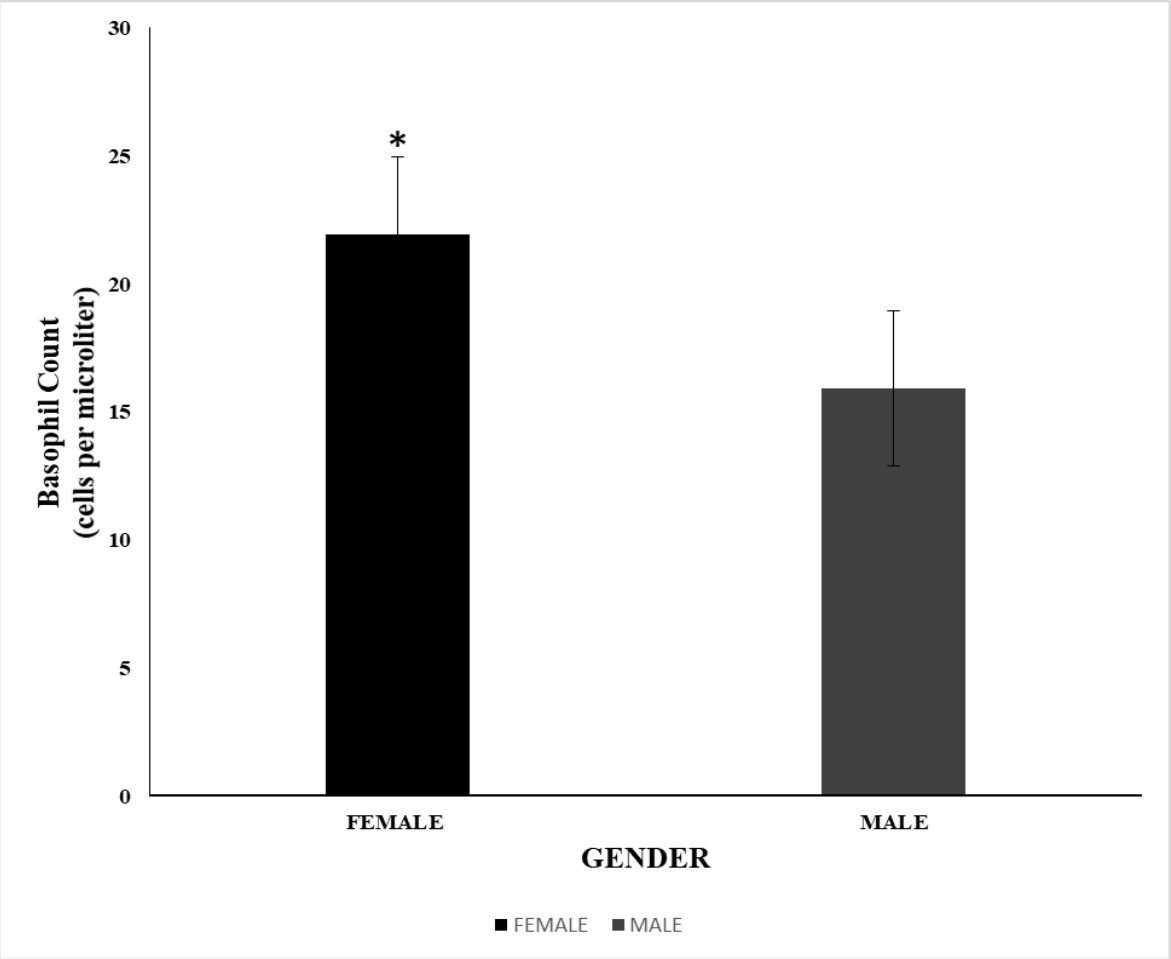

Fig 4.6.5: Female Basophil Count Compared To Male

TABLE 4.6.5: Descriptive Analysis of Basophil Count between Male And Female Human Adults
Mean ± Standard Error Mean (S.E.M)

GENDER	FEMALE	MALE
Total Basophil Mean	21 cells per microliter ± 1.223670062	15 cells per microliter ± 0.838660915

***p ≤ 0.05**

4.7 PLATELET COUNT

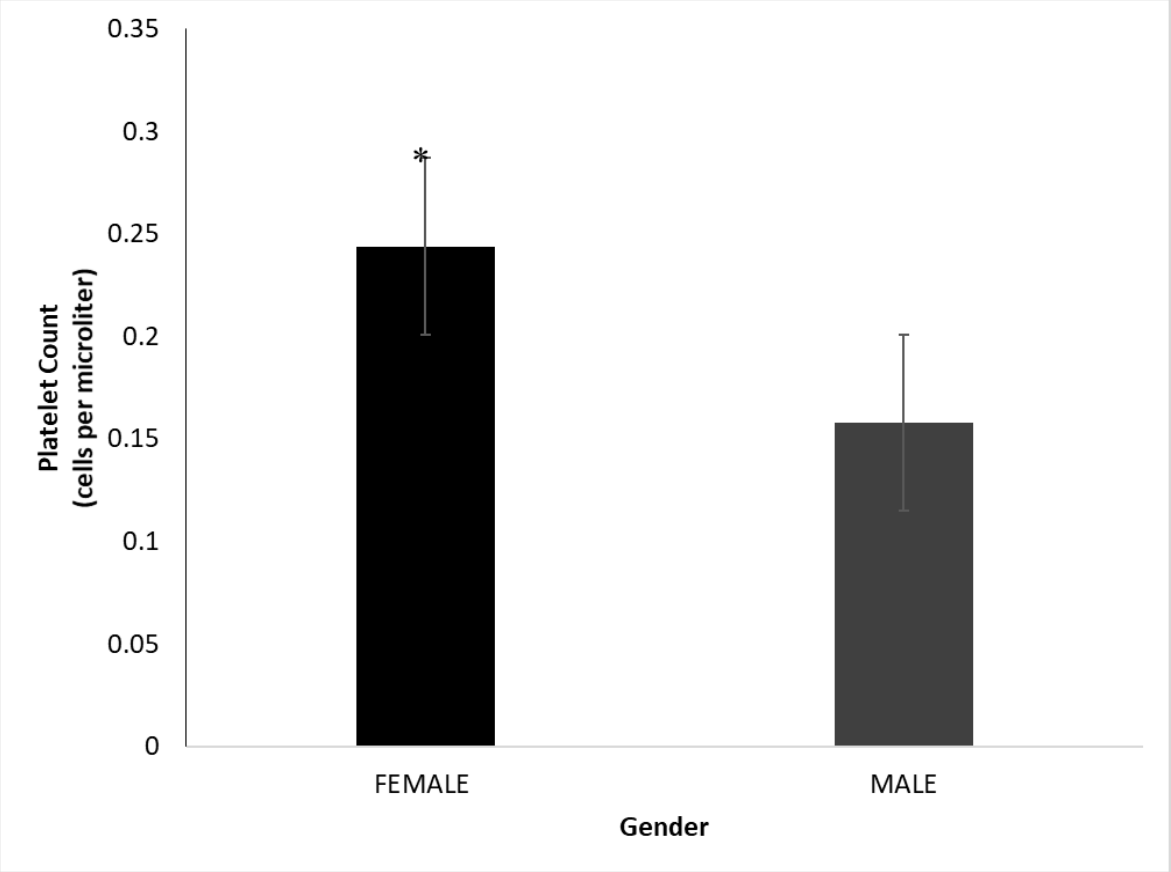

Fig 4.7: Female Platelet Count Compared To Male

TABLE 4.7: Descriptive Analysis of Platelet Count between Male And Female Human Adults

Mean ± Standard Error Mean (S.E.M)

GENDER	**FEMALE**	**MALE**
PCT Mean	0.244 cells per microliter	0.158 cells per microliter

***p ≤ 0.05**

CHAPTER FIVE

DISCUSSION

This study investigated the gender differences in hematological indices, showing statistically significant differences in each of the selected indices between males and females.

Fig 4.1 shows that males had a higher mean RBC count ($4.8275 \times 10^6/\mu L$) compared to females ($4.196 \times 10^6/\mu L$) with a **p value** of $\leq$ **0.05**. This result agrees with existing literature which attributes higher RBC counts in males to the influence of testosterone, which further influences erythropoiesis and the difference in body composition and iron metabolism (Bachman *et al*., 2014; Grau *et al*., 2018).

Similarly, Figures 4.2, 4.3, and 4.4 show that the mean values of MCV (74.645 fL), MCH (26.28 pg), and MCHC (35.285 g/dL) in males were slightly higher than females (72.47 fL, 25.4 pg, and 35.065 g/dL, respectively). These differences were statistically significant ($p \leq 0.05$) and can be attributed to the higher erythrocyte count and hemoglobin concentration in males, as MCV, MCH, and MCHC are derived from these indices.

Conversely, females showed higher total WBC counts ($4.39 \times 10^3/\mu L$) compared to males ($3.185 \times 10^3/\mu L$) in Fig. 4.6, with significant differences in differential WBC counts. As shown in Fig. 4.71, 4.72, 4.73, 4.74, 4.75,

compared to males, females had elevated lymphocytes count (2,203 vs. 1,728/μL), neutrophils count (1,488 vs. 1,050/μL), eosinophil count (43.9 vs. 31.85/μL), basophils counts (21 vs. 15/μL), and monocytes count (632 vs. 358/μL), all being statistically significant with a **p value** of ≤ **0.05**. These results are consistent with other studies on higher leukocytes and immune responses in females due to estrogen's immunoenhancing effects (Foo *et al*., 2016; Roved *et al*., 2017).

Correspondingly, there was significantly higher platelet count in females (0.244×10^3/μL) compared to males (0.158×10^3/μL) (**$p \leq 0.05$**). Although, there has been several studies and literature that assents on these differences but none specifies the reason for these differences.

In conclusion, the results of this study highlights and buttress that there are significant differences of the selected hematological parameters between males and females and these variations can be attributed to physiological factors such as hormonal influences and body composition.

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