ASSESSMENT OF BODY MASS INDEX IN RELATION TO RENAL FUNCTION PARAMETERS AMONG APPARENTLY HEALTHY YOUNG ADULTS IN UNIVERSITY OF BENIN, BENIN CITY.

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BEING A PROJECT SUBMITTED TO THE DEPARTMENT OF MEDICAL LABORATORY SCIENCE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELORS DEGREE IN MEDICAL LABORATORY SCIENCE (BMLS) UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

.

SUPERVISED BY

DR. G.A. AIKPITANYI-IDUITUA

SEPTEMBER, 2025

CERTIFICATION

This is to certify that this project work was carried out by **FAYEYE TOYOSI** with the matriculation number **BMS2001161** under the supervision of **DR. G.A. AIKPITANYI** in partial fulfillment for the award of Bachelor of Medical Laboratory Science (B.MLS) Degree.

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(Ag. HEAD OF DEPARTMENT)

_____ _____

PROF. M. A. OLANIYAN **DATE**

(EXTERNAL EXAMINER)

DEDICATION

I dedicate this project to God Almighty for his love, grace, wisdom and the knowledge he bestowed upon me throughout my time at the University of Benin.

ACKNOWLEDGMENTS

I sincerely want to appreciate God Almighty for the grace to start and complete this project.

I would like to express my deep appreciation to my supervisor, DR. G.A. AIKPITANYI-IDUITUA for his counselling, constructive criticism, understanding and contribution to every stage of this project.

To my head of department Dr. (Mrs.) Z. OMORUYI and the entire members of staff of the department of medical laboratory Science, thank you for all the support and academic modelling all through this transformational phase.

Also, to my family (Late Mr. and Mrs. Kayode Fayeye, Mr. and Mrs. Seun Fayeye), my daddy and mummy in the Lord (Pastor and Mrs. Olawale Olubodun) a big thank you for your unwavering support and prayers which has been a great help and source of inspiration for me.

Lastly, to all my friends in person of James, Success, Tobi, Rachael, Modupe, Promise, Ebenezer and course mates, your immeasurable support is deeply appreciated.

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ABSTRACT

Body Mass Index (BMI) is a simple measure of body fitness and a potential predictor of kidney health. This study explored the relationship between Body Mass Index (BMI) and renal function parameters among 150 apparently healthy undergraduates aged 16–25 years at the University of Benin. Participants were carefully screened to exclude confounding conditions, and anthropometric measurements were taken. Venous blood samples were analyzed for serum creatinine, urea, electrolytes (sodium, potassium, chloride, bicarbonate), and estimated glomerular filtration rate (eGFR). Data were processed using SPSS version 20. Results showed that 10.7% of participants were underweight, 81.3% had normal weight, 5.3% were overweight, and 2.7% were obese. Mean renal function values were within normal ranges, sodium: 138.21 ± 2.74 mmol/L, potassium: 3.87 ± 0.22 mmol/L, bicarbonate: 23.32 ± 1.61 mmol/L, Chloride: 98.33 ± 2.36 mmol/L, urea: 28.07 ± 6.08 mg/dL, creatinine: 0.84 ± 0.17 mg/dL, and eGFR: 112.84 ± 21.11 mL/min/1.73 m^2. There was no significant correlation between BMI and all renal parameters. In this study, BMI did not significantly influence renal function. The presence of overweight and obesity highlights the need for proactive health education, lifestyle counseling, and regular renal screening to prevent future kidney disease. The study concludes that BMI is not significantly correlated with serum creatinine, urea, electrolytes, or eGFR in this population and recommends larger, longitudinal research to assess long-term effects of elevated BMI on renal health.

CHAPTER ONE

INTRODUCTION

1.1. Background of Study

Body Mass Index (BMI) is a widely used anthropometric measure to assess body fat based on a person's weight in relation to height (kg/m²). It categorizes individuals into underweight, normal weight, overweight, and obese. While BMI does not directly measure body composition (like muscle versus fat), it has been used extensively in epidemiological studies to evaluate associations with various health outcomes — including renal (kidney) function (Adamu, 2016).

Obesity and related metabolic disorders have been recognized as major public health concerns worldwide, especially among young adults including university students. One of the key indicators used to assess obesity is Body Mass Index (BMI), which is a simple, non-invasive measure that relates body weight to height (Kg/m2). In account to (Akinbodewa *et al*., 2022**;** Flegal *et al.*, 2020), BMI is widely used as an indicator of body fatness, its association with various health parameters, particularly renal function, has gained attention due to rising prevalence of obesity-related kidney disease. BMI is classified into different categories, which include: -

Underweight: BMI < 18.5 kg/m^2,

Normal weight: BMI 18.5 - 24.95 kg/m^2,

Overweight: BMI 25 - 29.95 $kg/m^2$and

Obesity: BMI $\geq$ 30 kg/m^2

The kidney plays a vital role in removing waste products from the blood, maintaining fluid balance, and controlling electrolyte levels and blood pressure. Carrying excess weight can have a direct impact on kidney function. Excess body weight forces the kidneys to work harder, causing them to filter waste beyond their normal capacity. Over time, this increased demand raises the risk of developing kidney disease. When body weight is excessive, the kidneys are required to exert more effort to perform their functions. There is a connection between obesity and excess body weight and a higher likelihood of chronic kidney disease (CKD) and other renal issues, which can progress quietly over time; and commonly used parameters for evaluation of kidney function include serum creatinine, urea, and glomerular filtration rate (GFR) (Flegal *et al.,* 2020; Akinbodewa *et al*., 2022).

According to Schmidt *et al.*, 2019, rates of obesity and chronic kidney disease (CKD) continue to increase, despite declines in established cardiovascular risk factors such as smoking, hypertension, and hyperlipidemia. Furthermore, there is a significant correlation between body mass index (BMI) and the likelihood of developing CKD. Given its close relationship with diabetes and hypertension, obesity plays a vital role in renal diseases. Excess weight and obesity significantly increase the risk of chronic kidney conditions. Additionally, obesity influences the progression of existing kidney disease by heightening the chances of developing conditions such as diabetic nephropathy, hypertensive nephron sclerosis, and focal and segmental glomerulosclerosis. Changes in renal hemodynamics, structure, and histology are associated with obesity.

University students represent a unique demographic group transitioning from adolescence to adulthood, a period characterized by the adoption of lifestyle behaviors that could impact future health outcomes. Students, especially in Nigeria, may adopt sedentary lifestyles, consume calorie-dense fast foods, and experience stress from academic pressures, contributing to weight gain and possible obesity. This highlights the importance of early screening and health assessments to detect potential risks of obesity-related conditions, including kidney dysfunction.

Previous studies conducted among young adults, including university students, have demonstrated a positive correlation between high BMI and impaired renal function (Schmidt *et al*., 2019). However, there is limited research focusing specifically on Nigerian university students, particularly at the University of Benin. Therefore, assessing the relationship between BMI and renal parameters in this population will provide valuable insights into the early effects of obesity on kidney health, helping to inform public health strategies aimed at reducing the risk of kidney disease.

The rising prevalence of obesity among young adults, including university students, underscores the need for an in-depth understanding of its impact on kidney function. By investigating the relationship between BMI and renal parameters among apparently healthy students at the University of Benin, this study aims to provide critical data that may influence health interventions aimed at preventing obesity-related kidney diseases. Early detection of altered renal parameters in overweight or obese individuals could facilitate timely lifestyle modifications and interventions, promoting long-term kidney health among university students.

1.2 Statement of Problem

The prevalence of obesity and overweight is rising globally, significantly affecting young adults, including university students. Body Mass Index (BMI) is commonly used as an indicator of body fat and overall health, but its relationship with renal parameters, which are critical for assessing kidney function and overall health, remains inadequately explored in this demographic (Prasad *et al*., 2022; Ajayi *et al.*, 2023).

In Nigeria, limited research has been conducted to investigate how BMI correlates with renal function indicators such as serum creatinine, blood urea nitrogen (BUN), and electrolyte levels in apparently healthy young adults. Understanding this relationship is crucial, as it can provide insights into the potential risks associated with altered BMI levels and their impact on renal health. The University of Benin, with its diverse student population, presents an opportunity to investigate these relationships. Therefore, this study aims to assess the correlation between BMI and various renal parameters in apparently healthy students at the University of Benin. By identifying these relationships, the research seeks to contribute to a better understanding of renal health risks associated with obesity and provide a basis for future preventive health strategies.

1.3 Justification of Study

The increasing prevalence of obesity and overweight among young adults, including university students, has become a significant public health concern. Body Mass Index (BMI), a widely used measure of obesity, has been associated with various metabolic and cardiovascular diseases, but its effect on renal health is less understood. Renal function, assessed through parameters such as serum creatinine, blood urea nitrogen (BUN), and

electrolytes, is crucial for maintaining overall health, and changes in these parameters can be early indicators of kidney disease.

In Nigeria, studies exploring the relationship between BMI and renal function in young adults are scarce, especially within the university setting, where lifestyle factors such as diet and physical activity can vary widely. Assessing this relationship in apparently healthy students at the University of Benin is important for several reasons:

Preventive Health: Early detection of potential renal dysfunction in students with abnormal BMI can lead to timely interventions, helping to prevent the progression of kidney-related diseases.

Public Health Relevance: Given the growing rates of obesity, understanding its impact on renal function will provide valuable data to inform public health policies aimed at preventing obesity-related renal problems in young adults.

Contribution to Existing Literature: There is limited research on the correlation between BMI and renal parameters in young Nigerian populations. This study will fill a gap in the current body of knowledge and contribute to understanding how BMI impacts renal health in young, apparently healthy individuals.

Targeted Interventions: By identifying students at risk of renal impairment based on BMI, the findings could guide the development of campus-based health initiatives and educational programs focusing on weight management and renal health.

This study is therefore justified as it seeks to address a critical area of public health concern, with the potential to improve both renal and overall health outcomes for university students.

1.4 Aim of the Study

The aim of this study is to assess the relationship between Body Mass Index (BMI) and renal function parameters, including serum creatinine, blood urea nitrogen (BUN), and electrolytes, among apparently healthy students at the University of Benin. The study seeks to determine whether variations in BMI correlate with changes in renal function and to identify potential health risks associated with abnormal BMI in this population.

1.5 Specific Objectives

The specific objectives of this study were to:

1. Determine the BMI distribution among apparently healthy students at the University of Benin.

2. Measure the renal parameters (serum creatinine, blood urea nitrogen, and electrolytes) of the study participants.

3. Assess the correlation between BMI and markers of renal function.

4. Identify any significant differences in renal parameters among students classified as underweight, normal weight, overweight, or obese based on their BMI.

1.6 Research Questions

1. What is the distribution of Body Mass Index (BMI) among apparently healthy students at the University of Benin?

2. What are the levels of renal function parameters (serum creatinine, blood urea nitrogen, and electrolytes) among the students?

3. Is there a significant correlation between BMI and serum creatinine levels in the study population?

4. Is there a significant correlation between BMI and blood urea nitrogen (BUN) levels in the study population?

5. How does BMI correlate with electrolyte levels in the study population?

6. Are there significant differences in renal parameters between students categorized as underweight, normal weight, overweight, and obese based on their BMI?

1.7 Research Hypotheses

1.7.1 Null Hypothesis

1. There is no difference in the BMI of apparently healthy students in the University of Benin

2. The levels of renal function parameters (serum creatinine, blood urea nitrogen, and electrolytes) are not different among the students.

3. There is no significant correlation between BMI and serum creatinine levels in the study population.

4. There is no significant correlation between BMI and blood urea nitrogen (BUN) levels in the study population.

5. The BMI does not correlate with electrolyte levels in the study population

6. There is no significant differences in renal function parameters between students categorized as underweight, normal weight, overweight, and obese.

1.7.2 Alternate Hypothesis

1. There is difference in the BMI of apparently healthy students in the University of Benin

2. The levels of renal function parameters (serum creatinine, blood urea nitrogen, and electrolytes) are different among the students.

3. There is significant correlation between BMI and serum creatinine levels in the study population.

4. There is significant correlation between BMI and blood urea nitrogen (BUN) levels in the study population.

5. The BMI does correlate with electrolyte levels in the study population

6. There is a significant differences in renal function parameters between students categorized as underweight, normal weight, overweight, and obese.

CHAPTER TWO

LITERATURE REVIEW

2.1 History of Body Mass Index

In account of Afshin, *et al*., 2020, in the early to mid-20th century, obesity was primarily a concern in high-income countries, including most of Europe and the United States. In contrast, low-income countries faced significant burdens of under nutrition, characterized by high rates of stunting, wasting, underweight, and infectious diseases. But in the 21st century, obesity has expanded to low- and middle- income countries of every region of the world (Agofure, 2018). At present, obesity is recognized as one of the most serious global health challenges. Over time, it has evolved from being a local issue to a widespread worldwide concern. Therefore, accurate measurement of obesity is needed for the treatment of underweight, overweight, and obese people. Body Mass Index (BMI) is a widely used and reliable anthropometric measure for assessing obesity, as well as an individual's nutritional and health status, applicable to both adult men and women. It also serves as a reliable indicator of the risk for various diseases associated with excessive body fat. At present it is extensively used in many fields because of its simplicity in measurement and its availability, such as in medical office, laboratory, gym, home, etc. (Araujo *et al.,* 2020). In these areas, it is utilized by a wide range of individuals, including amateur trainers, professionals, scientists, and researchers. The World Health Organization (WHO) recognizes BMI as a key indicator of obesity and has established classifications for overweight and obesity based on BMI values. At present BMI is the best available

anthropometric estimate of body fatness for public health purposes. It is related to both physical and psychological health, such as overall mortality, chronic somatic illnesses, psychiatric disorders, etc. (Araujo *et al.,2020*).

Lisonkova *et al.,* 2020 stated that, Body Mass Index (BMI) is a measure of body fat that takes into account a person's height and weight. It is calculated by dividing an individual's weight (in kilograms or pounds) by the square of their height (in meters or inches). Hence, its unit is kg/m^2 or $lb/inch^2$. The BMI can be finding out using a table or a chart. An ideal BMI is lies within the range 18.5 BMI - 29.9 BMI also provides nutritional status in adults (Strain and Zumoff.,2010). We have some alternative indirect anthropometric measurements indices, such as body volume index, Bennindex, Ponderal index, etc. There are some important direct anthropometric measurements, such as waist circumference (WC), waist-hip-ratio (WHR), bioelectrical impedance, hydrodensitometry (hydrostatic underwater weighing), isotope dilution, sagittal abdominal diameter, dual energy x-ray absorptiometry (DXA), magnetic resonance imaging (MRI), computer tomography (CT) scan, and skin-fold thicknesses (Fleischman *et al.* 2020). These measurements are considered more precise indicators of visceral fat accumulation, adverse metabolic profiles, and disease risk, providing more accurate assessments of body fat. However, direct measurements of body fat are often time-consuming and costly, requiring advanced facilities, highly trained personnel, complex methodologies, and facing challenges such as limited retrospective data and technical difficulties. On the other hand, BMI provides ready result, and one can easily find it from chart or easily can calculate using a calculator (Berrington de Gonzalez *et al*, 2020). Body Mass Index (BMI) is calculated by dividing an individual's weight in kilograms by the square of their height in meters. Although it does

not directly measure body fat, it serves as a strong indicator of the risk for various diseases. Overall, it is an affordable and simple method for screening weight categories.

BMI WEIGHT STATUS

Below 18.5 kg/m^2----------Underweight

18.5 – 24.9 kg/m^2----------Normal or Healthy Weight

25.0 – 29.9 kg/m^2----------Overweight

30.0 $kg/m^2$and above---------Obese.

To calculate BMI, use one of the following formulas:

Calculation with kilograms and meters (or centimeters):

Formula: weight (kg) / [height (m)] ^{2}

Example: Weight = 68 kg, Height = 165 cm (1.65 m)

Calculation: 68 ÷ $(1.65)^2$ = 24.98kg/m^2

According to Berrington de Gonzalez *et al.*, 2020; Okoronkwo *et al*., 2023, high BMI may indicate increased body fat. While BMI is useful as a screening tool, it does not provide a definitive assessment of an individual's body fat or overall health. To determine whether a high BMI represents a health risk, a healthcare provider must conduct further evaluations. These might include skinfold measurements, diet evaluations, physical activity, family history and other appropriate health screenings.

2.2 Overview of the Kidneys

The kidneys are two bean-shaped organs situated just above the waist, positioned between the peritoneum and the posterior wall of the abdomen. Both kidneys are located in the lower back, positioned behind the liver and intestines, and are partially protected by the 11th and 12th pairs of ribs.

2.2.1 Functions of the Kidney

The kidneys are the most vital and hardworking organs of the urinary system. While the other components primarily function as passageways or storage sites for urine, the kidneys perform several essential functions, including:

1. Eliminating waste products and foreign substances through urine

2. Regulating various properties of blood, including:

i. Ionic composition: The kidneys regulate the concentrations of various ions, including sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), chloride (Cl^-), and phosphate (HPO_4^{2-})

ii. pH: by excreting hydrogen ions (H^+) and retaining bicarbonate ions (HCO_3^-)

iii. Osmolality: by independently controlling the excretion of water and solutes in the urine

iv. Blood volume: by conserving or excreting water through urine, the kidneys help regulate blood pressure, either raising or lowering it as needed.

v. Blood pressure: by releasing the enzyme renin, a key component of the renin-angiotensin-aldosterone (RAA) system, which functions to raise blood pressure.

vi. Blood glucose levels: by producing and releasing new glucose molecules

3 Producing hormones:

i. Calcitriol: the active form of vitamin D, which plays a crucial role in regulating calcium levels

ii. Erythropoietin (EPO): which promotes the formation of red blood cells.

Normal kidney functions work together to maintain homeostasis. When a kidney is cut in half, two distinct regions become visible: the renal cortex — a smooth, reddish outer layer — and the renal medulla — a deeper, reddish-brown inner region.

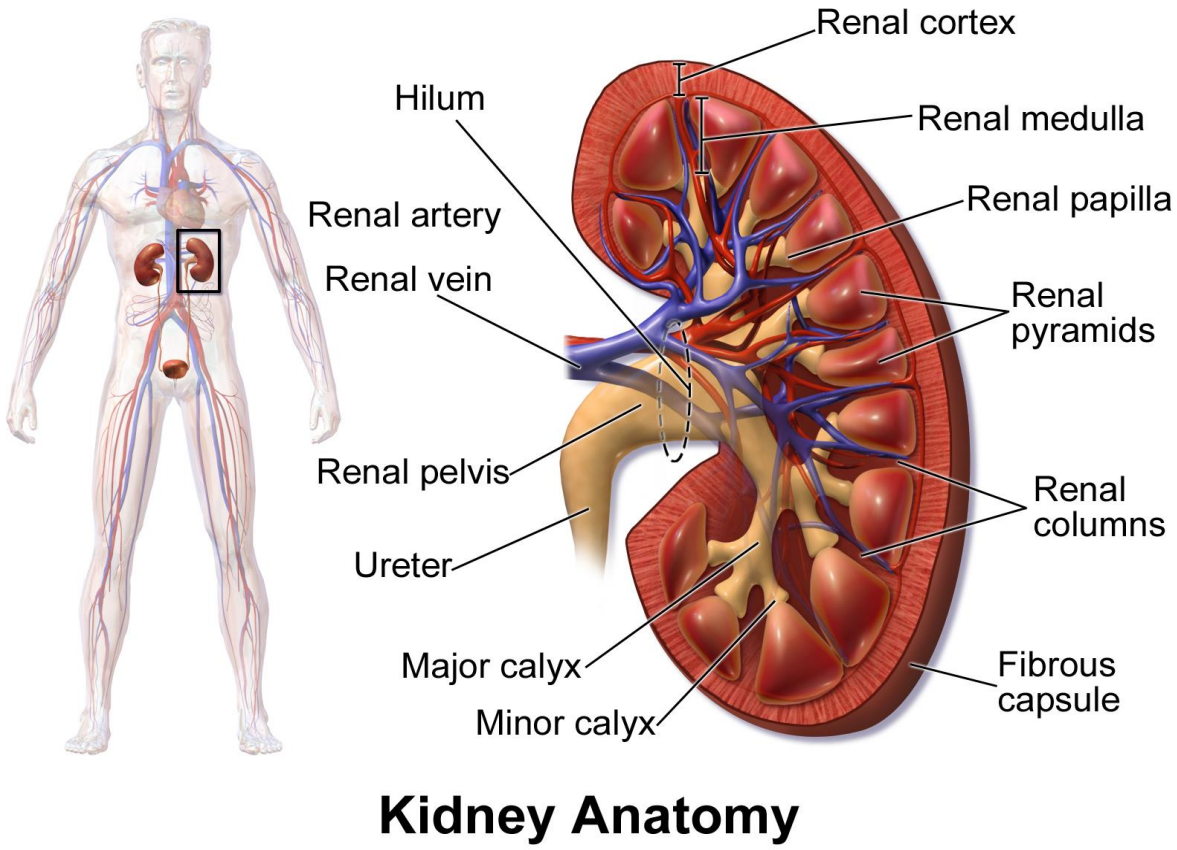

Figure 2.1: Medical gallery of A Kidney (Blausen Medical, 2014)

2.2.2 Renal Cortex

The renal cortex refers to the smooth-textured area extending from the exterior (renal capsule) to the bases of striated, cone-shaped structures called renal pyramids and into the spaces between them. The renal capsule is the membrane that covers the surface of the kidney.

2.2.3 Renal Medulla

The renal medulla is composed of 8–18 renal pyramids. The base of each pyramid faces the renal cortex, while its apex, known as the renal papilla, points toward the renal hilum—the area where the ureter, blood vessels, lymphatic vessels, and nerves enter and exit the kidney. Extensions of the renal cortex that project between the pyramids are called renal columns. Each renal lobe consists of a renal pyramid, the overlying portion of the renal cortex, and half of each adjacent renal column**.**

2.2.4 Nephron

Together, the renal cortex and renal medulla form the functional tissue of the kidney, known as the parenchyma. The parenchyma contains about one million microscopic structures called nephrons, which serve as the kidney's filtration units. Each nephron is composed of two main parts: the renal corpuscle and the renal tubule**.**

A renal corpuscle consists of the glomerulus—a network of capillaries—and the glomerular (Bowman's) capsule, a double-walled epithelial structure that encloses the

glomerular capillaries. This arrangement forms a thin, porous filtration membrane that permits the passage of water and small solutes while preventing most plasma proteins, blood cells, and platelets from being filtered. The resulting filtrate then flows into the renal tubule. The renal tubule is composed of three main sections, which are (in the order in which fluid passes): Proximal convoluted tubule (attached to the glomerular capsule), Loop of Henle (nephron loop), and Distal convoluted tubule (Bennington and Beckwith, 2019).

2.2.5 Proximal Convoluted Tubules

The proximal convoluted tubule, which connects directly to the glomerular capsule, is the first segment through which the filtrate passes. It is responsible for the greatest amount of solute and water reabsorption from the filtered fluid. Substances reabsorbed here include glucose, amino acids, lactic acid, water-soluble vitamins, and ions such as Na^+, K^+, Cl^-, Ca^{2+}, Mg^{2+}, HCO_3^-, and HPO_4^{2-}. At the same time, waste products such as $NH4^+$, urea and small amounts of creatinine are secreted into urine (Homan *et al.,* 2019).

2.2.6 Loop of Henle

The loop of Henle links the proximal and distal convoluted tubules. Its descending limb extends into the renal medulla, then makes a hairpin turn and ascends back toward the renal cortex. About 80–85% of nephrons are located in the outer region of the renal cortex, while the remaining 15–20% are situated deeper within it. The loop of Henle also facilitates further reabsorption of filtered ions and water.

2.2.7 Distal Convoluted Tubules

Reabsorption of the remaining Na^+, Cl^-, Ca^{2+}, and water continues as the filtrate moves through the distal convoluted tubule. By the time the fluid reaches the end of this segment, approximately 90–95% of the filtered solutes and water have been reabsorbed into the bloodstream. Remaining substances that have not been reabsorbed are excreted in the urine. (Homan *et al* 2019)

2.2.8 Ducts, Calyces and the Renal Pelvis

Distal convoluted tubules from several nephrons empty into a single collecting duct. The collecting ducts merge and then converge into larger papillary ducts, which subsequently drain into cup-shaped structures known as calyces. Urine then moves into a single large cavity called the renal pelvis, and subsequently through the ureter into the urinary bladder. (Bennington and Beckwith, 2019)

2.2.9 Renal Blood Supply

The kidneys are supplied with numerous blood vessels due to their critical function in waste removal and the regulation of blood volume and composition. Although the kidneys make up less than 0.5% of total body mass, they receive about 20–25% of the heart's resting cardiac output. In healthy adults, the renal blood flow through both kidneys averages approximately 1,200 mL per minute. Urine drains from the kidneys through the ureters into the bladder, and subsequently out through the urethra during urination (micturition) (Anson and kurth, 2019)

2.2.10 Ureters

There are two ureters — one for each kidney. The ureters transport urine from the renal pelvis to the urinary bladder. In addition to gravity and hydrostatic pressure, muscular contractions propel urine through these long, thick-walled, narrow tubes. Each ureter measures about 25–30 cm (10–12 in) in length and varies in diameter from 1–10 mm between the renal pelvis and the bladder. Like the kidneys, the ureters are located behind the peritoneum. They curve near their ends and pass through the bladder wall. Although no anatomical valve separates each ureter from the bladder, a physiological mechanism exists—when the bladder fills with urine, it compresses the ureteral openings, preventing backflow. If this valve does not operate properly, microbes may travel up the ureters to cause a kidney infection. (Raman *et al.*, 2020)

2.2.11 Urinary Bladder

The bladder stores urine. Located in the pelvic cavity, the urinary bladder is a hollow, expandable muscular organ. In males, it lies directly in front of the rectum, while in females, it is positioned in front of the vagina and below the uterus. Supported by folds of the peritoneum, the bladder gradually becomes rounded and distended as it fills with urine and collapses when empty. The bladder's capacity ranges from 700–800 mL, though it is slightly smaller in females due to the position of the uterus.

2.2.12 Urethra

The urethra is a narrow tube that transports urine from the urinary bladder to the outside of the body.

• In females, the urethra has a length of 4 cm (1.5 in) and opens to the exterior through the external urethral orifice between the clitoris and the vaginal opening

• In males, the urethra is approximately 20 cm (8 in) long and extends from the urinary bladder to the exterior, but the urethra first passes through the prostate, then through the deep muscles of the perineum and lastly through the penis. (Birder *et al*., 2020)

Body composition is recognized as a marker of nutritional status, reflecting body fat mass (FM) and somatic protein reserves. Studies show that, particularly in hemodialysis (HD) patients, (Leinig *et al.,* 2020) body mass index (BMI) and lean body mass (LBM) are significantly lower, compared with healthy individuals. Also, after the initiation of dialysis treatment, patients on HD2 and on peritoneal dialysis (PD) (Kopple, 2021) present a significant reduction in LBM and an increase in body FM. Low BMI and loss of muscle mass were associated with morbidity and mortality in chronic kidney disease (CKD) patients (Araujo *et al* 2020). The association between low body mass and increased mortality is not unexpected. However, in recent years, another important observation has emerged—studies have shown a significant reduction in mortality among hemodialysis (HD) patients. With an above-normal BMI (Beddhu *et al.,* 2020). According to Fleischman *et al.,* 2020, this phenomenon is known as “reverse epidemiology.” In line with this, one study suggested that the survival advantage observed in hemodialysis (HD) patients is linked to lean body mass (LBM) rather than fat mass (FM). For the healthy population, it

has been recognized that BMI is more strongly correlated with body FM, and less with LBM, using techniques such as dual-energy x-ray absorptiometry (DEXA) (Strain and Zumoff, 2022). Dual-energy X-ray absorptiometry (DEXA) is widely regarded as the gold standard for assessing body composition. This technique offers high precision and minimizes the reliance on chemical constants required by other measurement methods. Although hydration status can still be a point of discussion, DEXA is relatively unaffected by it, making it particularly suitable for use in dialysis patients. However, only a limited number of studies have examined different CKD treatment modalities using DEXA while comparing patients to healthy individuals. Furthermore, to the best of our knowledge, no prior study has specifically explored the relationship between BMI and body composition in CKD patients. Therefore, the present study aimed to analyze body composition across various stages of CKD and to examine its correlation with BMI. Our hypothesis is that (as observed in the general population) a strong correlation exists between BMI and adiposity in CKD patients (Strain and Zumoff, 2022). Chronic kidney disease (CKD) is recognized as an important healthcare problem, with increasing prevalence and pandemic size (Kambham *et al.*, 2021). The potential relationship between chronic kidney disease and obesity was postulated by a large number of experimental and epidemiologic studies and is a subject of wide debate. There are many pathways by which obesity may contribute to renal disease: hormonal factors, increased sympathetic activity, proinflammatory state, lipid disturbances, hemodynamic factors (Wahba and Mak, 2020). Shankar *et al.*, 2020 made mention that this relationship was found in the general population but studies are conflicting and difficult to compare taking into consideration that they relate to different races, different populations and different markers used to quantify obesity Preventing

CKD and obesity and clarifying the relationship between them is an important task for current medicine because both obesity as well as chronic kidney disease confers an extremely high risk for cardiovascular morbidity and mortality and additional costs for health care system (Braun *et al.,* 2022).

Afshin *et al.,* 2020 gave an account that the prevalence of a high body mass index (BMI), including being overweight and obese, is increasing globally and contributes considerably to increased all-cause mortality in the general population (Berrington de Gonzalez *et al.,* 2020) However, being underweight is also associated with an increased risk of death, especially in Benin city populations (Zheng *et al.,* 2021) and the BMI exhibits a U-shaped association with all-cause mortality in Benin city populations. Chronic kidney disease (CKD) is a major global health concern linked to a higher risk of cardiovascular morbidity and mortality, with an estimated worldwide prevalence of 11–13%. In patients undergoing dialysis (Kalantar-Zadeh *et al.,* 2020) and who have CKD, a high BMI is paradoxically linked with lower mortality, known as reverse epidemiology, or the obesity paradox. The obesity paradox in relation to all-cause mortality may be attributed to the high prevalence of malnutrition among these patients. Obesity causes glomerular diseases, usually referred to as obesity-related glomerulopathy (Kambham *et al.,* 2021). Studies have revealed that obesity is a risk factor for the incidence of CKD (Foster *et al.,* 2022) and end-stage renal disease (ESRD). The risk of ESRD begins to increase when the BMI exceeds 25 kg/m^2 in the general population and exceeds 35 kg/m in patients with CKD (Lu *et al.,* 2019) However, increasing evidence demonstrates that a high BMI is protective against renal function deterioration. Lu et al found no statistically significant increase in the incidence

of ESRD with higher BMI, while Chang et al. (2018) reported a lower risk of renal function decline in patients with elevated BMI. Huang et al. (2019) revealed that a high BMI was protective of renal function deterioration in CKD stage 3 or 4 among patients with diabetes. This phenomenon can be described as the obesity paradox in relation to renal outcomes among the CKD population. The obesity paradox for renal outcomes is counterintuitive, and only a limited number of studies have reported it, with even fewer exploring its underlying causes. Potential explanations include central obesity, advanced CKD, and malnutrition–inflammation. Research has shown that BMI may not reliably predict renal outcomes in patients with advanced CKD. Malnutrition–inflammation is linked to protein-energy wasting (PEW), which worsens as CKD progresses. The interplay between kidney dysfunction and systemic inflammation is delicate and readily spirals out of control due to the effects of cytokines, hormones, and uremic toxins (Zha and Qian, 2019). Anemia is linked to hypoxemia and can cause damage to the kidney tubulointerstitium, further impacting renal outcomes in CKD patients. Central obesity may be a more effective indicator of mortality than BMI because of the close relationship between adipose tissue dysfunction and metabolism syndrome, and our previous report revealed no central obesity paradox for mortality in patients with CKD (Shen *et al* 2021). The present study aimed to investigate the factors underlying the obesity paradox in renal outcomes among patients with advanced CKD. We hypothesized that advanced CKD and malnutrition–inflammation could alter the relationship between BMI and renal outcomes, and that central obesity might serve as a more accurate predictor of renal outcomes in CKD patients. To test these hypotheses, we conducted a cohort study involving 3,605 Asian patients with CKD stages 1–5, grouped according to their BMI or waist-to-hip ratio. In our study, both the proportion

of patients with chronic kidney disease and the number of overweight and obese individuals were notably higher than in other studies. One possible explanation for these findings is selection bias, as the study was conducted among hospitalized patients in a department with a high prevalence of chronic renal impairment. The large number of overweight and diabetic patients may also be partially attributed to the hypoproteic diet recommended for CKD, where reduced protein intake is often compensated by increased consumption of carbohydrates and fats, potentially leading to obesity. This effect can be further exacerbated by older age and a sedentary lifestyle. Indeed, in our study, patients with a BMI above 25 kg/m² had a statistically significantly higher mean age compared with those of normal weight. The main limitations of this study are: the retrospective design which does not allow causality assessment, using BMI as the single marker of obesity, single serum creatinine measurement and the use of MDRD formula for estimation of GFR with possible misclassification of patients with eGFI close to 60 ml/min/1.73 mp (Toth and Cannon, 2020). In conclusion, our study demonstrate that obesity assessed by body mass index showed no clear association with CKD.

2.2.12 Electrolytes

Electrolytes are charged atoms or molecules that conduct electricity and are denoted with a + or – to indicate their charge, such as sodium (Na^+). They play a vital role in maintaining overall health and are essential for cellular functions and reactions. Anions are electrolytes that carry a negative charge (–), while cations are electrolytes with a positive charge (+). Most electrolytes interact with hydrogen ions to help maintain acid-base balance. The major electrolyte has specialized functions that contribute to metabolism and fluid and

electrolyte balance. Electrolyte may be intracellular or extracellular. Electrolyte are essential minerals in the body that are necessary for nerve and muscle function, the body fluid balance and other critical process. Some of the electrolyte required by the body include Sodium, Potassium, Chloride and Bicarbonate.

2.2.12.1 Sodium

Sodium is the primary cation of extracellular fluid and contributes to about half of the osmotic pressure gradient between the interior of cells and their surrounding environment. Individuals consuming a typical Western diet, which is very high in salt, often ingest 130–160 mmol of sodium per day, whereas the human body requires only 1–2 mmol daily. This excess sodium intake is a significant factor in the development of hypertension in some people. Sodium is freely filtered through the glomerular capillaries in the kidneys; although a large portion is reabsorbed in the proximal convoluted tubule, some sodium remains in the filtrate and is excreted in the urine under normal conditions.

Sodium is essential for nerve impulse conduction and bone formation, but its primary role is maintaining extracellular fluid volume. It is the main electrolyte and a key contributor to blood osmolarity. About 60% of body weight consists of water, which equals roughly 40 liters in a 70 kg adult, with approximately 25 liters inside cells (intracellular) and 14 liters outside cells (extracellular). Maintenance of water balance is dependent on control of sodium. (Higgins, 2019).

2.2.12.2 Potassium

Potassium is the primary intracellular cation and plays a crucial role in establishing the resting membrane potential in neurons and muscle fibers following membrane depolarization and action potentials. Unlike sodium, potassium has minimal impact on osmotic pressure. Low potassium levels in the blood and cerebrospinal fluid are maintained by sodium–potassium pumps in cell membranes, which preserve normal concentration gradients between the intracellular and extracellular compartments. The recommended daily intake of potassium is 4,700 mg. Potassium is excreted both actively and passively through the renal tubules, particularly in the distal convoluted tubule and collecting ducts. It also participates in an exchange with sodium in the renal tubules under the influence of aldosterone, a process dependent on basolateral sodium–potassium pumps.

Hypokalemia is characterized by abnormally low levels of potassium in the blood. Like hyponatremia, it can result from either an absolute reduction of potassium in the body or a relative decrease in blood potassium due to redistribution. Absolute potassium loss may occur from inadequate intake, often associated with starvation, or from conditions such as vomiting, diarrhea, or alkalosis.

In accordance with Higgins, 2019, Hyperkalemia is defined as an elevated level of potassium in the blood and can impair the function of skeletal muscles, the nervous system, and the heart. It may result from excessive dietary potassium intake, leading to abnormally high potassium concentrations in the extracellular fluid (ECF). This can cause partial depolarization of the plasma membranes of skeletal muscle fibers, neurons, and cardiac cells, which may prevent these cells from properly repolarizing.

2.2.12.3 Chloride

In accordance to Groff and Gropper, 2019, stated that Chloride is the primary extracellular anion and plays a key role in maintaining osmotic pressure between the intracellular and extracellular fluids, contributing to proper hydration. It helps balance cations in the extracellular fluid, ensuring electrical neutrality. The secretion and reabsorption of chloride, along with sodium and potassium, are essential for regulating osmotic pressure and acid-base balance. As the most abundant anion in extracellular fluid, chloride is electronegative and acts as an oxidizing agent. Beyond its passive role in electrolyte balance, chloride is also necessary for the production of gastric hydrochloric acid by the parietal cells of the stomach's gastric mucosa.

2.2.12.4 Bicarbonate

Bicarbonate is the second most abundant anion in the blood, and its primary role is to help maintain the body's acid-base balance as part of the buffering systems. Bicarbonate ions are produced through a chemical reaction between carbon dioxide and water, which are byproducts of aerobic metabolism. Only a small fraction of CO_2 dissolves directly in body fluids; over 90% is converted into bicarbonate ions. CO_2 is generated in large amounts in tissues with high metabolic activity and is converted to bicarbonate within red blood cells via the enzyme carbonic anhydrase. Bicarbonate is then transported in the blood to the lungs, where the reaction reverses, and converting bicarbonate back to CO_2, which is exhaled as a metabolic waste product. (Groff and Gropper, 2019)

2.2.12.5 Urea

Urea also known as carbamide, is an organic compound with chemical formula $CO(NH_2)_2$. Urea is an amide composed of two $–NH_2$ groups linked by a carbonyl (C=O) functional group. It plays a key role in the metabolism of nitrogen-containing compounds in animals and is the primary nitrogenous substance in mammalian urine. Urea is a colorless, odorless solid, highly soluble in water, and practically non-toxic; in solution, it is neither acidic nor alkaline. The body primarily uses urea for nitrogen excretion. It is synthesized in the liver through the urea cycle by combining two ammonia (NH_3) molecules with one carbon dioxide molecule. Urea is also widely used in fertilizers as a nitrogen source and serves as an important raw material in the chemical industry. As the major excretory product of biochemical metabolism, urea is rich in nitrogen, and elevated levels can be harmful to red blood cell function. It has no further metabolic role once produced in the liver and is excreted by the kidneys, a process that is vital for mammalian metabolism. (Higgins, 2019).

2.2.12.6 Creatinine

Serum creatinine is a key indicator of kidney function, as it is a readily measurable byproduct of muscle metabolism that is excreted unchanged by the kidneys. Creatinine is produced through a biological process involving creatine, phosphocreatine, and adenosine triphosphate (ATP).

Creatine is primarily synthesized in the liver through the methylation of glycocyamine by S-adenosyl methionine. It is then transported via the bloodstream to other organs, including

muscles and the brain, where it is phosphorylated to form the high-energy compound phosphocreatine. (Taylor and Howard, 2019)

Creatinine is removed from the blood chiefly by the kidneys, primarily by glomerular filtration, but also by proximal tubular secretion. Little or no tubular reabsorption of creatinine occurs. If the filtration in the kidney is deficient, blood creatinine concentration rise. Therefore, creatinine concentrations in blood and urine may be used to calculate the creatinine clearance which correlate approximately with the glomerular filtration rate. (Taylor and Howard, 2019).

2.3 Relationship between Body Mass Index and Kidney

Body Mass Index (BMI) is closely associated with kidney health, particularly in individuals with chronic kidney disease (CKD). Because high BMI contributes to the development of hypertension, diabetes, and glomerular hyperfiltration—all of which can result in kidney damage—it is linked to an increased risk of chronic kidney disease (CKD). As kidney disease progresses, obesity can cause anatomical and functional changes in the kidneys, such as increased glomerular filtration rate and proteinuria (Amira *et al*., 2011; Hall *et al*., 2019).

2.4 Methods of Assessing Renal Function

Accurate assessment of kidney function is essential for managing all children and adolescents. During the neonatal period, drug disposition undergoes significant developmental changes, primarily due to the maturation and recruitment of nephrons (Filler, 2021). This was shown elegantly for ceftazidime and for famotidine (Pedersen *et*

al., 2020). Precise assessment of kidney function is also crucial for managing medications that are eliminated through the kidneys across all age groups. In numerous renal disorders, treatment decisions often rely on determining whether kidney function is normal or impaired. Further, when there is impaired kidney function, accurate assessment of kidney function is important for initiation of renal replacement therapy (Abbink *et al*., 2020) listing for renal transplant, evaluating interventions, and monitoring changes of function over time (Herger-Rosenthal *et al*., 2019). In drug dosing, renal tubular secretion may be more critical than glomerular filtration rate (GFR). However, tubular secretion is not easily measured and requires evaluation of both GFR and renal plasma flow (Beck *et al.,* 2020). GFR can sometimes be elevated due to glomerular hyperfiltration — a condition that may occur in various clinical conditions, including kidney disease. There is currently no universally accepted definition of glomerular hyperfiltration (Bokenkamp, 2020). However, it is thought that glomerular hyperfiltration can be caused by afferent arteriolar vasodilation as seen in patients with diabetes or after a high-protein meal, and/or by efferent arteriolar vasoconstriction owing to activation of the renin-angiotensin-aldosterone system, thus leading to glomerular hypertension (Bokenkamp, 2020). GFR may therefore be disproportionately high relative to the existing nephron count. Despite this limitation, GFR is still widely regarded as the best overall measure of kidney function (Filler *et al.,* 2021). GFR cannot be measured directly. The most widely used approach for estimating GFR relies on the concept of clearance. The renal clearance of a substance (Cx) is determined as:

$$Cx=UxV/Px$$

where **V** represents the urine flow rate (mL/min), **Ux** is the urine concentration of

substance x, and **Px** is the plasma concentration of substance x. Cx is expressed in milliliters per minute. If the substance is freely permeable across the glomerular capillary and is not synthesized, transported, or metabolized by the kidney, Cx is equal to GFR (Filler *et al.*, 2021).

2.4.1 Glomerular Filtration Rate Estimation

GFR is considered to be the best overall index of renal function. (Swan, 2020). GFR can be assessed by measuring the renal excretion of an appropriate marker, such as inulin, which is freely filtered at the glomerulus and is neither reabsorbed nor secreted by the renal tubules. Although not perfect, creatinine clearance offers a reasonably reliable estimate of GFR. In practice, GFR is often estimated from serum creatinine levels using equations like the Modification of Diet in Renal Disease (MDRD) or the Cockcroft-Gault formula, rather than measured directly, as direct measurement is impractical in routine settings. It is important to note that both the Cockcroft-Gault and MDRD equations provide only estimates of GFR, and when precise assessment of kidney function is required, direct measurement is preferred. While serum creatinine is a useful tool, its level alone does not reliably reflect renal function. The creatinine concentration in the blood is affected by a number of factors other than creatinine filtration, including diet, muscle mass, and sex. (Perrone, 2022) Substantial reductions in renal function may occur before the serum creatinine concentration is significantly elevated, because the relation between serum creatinine and GFR is nonlinear. (Levey, 2020) Thus, serum creatinine levels can remain within the normal range even when GFR has significantly declined. Older adults and women typically have lower muscle mass than younger men, which means their actual

renal function (GFR) may be lower than what serum creatinine levels alone would suggest. For example, an elderly woman with a serum creatinine of 1.4 mg/dL (123.8 mol/L), which is still within the normal range of many laboratories, may have a GFR rate indicative of renal insufficiency. (Levey *et al.,* 2020) For these reasons, the National Kidney Foundation's Kidney Disease Outcomes Quality Initiative (K/DOQI) recommends that clinicians use an estimated GFR (eGFR), calculated from serum creatinine, as an indicator of renal function rather than relying on serum creatinine alone. It also advises that laboratories include an eGFR report alongside serum creatinine test results. Laboratory-reported GFR may be easier for patients and physicians to interpret than serum creatinine levels. (Coresh *et al.,* 2022) As noted later in this article, caution is warranted due to variability in serum creatinine measurement methods across different routine laboratories.

2.4.2 Gold-Standard Measurement of Glomerular Filtration Rate

If a substance in stable concentration in the plasma is physiologically inert, freely filtered at the glomerulus, and is not secreted, reabsorbed, synthesized, or metabolized by the kidney, the amount of that substance filtered at the glomerulus is equal to the amount excreted in the urine (Filler *et al.,* 2022). The established gold standard for assessing GFR is the inulin clearance method. While investigating water reabsorption within the renal tubules of amphibians, Richards discovered that inulin—a fructose polymer derived from Jerusalem artichoke—is freely filtered through collodion membranes and not reabsorbed. Inulin meets the criteria for an ideal glomerular filtration marker: it is eliminated exclusively via glomerular filtration, with no tubular secretion or non-renal excretion. When considering inulin clearance, it is important to distinguish between single-nephron

GFR and total GFR. Total GFR is determined by multiplying the single-nephron GFR by the total number of functioning nephrons in both kidneys. In CKD, GFR may decline due to reduced filtration at the level of individual nephrons, a loss of nephron number, or both. Factors that decrease renal perfusion can lower single-nephron GFR. Overall, total GFR remains the most reliable indicator of functioning renal mass (Filler *et al.,* 2020).

2. Single bolus versus infusion technique: GFR with an exogenous marker can be measured either by infusion technique or single bolus (Pöge *et al.,* 2020). The gold standard is an infusion technique that involves a bolus injection, followed by a steady infusion, blood samples at 2, 3, and 4 h and timed urine collection (Miller *et al.,* 2019). In small children, catheterization is required, which is clearly very invasive. The single-bolus injection technique, which relies on plasma disappearance, is more convenient and eliminates the need for timed urine collection. However, infusion techniques have inherent disadvantages. After inulin or other GFR markers are injected, the marker initially distributes within the intravascular space. The volume of distribution is the extracellular space (Bokenkamp *et al.,* 2022). Time is needed for equilibration between compartments. Only the infusion technique with timed urine collection after 3–4 hours ensures both compartments are fully saturated. If samples are drawn too soon after a single bolus injection of a GFR marker, before equilibration occurs, GFR may be overestimated. In adults, the median equilibration time is generally considered around 20 minutes, but there is wide interindividual variability. Children may experience longer equilibration times due to differences in body composition, and no studies are known that specifically determine equilibration time for inulin in children. Conditions such as nephrotic syndrome, edema, or increased

extracellular volume can further prolong equilibration. Animal studies, such as in dogs, indicate that hydration status and hemodynamic changes significantly affect equilibration. Predicting equilibration time is not always possible, yet single bolus GFR protocols typically use fixed sampling times without accounting for patient hydration. On average, the difference between infusion and single bolus inulin clearance in children is 9.7 mL/min/1.73 m^2, with the single bolus method tending to overestimate GFR. For a patient with a true GFR of 20 ml/min/1.73 m2, this could mean a delay in transplant listing. (Bokenkamp *et al.*, 2022).

3. The third key concept involves the correct application of pharmacokinetic modeling for inulin excretion, which is frequently neglected in both infusion and single bolus injection techniques. Substances used to assess GFR exhibit a biexponential plasma disappearance curve when multiple peripheral venous samples are collected between 20 minutes and 4 hours after intravenous administration. These two exponential phases typically correspond to the equilibration of the marker throughout the extracellular fluid (ECF) compartment and its renal clearance, respectively. In contrast, The arterial plasma clearance curve follows a triexponential pattern: the first exponential phase represents the equilibration between plasma and the interstitial spaces of body tissues, primarily muscle and skin; the second, smaller exponential has an unclear role; only the third exponential reflects renal clearance.Proper evaluation requires two-compartment pharmacokinetic modeling, as demonstrated by Van Rossum et al., who emphasized the importance of a late sample at 240 minutes when using the single bolus method. It is recommended to collect at least three samples, starting no earlier than 90 minutes, with delayed sampling being particularly

important in patients with severe renal impairment. For inulin clearance, a bolus injection of 5,000 mg per 1.73 m^2 (maximum 5,000 mg) of Inutest from Fresenius should be administered at a constant rate over 30 seconds, ensuring no extravasation occurs, as this would overestimate GFR. Sample collection should ideally extend to 240 minutes. Analysis should employ a two-compartment model using the actual sampling times, preferably with pharmacokinetic software such as NONMEM or WINNONLIN. Limited availability of Inutest and these technical complexities may significantly restrict the widespread use of this method. Therefore, alternate methods of measuring GFR have been developed. (Bokenkamp and Herget-Rosenthal, 2019).

2.4.3 Serum Creatinine Assay

Given the influence of serum creatinine on GFR estimation, it is crucial that measurements are accurate and standardized across laboratories to ensure consistent interpretation. However, this standardization has not yet been fully achieved. A number of studies have documented some interlaboratory variation and lack of precision in serum creatinine assay. (Miller, 2020) The traditional method for measuring serum creatinine is the alkaline-picrate (Jaffé) method, which can be affected by interference from non-creatinine chromogens in plasma or serum, as well as certain drugs such as cephalosporins. Modern laboratory methods are less prone to such interference, resulting in lower measured serum creatinine levels compared with historical values. This can lead to higher calculated creatinine clearance and an overestimation of GFR. To address this, equipment manufacturers and clinical laboratories may adjust instrument calibration to report higher serum creatinine values, but this calibration is not standardized, causing variability both within and between laboratories. One study found that differences in serum creatinine assay calibration

exceeding 0.2 mg/dL (17.7 µmol/L) between laboratories were not uncommon. Another study showed that a high proportion of laboratories had a significant bias for creatinine that was primarily related to the instrument used rather than the method employed; bias was observed in laboratories using both enzymatic and alkaline-picrate assays. (Miller, 2020) It has been suggested that iodinated contrast media could interfere with the Jaffé method; however, there is no evidence that diatrizoate, an ionic high-osmolar contrast agent, affects serum creatinine measurements. The use of N-acetylcysteine (NAC) to prevent contrast-induced nephropathy (CIN) has been extensively studied, yielding inconsistent results—some trials report a reduced risk of CIN, while others show no benefit. A recent study indicates that the apparent benefit of NAC in certain trials may result from its effect on serum creatinine rather than a true improvement in GFR. In 50 healthy volunteers (mean age 32.8 years; 48% men) with normal renal function who did not receive contrast agents, NAC treatment significantly decreased serum creatinine levels (measured both enzymatically and via the Jaffé method) and correspondingly increased GFR calculated from serum creatinine, without affecting serum cystatin C levels, another marker of kidney function. It is possible that N-acetylcysteine causes a decrease in serum creatinine through other mechanisms such as renal tubular secretion or increased muscle metabolism. (Hoffmann, 2020) In a separate study, therapeutic doses of N-acetylcysteine were found not to interfere with serum creatinine measurements using the Jaffé method.

2.4.4 Limitations of Serum Creatinine as Endogenous Marker of Glomerular Filtration Rate

Serum creatinine remains the most widely used endogenous marker of GFR for estimating GFR. Creatinine is a metabolic byproduct whose measurement can be affected by methodological factors. Blockade of tubular secretion with H2 antagonists has shown promising results in addressing the issue of creatinine secretion, though the use of cimetidine protocols in children is still limited. While creatinine clearance measurements using timed urine collections can provide greater accuracy, they are challenging for pediatric patients, time-consuming, and impractical for routine use. Small molecular proteins have emerged as superior endogenous markers of GFR. For the new Schwartz formula, cystatin C and urea as well as creatinine measurements are required (Olsen *et al.*, 2019).

2.4.5 Cystatin C

The characteristics and properties of cystatin C have been reviewed in detail in other sources. Earlier studies of the serum level of cystatin C in large patient cohorts have failed to correlate the serum level to any pathophysiological state besides those affecting the glomerular filtration rate, which also is compatible with a stable secretion of cystatin C from most human tissues (Grubb, 2020). However, very large doses of glucocorticoids have recently been described to increase the production of cystatin C, whereas low and medium doses of glucocorticoids do not seem to alter its production (Foster, 2019). Thyroid

dysfunction can influence cystatin C levels; however, our recent studies found no association between cystatin C and thyroid function markers. The reference values for cystatin C obtained in a carefully selected population are 0.75±0.09 mg/l for children aged 4–19 years, 0.74±0.10 mg/l for males and 0.65±0.09 mg/l for females (aged 20–59 years), and 0.83±0.10 mg/l for older individuals (> or =60 years) (Galteau *et al.,* 2021). Renal function undergoes physiological maturation during the first year of life. Accordingly, cystatin C levels are much higher at birth, reaching up to 2.8 mg/L, and decline rapidly thereafter as kidney function matures. Age-related variations must also be considered in adults. Recently, new reference intervals with a detailed age distribution have been published from Central Europe, based on 985 healthy individuals over 25 years of age. Studies of the handling of human cystatin C in rats have shown that the plasma renal clearance of cystatin C is 94 % of that of the generally used GFR-marker 51Cr-EDTA and that cystatin C thus is practically freely filtered in the glomeruli (Hannemann, 2021). At least 99% of filtered cystatin C is degraded in the renal tubular cells. In an experimental study where rat GFR was variably decreased by constricting the aorta above the renal arteries, cystatin C plasma clearance correlated strongly with ^{51}Cr-EDTA clearance (r = 0.99), with a y-intercept not significantly different from zero. After these encouraging studies, additional studies suggested that the reciprocal of cystatin C correlates better with a gold-standard GFR measurement than the reciprocal of serum creatinine (Tenstad, 2019). Cystatin C has been shown to be a GFR marker independent of body composition. The advent of automated, rapid particle-enhanced immunoturbidimetric and immunonephelometric assays—offering greater precision than earlier radioimmunoassays or ELISAs—has facilitated the widespread clinical adoption of serum cystatin C as a

reliable marker of GFR. The diagnostic performance of cystatin C in comparison with serum creatinine was first analyzed in 2002 with a meta-analysis of 46 studies, in both adults and children (Kyhse-Andersen *et al.,* 2021). A pooled data analysis comparing the correlation between GFR and the reciprocals of serum creatinine and cystatin C in 3,703 individuals found significantly stronger correlations for cystatin C (mean r = 0.816 [95% CI: 0.804–0.826]) than for serum creatinine (mean r = 0.742 [95% CI: 0.726–0.758]). Receiver operating characteristic (ROC) analyses from a pooled sample of 997 individuals also demonstrated a significantly higher area under the curve for cystatin C (mean = 0.926 [95% CI: 0.892–0.960]) compared with serum creatinine (mean = 0.837 [95% CI: 0.796–0.878]). This meta-analysis indicates that cystatin C is superior to serum creatinine for detecting impaired GFR in cross-sectional studies. More recently, another meta-analysis of 24 studies (n=2,007) also confirmed that the diagnostic accuracy favored cystatin C (Roos *et al.,* 2020), although in this more recent study, the diagnostic odds ratios started to overlap, most probably due to the IDMS testing of serum creatinine. Measuring cystatin C is more costly than measuring creatinine.

In summary, inulin remains the gold standard for measuring GFR; however, its use is restricted by limited availability, procedural complexity, and invasiveness. Nuclear medicine GFR scans have largely supplanted inulin clearance in most centers, though they are not entirely equivalent. Iothalamate is limited by tubular secretion, while ^{51}Cr-EDTA and ^{99}Tc-DTPA exhibit plasma protein binding that reduces their clearance compared with inulin. Iohexol is theoretically an ideal marker due to low plasma protein binding and its non-radioactive nature, allowing repeated use in children without radiation exposure; however, it shows considerable variability. Clinical comparisons between inulin-based

GFR measurements and nuclear medicine scans generally favor ^{51}Cr-EDTA, as it demonstrates the lowest bias and best agreement in both transplant and non-transplant patients. Accuracy can be compromised by extravasation, early sampling before equilibration across the extracellular volume, or failure to apply an appropriate two-compartment pharmacokinetic model. Most centers rely on log transformation, and precise non-linear two-compartment modeling with exact time points is rarely used. Endogenous markers have more limitations, although low molecular weight proteins are generally more reliable than creatinine. Combining cystatin C, urea, and creatinine can provide a reasonably good agreement between measured and estimated GFR. Cystatin C appears to be slightly superior to beta trace protein with the exception of during pregnancy and the neonatal period. (Benlamri *et al.*, 2020).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area and Participants

The area for this study was University of Benin in Benin City, Edo State, Benin City is in Edo State, Nigeria and it is located at 6.34 latitude and 5.63 longitude. It is situated at an elevation of 88 meters above sea level. Benin City has a population of about 1,125,058 people. It is located in the south - south geo-political zone of Nigeria.

The subjects for this study were students of University of Benin, Benin City. A total of one hundred and fifty students were recruited for this study. Informed consent was obtained from each participant after proper notification and information on the nature of the research, risk involved, benefits as well as confidentiality by using a questionnaire.

3.1 Research Design

This is a cross-sectional study. The instrument for the collection of data was questionnaire. The questionnaire had two main sections i.e. the demographic variables such as age, sex, educational background together with the anthropometric and basic health indices

3.2.1 Inclusion Criteria

The study includes apparently healthy, 16-25-year-old undergraduate students of the University of Benin who granted informed consent and met specific health and enrollment criteria.

3.2.2 Exclusion Criteria

The study excluded undergraduate students with renal insufficiency or disease, pregnancy, chronic conditions, substance abuse, renal-altering medications, mental health issues, or inability to provide informed consent.

3.2 Ethical Approval

Ethical approval was obtained from the Ethical Committee of the School of Basic Medical Science, University of Benin, Benin city, Edo State.

3.4 Sample Size

The sample size for the study was based on three factors, which are:

1. The estimated prevalence of variables of interest from the literature review
2. Confidence level of 95%
3. The acceptable margin of error

The sample size was calculated using the formula:

$$N = \frac{X^2 \text{ x } M \text{ x } (1 - M)}{Z^2}$$

(Aderibigbe *et al.*, 2024)

Where:

N= required sample size

X = Confidence level interval of 95%

M = Estimated prevalence of obesity of variable interest from the literature of 50%

Z= Margin of error at 8% $(standard\ \ value\ of\ 0.08)$

$$N = \frac{1.96^2 \text{x } 0.5 \text{ x } (1 - 0.5)}{0.08^2}$$

$$N = \frac{3.8416 \text{ x } 0.5 \text{ x } 0.5}{0.0064}$$

$$N = \frac{0.9604}{0.0064}$$

$$\text{N} = 150$$

3.4.1 Data Collection for Measurement of Body Mass Index

Using a well calibrated mechanical weighing scale, the participant was asked to stand straight on the weighing scale removing any object which could interfere with weight measurement, then the weight was read from the scale and recorded in kilogram (kg).

Using a measuring tape, the participant was asked to stand barefooted on his or her heels, with head and back touching the wall, ensuring he or she was standing straight with the head-level and looking forward. Measurement was taken from the ground to the top of the head of the participant and recorded meter (m).

3.4.2 Calculation of Body Mass Index

With weight measured in kg,and the height measured in m

$$\text{BMI} = \frac{\text{weight in kg}}{\text{Height in m}^2}$$

3.5 Sample Collection

3.5.1 Sample Collection for the Measurement of Renal Function Parameters

About 5 mL of venous blood was collected under aseptic conditions from the antecubital vein of the participant using a sterile syringe and needle. The sample was dispensed into a clean sample container containing lithium heparin as the anticoagulant. The sample was then centrifuged at 5000 rpm for 5 minutes to separate the plasma from whole blood. The plasma was then decanted into another clean and dry plain container. The sample was analyzed immediately or kept frozen at -20^{o}C for not more than four weeks when immediate analyses was not possible.

3. 5.2 Determination of Serum Creatinine

Principle: The assay is based on the reaction of creatinine with sodium picrate as described by Jaffe. Creatinine reacts with alkaline picrate forming a red complex. The intensity of the color formed is proportional to the creatinine concentration in the sample (Sadoh *et al*., 2014).

Procedure

To 1ml of serum, 2ml of distilled water was added. The protein was precipitated by adding 0.5ml of sodium tungstate and 1ml of 0.67N hydrochloric acid in a drop wise manner, mixed gently and allowed to stand for 10mins before centrifugation.3ml of the supernatant fluid was dispensed into another test tube and 1ml of picric acid reagent was added followed by 1ml of 0.75M sodium hydroxide. 1ml of standard creatinine solution and 1ml of distilled water were treated similarly to serve as standard and blank respectively. The

colour developed was read spectrophotometrically at a wavelength 520nm after 15mins. Controls were also treated similarly.

3.5.3 Determination of Serum Blood Urea Nitrogen

Berthelot method (Urease method) was used.

Principle: Urease catalyzes the hydrolysis of urea into ammonia and carbon dioxide, the ammonia reacts with phenol and hypochlorite to form a blue colored complex sample which is measured spectrophotometrically at a wave length of 530nm.

Procedure

Exactly 100uL of the urease reagent was dispensed into a clean test tube, and 10uL of the sample was added and incubated for 10minutes. Thereafter, 2mL of reagent 2 (Phenol nitroprusside solution) and 2 mL of reagent 3 (Alkaline hypochlorite) were added to the tube and incubated for another 15minutes. The colour developed was read spectrophotometrically at 520 nm against reagent blank. 1ml of standard urea solution and 1ml of distilled water were treated similarly to serve as standard and blank respectively. Controls were also treated similarly

3.5.4 Determination of Serum Electrolytes

The ion selective electrode (ISE) instrument was used for electrolytes analysis

Principle of ISE: The ISE measures the potential difference across the ion selective membrane. The potential difference is directly proportional to the ion concentration in the sample

Procedure

The instrument was calibrated using standard solution of known concentration of Na^+, K^+, Cl^- and HCO_3^-. The sample was introduced into the measuring chamber of the instrument; the electrode was allowed to stabilize and equilibrate with the sample and the results were read off from the digital display. The sample was introduced into the measuring chamber of the machine. The electrode was allowing to stabilize and equilibrate with the sample.

3.6 Statistical Analysis

The results were analyzed using the statistical package for social sciences program (SPSS) version 20.0(Chicago IL). Values obtained in this study were presented as mean ±standard error of mean (SEM). Student t-test was used to compare values. The groups were analyzed using a cross-tabulation Pearson chi-square test. Within class, chi-square goodness of fit was applied. Level of significance was set at $p<0.05$.

CHAPTER FOUR

RESULTS

Table 4.1 presents the distribution of Body Mass Index (BMI) categories across different faculties, age groups, and gender among study participants. All the BMI categories including underweight, normal weight, overweight, and obesity were observed.

Across faculties, the majority (Average 81.3%) of students were observed to have normal BMI. Others were 10.7% underweight, over weight 5.3% obese 2.7%. Specifically, the Faculty of Arts had 93.3%, Education (91.7%), Engineering (90%), Management Sciences (90%), and Physical Sciences (88.7%). In contrast, the Faculty of Medicine had a relatively high proportion of underweight students (50%). The Faculty of Environmental Sciences showed the highest proportion of obese students (16.7%), although the overall number tested was small (n=6). This is graphically represented in Fig 1.

When stratified by age, most students across all age groups maintained normal BMI. Underweight cases were more common among younger students, particularly those aged 16–18 years (14.2%) and 19–21 years (12.8%). Overweight and obesity cases were relatively evenly distributed across the 19–27-year age range, with very few or no cases in the youngest (16–18 years) and oldest (28–30 years) groups. This is graphically represented in Fig 2.

Both male and female students displayed similar BMI distributions: 61 students in each group were within the normal weight range, while 8 were underweight, 4 overweight, and 2 obese. This indicates no marked gender differences in BMI distribution within this sample. This is graphically represented in Fig 3

Table 4.1: Faculty, Age and Gender Distribution of the Study Participants

Characteristics	No. tested	BMI category (kg/m^2) (%)			
		Underweight (n=16)	Normal weight (n=122)	Overweight (n=8)	Obese (n=4)
Faculty					
Arts	30	1 (3.3)	28 (93.3)	0	1 (3.3)
Basic Medical Sciences	30	5 (16.8)	20 (66.7)	4 (3.3)	1 (3.3)
Education	24	0	22 (91.7)	2 (8.3)	
Engineering	20	1	18 (90.0)		1 (5.0)
Environmental Sciences	6	0	5 (83.3)		1 (16.7)
Life Science	13	2	9 (69.2)	2 (15.4)	
Management science	10	1	9 (90.0)		
Medicine	10	5	5 (50.0)		
Physical Science	7	1	6 (88.7)		
Age (years)					
16-18	28	4	23	1	0
19-21	47	6	36	3	2
22-24	43	3	36	3	1
25-27	24	3	19	1	1
28-30	8	0	8	0	0
Gender					
Male	75	8	61	4	2
Female	75	8	61	4	2

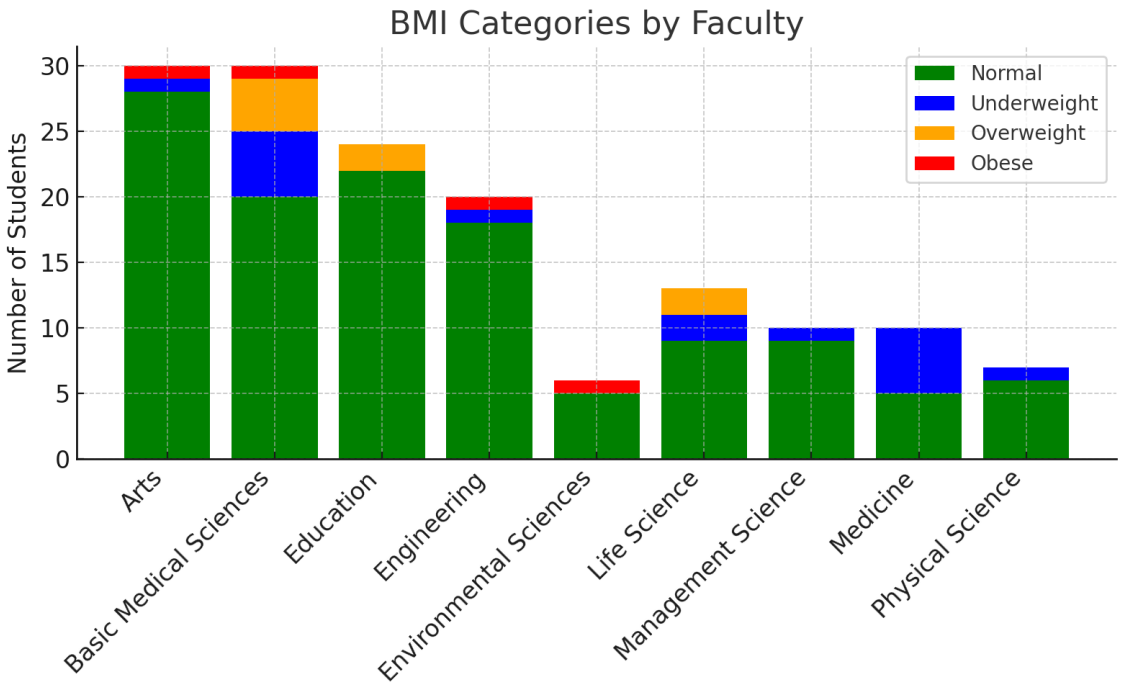

Fig 4.1: BMI Categories by Faculty

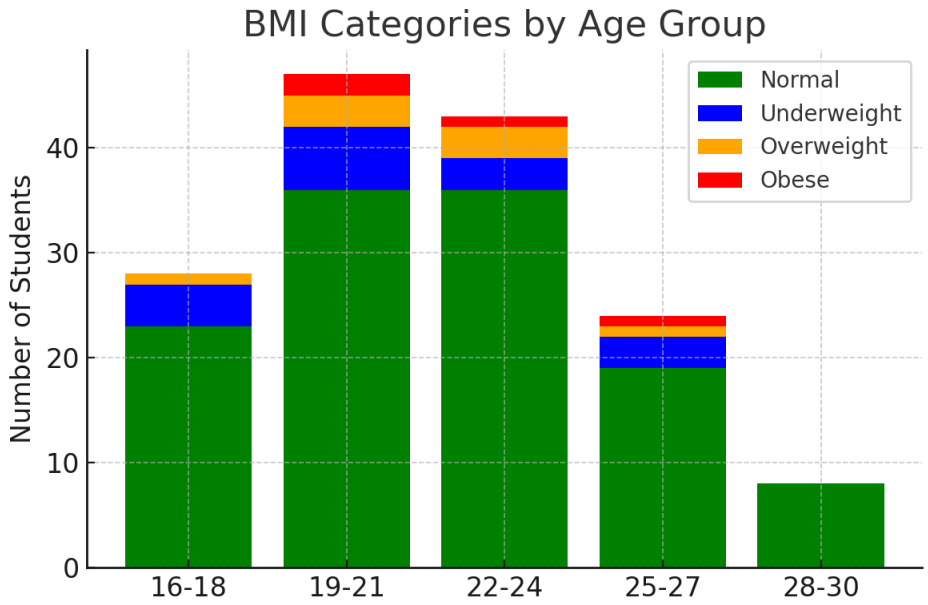

Fig 4.2: BMI Categories by Age Group

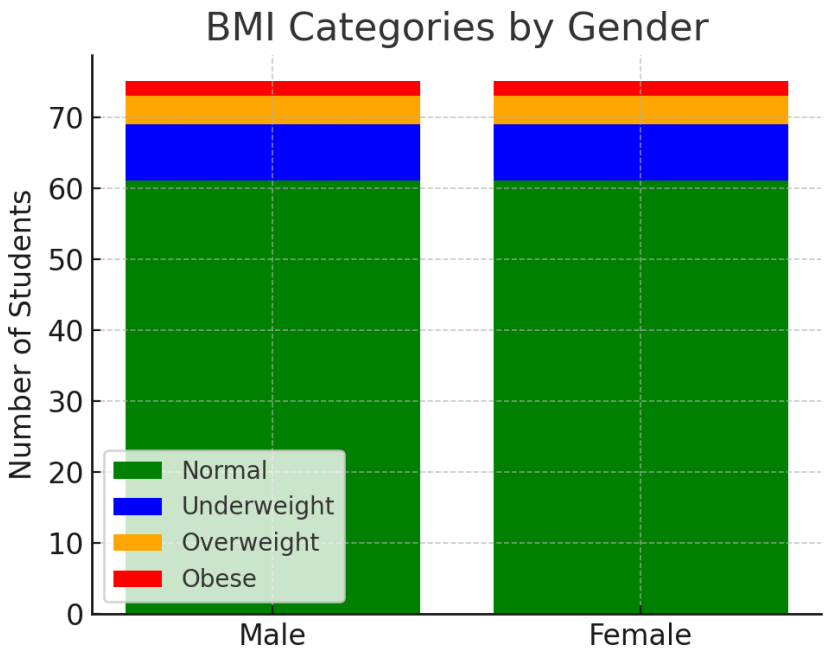

Fig 4.3: BMI Categories by Gender

Table 4.2 shows the renal function parameters of study participants with average mean and standard deviation. Sodium concentration was 138.21 ± 2.74 mmol/Potassium level was 3.87 ± 0.22 mmol/L**,** bicarbonate level was 23.32 ± 1.61 mmol/L, chloride value was 98.33 ± 2.36 mmol/L, serum urea concentration was 28.07 ± 6.08 mg/dL**,** serum creatinine level was 0.84 ± 0.17 mg/dL and the eGFR was 112.84 ± 21.11 mL/min/1.73 m^2**.**

Table 4.2: Renal Function Parameters of Study Participants

Renal Parameters	Na^+ (mmol/L)	K^+ (mmol/L)	HCO^-_3 (mmol/L)	Cl^- (mmol/L)	Urea (mg/dL)	Creatinine (mg/dL)	eGFR (mL/min/1.73m^2)
Mean and Standard Deviation Average	138.21 ±2.74	3.87 ±0.22	23.32 ±1.61	98.33 ±2.36	28.07 ±6.08	0.84 ±0.17	112.84 ±21.11

Table 4.3 demonstrates a weak correlation between BMI and Renal Function Parameter, where the correlation between BMI and Sodium to give Sodium (r = -0.0679), BMI and Potassium (r = -0.0898), BMI and Bicarbonate (r = 0.0025), BMI and Chloride (r = 0.0167), BMI and Urea (r = -0.1509), BMI and Creatinine (r = 0.0452), BMI and eGFR (r = 0.0030). This is graphically represented in Fig 4.4

Table 4.3: Correlation between BMI and Renal Parameters

Parameters	R-value
BMI vs Sodium	-0.0679
BMI vs Potassium	-0.0898
BMI vs Bicarbonate	0.0025
BMI vs Chloride	0.0167
BMI vs Urea	-0.1509
BMI vs Creatinine	0.0452
BMI vs eGFR	0.0030

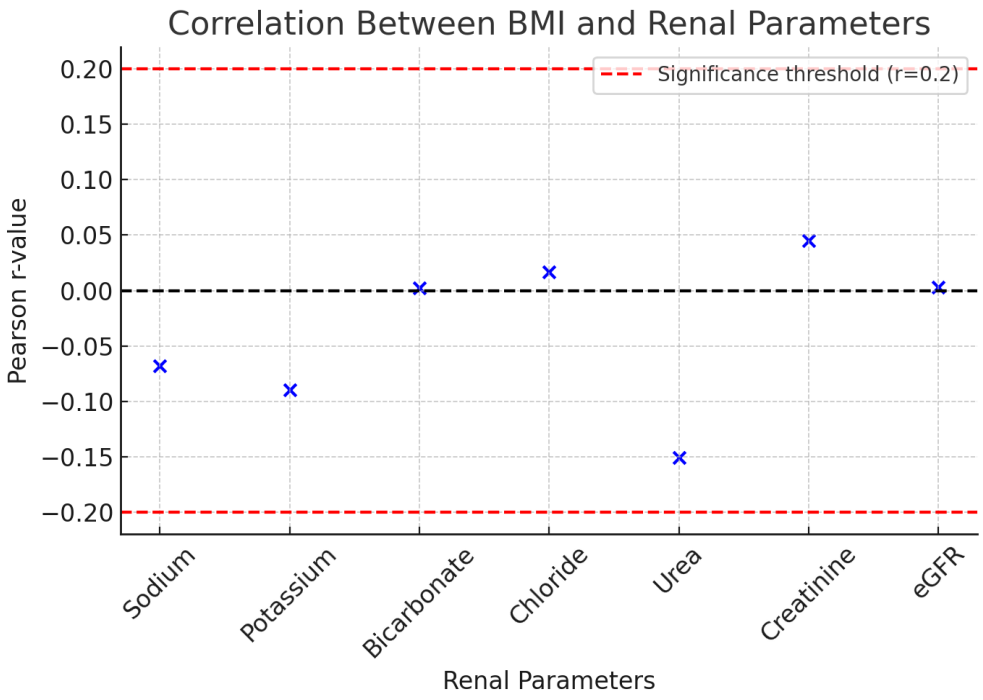

Fig 4.4: Strength and direction of correlations between BMI and renal parameters.

Table 4.4 represents the relationship between body mass index (BMI) categories and renal function parameters among Study participants. One-way ANOVA was applied to

determine differences, with statistical significance considered at $p \leq 0.05$. Sodium (Na^+), a statistically significant difference was observed across BMI categories ($p = 0.0302$). Underweight individuals recorded the highest sodium levels (140.00 ± 2.28 mmol/L), whereas obese individuals had the lowest (137.50 ± 4.80 mmol/L). This suggests BMI may influence sodium regulation. Potassium (K^+), no significant differences were detected ($p = 0.7340$). Potassium levels remained stable across all BMI groups, Bicarbonate (HCO_3^-), differences across BMI groups were not statistically significant ($p = 0.6188$).

Mean values were comparable, suggesting little or no BMI effect on bicarbonate balance. Chloride (Cl^-), no significant difference was observed ($p = 0.0927$). However, overweight participants showed slightly higher mean chloride levels (99.75 ± 2.12 mmol/L). Urea, no statistically significant variation was found ($p = 0.1569$). Overweight individuals had the lowest mean urea values (23.75 ± 7.07 mg/dL), whereas obese individuals had slightly higher levels (30.00 ± 6.58 mg/dL). Creatinine did not differ significantly across BMI categories ($p = 0.3906$). Obese individuals exhibited marginally higher mean creatinine (0.95 ± 0.25 mg/dL). Estimated Glomerular Filtration Rate (eGFR), no significant differences were observed ($p = 0.8355$). All BMI groups demonstrated eGFR values above 90 mL/min/1.73 m^2.

Table 4.4: Relationship between BMI Categories and Renal Parameters among Study Participants

Parameters	Underweight (n= 16)	Normal weight (n= 122)	Overweight (n=8)	Obese (n=4)	p-value
Sodium (mmol/L)	140.00 ± 2.28	137.93 ± 2.63	139.13 ± 3.4	137.50 ± 4.80	0.0302*
Potassium (mmol/L)	3.87± 0.24	3.88 ± 0.21	3.81 ± 0.22	3.8± 0.27	0.7340
Bicarbonate (mmol/L)	23.06 ± 1.81	23.36 ± 1.58	23.63 ± 1.92	22.50 ± 1.29	0.6188
Chloride (mmol/L)	99.34 ± 2.09	98.15 ± 2.38	99.75 ± 2.12	98.00 ± 2.16	0.0927
Urea (mg/dL)	29.44 ± 25.63	28.11 ± 6.00	23.75 ± 7.07	30.00 ± 6.58	0.1569
Creatinine (mg/dL)	0.81 ± 0.16	0.85 ± 0.17	0.79 ± 0.19	0.95 ± 0.25	0.3906
eGFR(mL/min/1.73 m^2)	116.28 ± 19.73	112.29 ± 21.01	116.10 ± 22.03	108.47 ± 33.32	0.8355

* One Way ANOVA; Significant at $p < 0.05$

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

This study examined the distribution of Body Mass Index (BMI) among undergraduate students of the University of Benin and explored its relationship with renal function parameters. The findings reveal that the majority of the student population fell within the normal BMI range, although notable proportions were underweighted or overweight/obese in specific faculties and age groups. Renal indices, including sodium, potassium, bicarbonate, chloride, urea, creatinine, and estimated glomerular filtration rate (eGFR), were within normal ranges for all participants, with limited variation across BMI categories. Importantly, correlation analysis showed no strong relationship between BMI and renal function parameters, except for a significant difference in sodium levels across BMI groups.

These results provide valuable insights into the health status of young Nigerian adults, highlighting both areas of strength (generally normal BMI and preserved renal function) and areas of concern (subgroup variations in underweight and obesity).

Across most faculties, students maintained normal BMI, notably in Arts (93.3%), Education (91.7%), Engineering (90%), and Management Sciences (90%). However, Medicine had the highest proportion of underweight students (50%), consistent with evidence that academic workload and irregular meal schedules predispose medical students in Nigeria to undernutrition (Senbanjo *et al.*, 2012). In contrast, the Faculty of Environmental Sciences had the highest proportion of obese students (16.7%), though the

number tested was small. Nigerian studies have shown that sedentary lifestyle patterns, such as prolonged sitting for computer-based work, increase obesity prevalence in university populations (Chukwuonye *et al.,* 2013).

Underweight was more common among younger students (16–21 years), while overweight and obesity were observed in the 19–27-year range. This reflects nutritional transition in Nigeria, where adolescents and younger adults often struggle with undernutrition while older youths increasingly experience overweight and obesity due to dietary changes and reduced physical activity (Okoronkwo *et al.,* 2023). The absence of overweight/obesity in the 28–30 age group may be due to the small sample size, but it may also reflect more established dietary and lifestyle practices. Similar findings were documented in Enugu, where underweight peaked among younger undergraduates while overweight increased with age (Wachukwu *et al.*, 2015).

This study found no gender differences in BMI distribution: males and females had identical proportions of underweight, normal, overweight, and obese categories. This contrasts with many Nigerian studies that consistently report higher prevalence of overweight and obesity among females (Amira *et al.*, 2011; Chukwuonye *et al.,* 2013). The uniformity observed here may be explained by the shared university environment—students often eat at the same cafeterias, experience similar schedules, and have comparable recreational opportunities, minimizing gender-specific disparities.

Average serum sodium (138.21 ± 2.74 mmol/L), potassium (3.87 ± 0.22 mmol/L), bicarbonate (23.32 ± 1.61 mmol/L), chloride (98.33 ± 2.36 mmol/L), urea (28.07 ± 6.08

mg/dL), creatinine (0.84 ± 0.17 mg/dL), and eGFR (112.84 ± 21.11 mL/min/1.73m²) were all within normal reference ranges, indicating preserved renal function.

Similar findings have been reported among healthy young Nigerian adults in Lagos and Port Harcourt, where renal function parameters fell within normal limits, reflecting absence of chronic disease burden at this age (Afolabi *et al.*, 2018; Olanrewaju *et al.,* 2020). The high mean eGFR observed in this study is consistent with youthful renal reserve capacity, which typically declines with age.

No strong correlations were observed between BMI and renal indices (all r-values < 0.2). This is consistent with evidence that, in young healthy individuals, compensatory renal mechanisms (e.g., glomerular hyperfiltration) buffer the effects of BMI variations on renal function (Kovesdy, 2017). In Nigeria, Oluyombo *et al*. (2021) reported that obesity and higher BMI were significantly associated with CKD progression in older adults. The absence of such associations in this study likely reflects the younger age of participants, suggesting that early adulthood represents a **"**window of opportunity**"** for prevention before BMI translates into renal risk.

A statistically significant difference was found in serum sodium levels across BMI categories ($p = 0.0302$)**,** with underweight individuals showing the highest mean sodium and obese individuals the lowest. This supports evidence from Nigerian clinical studies suggesting that BMI may subtly influence sodium handling and blood pressure regulation (Akintunde *et al.,* 2013). No significant differences were observed for potassium,

bicarbonate, chloride, urea, creatinine, or eGFR, highlighting the preserved renal resilience in this young population.

This study partly aligns with Nigerian and global evidence:

Amira *et al*., (2011) reported obesity as a predictor of proteinuria in Lagos, linking excess BMI to renal stress. Chukwuonye *et al*., (2013) in Abia State documented increasing overweight/obesity among young adults, stressing its contribution to non-communicable diseases. Wachukwu *et al*., (2015) observed rising CKD risk factors, including obesity, among Nigerian university populations. Oluyombo *et al*., (2021) established that high BMI significantly predicts CKD progression in Nigerian adults, emphasizing the long-term risk.

In contrast, this study found no significant BMI–renal correlation, likely because of the younger, healthier sample.

Underweight in medical students calls for nutritional interventions to prevent long-term health consequences**.** Obesity, though low in prevalence, requires monitoring as it is a known precursor of hypertension, diabetes, and CKD. Faculty-specific health promotion programs could address discipline-related risk factors (e.g., sedentary behavior in Environmental Sciences). Early lifestyle interventions in young adults may help prevent the progression from high BMI to CKD later in life.

When BMI was stratified into categories (Table 4.4), sodium showed a significant difference ($p = 0.0302$) across BMI groups. Underweight individuals had the highest sodium levels, whereas obese individuals had the lowest. This suggests a possible influence

of body composition on sodium balance and regulation. However, potassium, bicarbonate, chloride, urea, creatinine, and eGFR did not differ significantly across BMI groups.

These finding highlights that in apparently healthy young adults, BMI does not exert a strong influence on renal indices. Yet, the significant sodium variation may serve as an early indicator of subtle alterations in renal handling of electrolytes associated with body composition. If sustained, such alterations could predispose individuals to future renal and cardiovascular risks.

The predominance of normal BMI and relatively low prevalence of obesity in this study aligns with findings from other Nigerian universities (Wachukwu *et al.,* 2015; Uzomba *et al.,* 2019). However, the association of underweight with medical students and younger age groups adds new insight into subgroup vulnerabilities.

The lack of significant correlation between BMI and renal indices contrasts with reports in clinical populations, where obesity is a strong predictor of CKD progression (Kovesdy, 2017). This emphasizes the importance of age and health status as modifiers of the BMI–renal function relationship

5.2 Conclusion

In conclusion, undergraduate students of the University of Benin largely displayed normal BMI and preserved renal function. Underweight was common among younger students and medical students, while obesity appeared in small numbers in Environmental Sciences. Sodium levels differed significantly by BMI category, suggesting early signs of BMI-related metabolic influence. While no significant correlations were found between BMI

and renal indices, evidence from Nigerian and global studies underscores that obesity in young adulthood, if unchecked, can lead to chronic kidney disease in later years.

5.3 Contribution to Knowledge

The results suggest that while most participants were within normal BMI and biochemical ranges, subtle deviations highlight the sensitivity of renal markers to anthropometric and dietary influences. Elevated urea levels, in particular, may signal dietary excesses or early renal stress, even in apparently healthy individuals. The consistent correlations observed reinforce established physiological pathways linking electrolytes, acid-base balance, and renal clearance. From a public health perspective, the findings emphasize the need for routine biochemical monitoring in young adults, particularly university populations where dietary habits and lifestyle factors may predispose to long-term renal or metabolic disturbances. Preventive measures, including nutritional education and hydration awareness, could mitigate risks.

5.4 Limitations

1. Sample Size and Scope: The study was limited to undergraduate students from a single institution, which may not adequately represent the broader population.
2. Cross-sectional Design: The cross-sectional nature of the study restricts the ability to establish causality or monitor changes in BMI and liver function over time.
3. Unmeasured Variables: Key factors such as dietary habits, physical activity levels, alcohol consumption, and genetic predispositions were not accounted for, which may have influenced liver function outcomes.

4. Regional Variations: Differences in lifestyle and environmental factors between regions could limit the generalizability of the findings to other populations.

5.5 Recommendations

1. Longitudinal Research: Future studies should adopt longitudinal designs with greater sample size to explore the dynamic relationship between BMI and renal function over time and investigate causal pathways.
2. Broader Analysis: Expanding research to include diverse populations and incorporating lifestyle and genetic factors would provide a more comprehensive understanding of the determinants of renal health.
3. Health Education Programs: Academic institutions should implement health education initiatives focusing on the importance of maintaining a healthy weight, balanced nutrition, and regular physical activity.
4. Routine Screening: Periodic BMI and renal function assessments should be conducted for early detection of potential health risks among students.
5. Policy Interventions: Universities should develop supportive environments that encourage healthy eating and active lifestyles, including access to nutritious food options and recreational facilities.

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