

**AN ASSESSMENT OF MALNUTRITION ON DIALYSIS ADEQUACY
OF PERITONEAL DIALYSIS PATIENTS AT PUBLIC NEPHROLOGY
FACILITY IN THE GAUTENG PROVINCE**

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DECLARATION OF INDEPENDENT WORK

I, Nelly Lerato Setjie, Identity Number _____ and Student Number _____, do hereby declare that this research project submitted to the Central University of Technology, Free State for the Master of Health Science (Clinical Technology), is my independent work, and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State, and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any qualification. I further declare that all sources cited or quoted are indicated and acknowledged using a comprehensive list of references.

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01/02/2026

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DEDICATION

I dedicate this work to:

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ABSTRACT

Background: The physiological changes and metabolic disturbances in PD patients often lead to malnutrition, further complicating dialysis adequacy and affecting patient outcomes and quality of life. The current study aimed on the assessment of nutritional status on dialysis adequacy in PD patients, while also determining the correlation between dialysis malnutrition, dialysis adequacy and biochemical markers in PD patients. The outcome of examining this relationship contributes to clinical practice and improved outcomes for PD patients in resource-limited settings.

Methods: The study included 81 patients (50 males and 31 females) undergoing peritoneal dialysis for more than three months at selected two public nephrology units in Gauteng, South Africa. The nutritional status of peritoneal dialysis patients was assessed using the Dialysis Malnutrition Score (DMS), anthropometry, dialysis adequacy (Kt/V), and biochemical indicators (serum albumin, serum urea, and serum creatinine).

Results: Our findings, based on the Dialysis Malnutrition Score questionnaire, showed a large proportion of malnutrition scores: 34.57% severe, 32.10% moderate, and 14.81% mild. However, there were no correlation between dialysis adequacy and malnourishment status; this was not statistically significant, $p=0.9714$. Adequate dialysis (≥ 1.4 Kt/V) was achieved by 61.73% of patients, who were significantly younger than those who did not reach the target Kt/V of 1.4. The mean Body Mass Index was 25.56 kg/m², with 17.28% classified as obese and 2.47% as underweight, alongside notable variability in triceps skinfold thickness (median 23 mm; IQR: 18–31 mm). There was a significant correlation between dialysis adequacy and triceps skinfold ($p=0.0006$). The arm muscle area of our patients was also statistically significant ($p<0.001$), according to the Shapiro-Wilk test for normality. The median serum albumin was 34 g/L, with hypoalbuminemia common among the severely malnourished group. There was a significant correlation between dialysis adequacy and serum albumin ($p=0.0057$). There was no significant correlation between dialysis adequacy and Serum urea and creatinine levels.

Conclusion: Our study has shown a relatively severe and moderate malnutrition among our sample population. This suggests that metrics reflecting lean body mass and somatic protein stores are strong predictors of a patient's ability to achieve adequate PD. With this, there still remained a large group of our patients receiving adequate dialysis. Subsequently, our findings showed a significantly smaller group remained to achieve inadequate dialysis. This was related to various other reasons, such as age, anthropometrics and decreased albumin levels. The high prevalence of malnutrition, coupled with the predictive power of anthropometrics, mandates further clinical efforts to focus on improving body composition and nutritional status as an integral strategy for optimising dialysis clearance and overall patient outcomes in Gauteng PD facilities.

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LIST OF ABBREVIATIONS

AMA	Arm Muscle Area
APD	Automated Peritoneal Dialysis
BMI	Body Mass Index
BMI	Body Mass Index
BUN	Blood Urea Nitrogen
CAPD	Continuous Ambulatory Peritoneal Dialysis
CKD	Chronic Kidney Disease – Stage 1–5
CKD-MBD	Chronic Kidney Disease-Mineral and Bone Disorders
Cm	Centimetre
CRP	C-reactive protein
CV	Cardiovascular
CVD	Cardiovascular Disease
DMS	Dialysis Malnutrition Score
DPI	Dietary Protein Intake
ESAs	Erythropoiesis-Stimulating Agents
ESKD	End-Stage Kidney Disease
g/L	Grams Per Litre
GCP	Good Clinical Practice
GFR	Glomerular Filtration Rate
GH	Growth Hormone
GH	Growth Hormone
HCO ₃	Bicarbonate
HGS	Handgrip Strength
HSREC	Health Science Research Ethics Committee
IDPN	Intradialytic Parenteral Nutrition
IGF-1	Insulin Growth Factor 1

IL-6	Interleukin-6
IMA	Inflammation-Malnutrition-Atherosclerosis
ISPD	International Society of Peritoneal Dialysis
KDOQI	Kidney Dialysis Outcomes Quality Initiative
Kg	Kilogram
Kt/V	Clearance x time / Volume
mg/L	Milligram per litre
MIS	Malnutrition Inflammation Score
MUAC	Mid Upper Arm Circumference
NHL	National Health Laboratory
PD	Peritoneal Dialysis
PEM	Protein Energy Malnutrition
PEW	Protein Energy Wasting
PMD	Peritoneal Membrane Dysfunction
QoL	Quality of Life
RRT	Renal Replacement Therapy
SAMAREC	South African Medical Association Research Ethics Committee
SARS	South African Renal Society
SBAH	Steve Biko Academic Hospital
SGA	Subjective Global Assessment
TSF	Triceps Skin Fold
UFF	Ultrafiltration Failure
URR	Urea Reduction Ratio
WHO	World Health Organisation

CHAPTER 1: INTRODUCTION

1.1 Background

Chronic kidney disease (CKD) is one of the critical global health issues, and millions of people are affected by this disease (Xing et al., 2024). Patients with CKD often progress towards end-stage kidney disease (ESKD), requiring renal replacement therapy (RRT) (Levey et al., 2007). Approximately 272 000 people worldwide are estimated to be on peritoneal dialysis (PD), representing only about 11% of all patients on RRT (Li et al., 2017; Jain et al., 2012; Thurlow et al., 2021). In South Africa, PD is a significant renal replacement therapy modality, accounting for 26% of the patients in the public sector. The "PD-first" approach is most often embraced in the public sector as it offers a potential solution to increase access to RRT in resource-limited settings (Adeniyi et al., 2020). Peritoneal Dialysis is not only an effective treatment, but also an advantageous one, as it helps to preserve residual renal function longer than haemodialysis (Li et al., 2023). This is a crucial benefit, as it may lead to better patient outcomes and quality of life (Yang et al., 2022). Despite the potential advantages of PD in expanding access to RRT in South Africa's public sector, a multi-faceted approach addressing socioeconomic challenges, healthcare infrastructure and patient-related factors is essential for its successful implementation as a primary treatment modality (Moosa et al., 2012).

Peritoneal dialysis offers unique nutritional considerations and benefits for dialysis patients, as it has fewer strict dietary restrictions and can potentially improve patients' quality of life and adherence to dietary guidance (Qin et al., 2022). Peritoneal dialysis can lead to protein and amino acid losses into the dialysate, necessitating a higher protein intake to maintain adequate nutritional status (KDOQI Guidelines, 2020).

The physiological changes and metabolic disturbances in PD patients often lead to malnutrition, further complicating dialysis adequacy and affecting patient outcomes and quality of life (Tian et al., 2017). Dialysis adequacy refers to the effectiveness of a dialysis treatment in removing waste products and excess fluid from a patient's body to maintain physiological balance (Wang et al., 2021b).

Several potential factors, such as uraemia-induced anorexia, protein losses in dialysate, chronic inflammation, metabolic acidosis, and nutrient losses during dialysis contribute to the risk of malnutrition in PD patients (Carrero et al., 2018). It is associated with an increased risk of morbidity, mortality and decreased quality of life. (Mehrotra et al., 2021). Malnutrition can occur due to decreased energy intake associated with uremic syndrome and systemic chronic inflammation (Satirapoj et al., 2017). Malnutrition in patients with PD is a significant problem, affecting 20–50% of these individuals (Ikizler et al., 2020).

Malnutrition is a major concern in PD patients, as it contributes to muscle wasting, a common consequence of malnutrition in PD patients. This contributes to weakened immunity and increased susceptibility to infections such as peritonitis, which further deteriorates dialysis outcomes (Martín-del-Campo et al., 2023). Muscle wasting is particularly concerning, as it can lead to frailty, making it difficult for patients to perform daily activities and adhere to their treatment regimen (Wong et al., 2021). Infection risk is another major concern in malnourished PD patients, as the infection compromises the immune system due to poor nutrition. Peritonitis is a serious infection of the peritoneal membrane that can reduce dialysis adequacy further. Frequent infections not only worsen nutritional status, but also increase hospitalisation rates and healthcare costs (Wierdsma et al., 2021).

Early identification and management of malnutrition in PD patients are critical for improving clinical outcomes. The Dialysis Malnutrition Score (DMS) questionnaire is used as the key instrument to assess the nutritional status of the PD patients. This validated tool was designed for dialysis patients and integrates subjective global assessment (SGA) elements such as dietary intake and patient well-being to provide a comprehensive screening for malnutrition risk (Rambod et al., 2009). The DMS combines key indicators of nutritional status into a single score. The resulting score allows for the categorisation of patients into different nutritional risk levels (e.g. well nourished, mildly malnourished, severely malnourished), which facilitates clinical management (Mehrotra et al., 2011). These nutritional screening tools help healthcare providers to implement timely interventions in order to prevent further nutritional deterioration (Sallam et al., 2023).

Maintaining adequate dialysis delivery is clinically significant to improving the prognosis of patients undergoing PD treatment (Johnson, 2019). Inadequate dialysis can lead to the accumulation of uremic toxins, resulting in a range of complications, including cardiovascular disease (like atherosclerosis and vascular calcification), neurological issues (uremic encephalopathy, fatigue, confusion), immune dysfunction leading to increased infection risk, mineral and bone disorders, and generalised inflammation and a diminished quality of life (Blake et al., 2019). However, the presence of malnutrition complicates the management of patients on PD. It can influence dialysis adequacy by impairing the patient's ability to tolerate the treatment, leading to muscle loss, poor wound healing, and a decreased ability to maintain fluid and solute balance, which can necessitate more intense or frequent dialysis sessions (Chan et al., 2024).

Malnutrition exerts a negative impact on dialysis adequacy, whereas inadequate dialysis may further deteriorate malnutrition, creating a circle of effects (Brown et al., 2020). Malnourished PD patients often experience suboptimal dialysis adequacy due to impaired peritoneal membrane function, reduced ultrafiltration, and inadequate toxin clearance (Kiebalo et al., 2020a). This condition exacerbates the already fragile health status of patients, leading to higher hospitalisation rates and increased mortality (Chan et al., 2024). The International Society for Peritoneal Dialysis (ISPD, 2020) recommends a comprehensive approach to PD patient care, including many measures such as nutritional status and dialysis adequacy assessments (Brown et al., 2020). However, the specific interaction of malnutrition with adequacy in the South African context remains rarely investigated (Madiba et al., 2020).

Serum albumin also plays a significant role in assessing malnutrition in PD patients, as it is a major protein synthesised by the liver. It serves as a key indicator of visceral protein stores and is often reduced in malnourished patients (Mehrotra et al., 2011). Low albumin levels can arise not only from inadequate protein intake, but also due to protein losses across the peritoneal membrane during dialysis bag exchanges and inflammation (Rambod et al., 2009). A multidisciplinary approach is essential in managing malnutrition and dialysis adequacy among PD patients. Nephrologists, dietitians and nurses should work collaboratively to develop individualised nutritional care plans (Kim et al., 2021). This approach ensures that dietary plans consider patient

comorbidities, dialysis modalities, and socioeconomic constraints (Carrero et al., 2021b).

Policy interventions aimed at improving the nutritional status of PD patients should focus on increasing access to dietary counselling, providing financial support for renal-friendly foods, and integrating nutrition education into routine dialysis care (Mentxakatorre et al., 2024). Effective policies can help to reduce the burden of malnutrition and enhance the quality of life for PD patients (Massironi et al., 2023). Public nephrology facilities in Gauteng province face significant challenges in managing malnutrition among PD patients (Mokgokong et al., 2023). Limited resources, high patient load, and inadequate dietary counselling services contribute to the burden of malnutrition in these settings (Department of Health, 2021). Strengthening nutritional support services in public healthcare facilities is crucial for improving patient outcomes (Zanini et al., 2025).

Research on the relationship between nutritional status, in particular malnutrition, and dialysis adequacy in South Africa remains limited. However, research has indicated that malnourished PD patients have lower Kt/V values and reduced creatinine clearance, leading to suboptimal dialysis outcomes (Lin et al., 2025b). Most studies focus on developed countries with advanced healthcare infrastructure, leaving a gap in understanding how these factors interact in resource-limited settings (Nephrology Society of South Africa, 2022). Addressing this gap is essential for developing context-specific interventions that are feasible in public nephrology facilities (Almaslum et al., 2024). Thus, this study aimed to assess nutritional status on dialysis adequacy in PD patients at public nephrology facilities in Gauteng Province, South Africa. The outcome of examining this relationship could contribute to clinical practice and improved outcomes for PD patients in resource-limited settings.

1.2 Problem Statement

Despite advances in peritoneal dialysis (PD) therapy, malnutrition remains a persistent challenge for patients with chronic kidney disease (CKD), significantly increasing morbidity and mortality rates (Kumar, 2020). The complex relationship between malnutrition and dialysis adequacy in PD patients is a significant problem to investigate, particularly in resource-limited settings in public nephrology facilities in

South Africa (Shao et al., 2024). Malnutrition in PD patients is a multifactorial cause that arises from a multitude of factors, including reduced food intake, increased catabolism, dialysis-related nutrient losses, and inadequate dialysis (defined by urea clearance Kt/V), which can worsen nutritional status and have a negative impact on clinical outcomes (Sharma et al., 2019; Carrero et al., 2018).

Dialysis adequacy may be compromised by the patient's nutritional status. Adding another layer of complexity is the role of biochemical markers such as serum albumin, which serves as an indicator of nutritional status and predictors of patient outcomes. The biochemical markers can be influenced by both nutritional status and dialysis adequacy, making their interpretation challenging (Ikizler et al., 2020). A comprehensive understanding of the association between malnutrition and dialysis adequacy, as well as their correlation with biochemical markers, is essential to inform targeted interventions and improve patient care and outcomes for PD patients within the specific context of public healthcare in Gauteng province, South Africa (Vanholder et al., 2023; Satirapoj et al., 2017).

Therefore, the current study aimed to assess the nutritional status on dialysis adequacy in PD patients, while also determining the correlation between dialysis malnutrition, dialysis adequacy and biochemical markers in PD patients. By identifying the causes and consequences of malnutrition and dialysis adequacy, the study sought to inform evidence-based strategies for the assessment, prevention, clinical interventions and management of malnutrition in PD patients within the South African public healthcare context aimed at improving PD outcomes.

1.3 Aim of the Study

The aim was to assess malnutrition in dialysis adequacy of peritoneal dialysis patients at public nephrology facilities in Gauteng province.

1.4 Objectives of the Study

- To assess the nutritional status of PD patients by using the Dialysis Malnutrition Score (DMS) questionnaire and anthropometric assessment tools.

- To determine the dialysis adequacy in PD patients by using the Kt/v formula and Urea Reduction Ratio (URR).
- To determine the factors influencing dialysis adequacy in PD patients.
- To determine the correlation between dialysis malnutrition, dialysis adequacy, and biochemical markers in PD patients.

1.5 Hypothesis

1.5.1 Alternative Hypothesis

Nutritional status has an impact on dialysis adequacy in PD patients.

1.5.2 Null Hypothesis

Nutritional status doesn't have an impact on dialysis adequacy in PD patients.

1.6 Significance of the Study

The problem statement highlights the ongoing challenge of malnutrition in peritoneal dialysis patients despite advances in PD therapy (Kiebalo et al., 2020b). Malnutrition remains relatively common and has been reported in the literature to range from 18% to 56%, depending on the assessment method used (Dong, 2011). A notable example of this variability is shown in a 2021 study published in *Clinical Nutrition ESPEN*, which examined the nutritional status of geriatric patients in a rehabilitation hospital. Using the Mini Nutritional Assessment-Short Form (MNA-SF), 59.5% of patients were identified as being at risk of malnutrition or malnourished. However, when the Malnutrition Universal Screening Tool (MUST) was applied to a similar cohort in other studies, the rates tended to be lower. For example, a UK study found that MUST identified around 28% of hospital admissions as at medium or high risk (Gault et al., 2021).

This difference demonstrates how tools designed specifically for older adults, such as the MNA-SF, which considers age-related factors, can detect higher rates of malnutrition compared to more universal screening tools (Poulia, 2023). Coupled with

its significant impact on morbidity, mortality and quality of life, its high prevalence therefore underlines the urgency to address the management and interventions on malnutrition (Ma et al., 2018). Early detection and management of malnutrition are crucial for improving patient outcomes in the dialysis population. Visiedo (2022) advocates the establishment of standardised management guidelines that incorporate regular nutritional screening and intervention programs. This study contributes to the effort of examining the link between malnutrition and dialysis adequacy in the context of South Africa's public nephrology facilities, with findings relevant to scarce resources.

The research investigated the correlation among nutritional status, adequacy of dialysis, and related biochemical markers, hence helping to establish more effective and efficient strategies for the treatment and care of PD patients. The role of dialysis adequacy as quantified by Kt/V urea clearance is one of the primary factors of a patient's well-being in terms of reducing symptoms, decreasing treatment-related burdens, and improving overall quality of life (Costacurta et al., 2022; KDOQI Guidelines, 2020).

1.7 Scope of the Study

The study focused on peritoneal dialysis patients who were receiving treatment at Steve Biko Academic Hospital and Helen Joseph Hospital in Gauteng province, South Africa. It assessed nutritional status, dialysis adequacy, and associated clinical parameters for three months. Patients on haemodialysis and those with acute kidney injury requiring temporary dialysis were excluded from the study.

1.8 Organisation of the Study

The study is structured into eight chapters.

Chapter 1 introduces the study, outlining the background, problem statement, research objectives, and significance.

Chapter 2 presents a review of related literature on malnutrition, dialysis adequacy, nutritional assessment and biochemical markers.

Chapter 3 details the research methodology, including study design, population, and data collection techniques.

Chapter 4 illustrates the results of the study.

Chapter 5 discusses the findings and analysis of data.

Chapter 6 provides conclusions and recommendations.

Chapter 7 provides the references used in the study.

Chapter 8 includes all the appendices used and relevant to the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

End-stage kidney disease (ESKD) poses a significant global health burden, necessitating renal replacement therapy (RRT) for patient survival. Peritoneal dialysis (PD) is an increasingly utilised RRT modality, offering advantages such as home-based therapy, greater patient autonomy, and often lower infrastructure costs compared to haemodialysis (Mehrotra et al., 2011b; Van der Merwe et al., 2018). However, patients on PD are highly susceptible to malnutrition, specifically a condition termed Protein-Energy Wasting (PEW), which has a significant impact on their quality of life, morbidity and mortality (Fouque et al, 2008b). Crucially, PEW also has a reciprocal relationship with dialysis adequacy, a key determinant of clinical outcomes in PD patients (Saran et al., 2009).

Malnutrition is a significant and prevalent complication in patients undergoing peritoneal dialysis (PD), affecting 10–50% of the chronic kidney disease (CKD) population (Qaisar & Ashrafet al., 2020). It is also associated with increased hospitalisation rates, susceptibility to infections, and fatigue (Kalantar-Zadeh & Fougue, 2017). Prevalent concerns among peritoneal dialysis (PD) patients, significantly influencing dialysis adequacy and overall clinical outcomes, includes peritonitis, catheter-related complications, ultrafiltration failure, and protein loss (Shammas et al., 2023). This literature review aims to explore the multifaceted relationship between malnutrition and dialysis adequacy in PD patients, with a specific focus on the challenges and implications within the context of public nephrology facilities in Gauteng province, South Africa. It delves into theoretical models that explain malnutrition, methods for assessing nutritional status, the parameters of dialysis adequacy, and the complex interplay between these two critical aspects of care for PD patients.

2.2 End-Stage Kidney Disease (ESKD) and Renal Replacement Therapy (RRT)

End-Stage Kidney Disease (ESKD) signifies the most advanced stage of chronic kidney disease (CKD). This diagnosis is established when the kidney function deteriorates to a point where it is no longer sufficient for sustained survival without the intervention of RRT, which includes either kidney transplantation or dialysis (Goldman, 2020). Peritoneal dialysis (PD) is often considered the first-line therapy to maintain residual renal function, which is a key predictor of patient survival and quality of life (Wang et al., 2021a).

2.2.1 Global Burden of End-Stage Kidney Disease (ESKD) and Peritoneal Dialysis in South Africa

Globally, the incidence and prevalence of ESKD are rising, driven by increasing rates of non-communicable diseases such as hypertension, diabetes mellitus, and HIV-associated nephropathy (Webster et al., 2017). Chronic Kidney Disease is ranked by the World Health Organisation (WHO) as one of the top 10 causes of death worldwide (Carney, 2020). The International Society of Nephrology predicts that around 11 out of every 100 people will have chronic kidney disease (CKD) in South Africa (a figure reported to be based on 2017 estimates) (Kovesdy, 2022a). South Africa, like many low- and middle-income countries, faces a unique challenge in managing ESKD, compounded by a high burden of infectious diseases and socio-economic disparities (Naicker, 2013). Public healthcare facilities, particularly in provinces like Gauteng, are often overwhelmed by patient volumes and limited resources, having an impact on the provision of comprehensive RRT and supportive care services (Moosa, 2012).

2.2.2 Renal Replacement Therapy (RRT)

For patients with end-stage kidney disease (ESKD), renal replacement therapy is essential for survival. The primary modalities include peritoneal dialysis, haemodialysis and kidney transplantation, each offering a distinct approach to replacing lost kidney function (Wang et al., 2021a).

Peritoneal dialysis (PD) is a form of dialysis that utilises the patient's abdominal lining, the peritoneum, as a natural filter. A soft plastic tube called a catheter is surgically placed into the abdominal cavity. Through this catheter, a sterile cleansing fluid known as dialysate is infused and left to "dwell" for a prescribed period (Htay et al., 2021b). During this dwell time, waste products and excess fluid from the blood vessels in the peritoneum pass into the dialysate, which is then drained from the body and discarded. This process can be performed manually by the patient multiple times throughout the day, Continuous Ambulatory Peritoneal Dialysis (CAPD), or automatically at night by a machine called a cycler, Automated Peritoneal Dialysis (APD), offering patients greater flexibility compared to traditional in-centre haemodialysis (Bazaev et al., 2018). The fundamental principles governing this exchange are diffusion, osmosis and convection, driven by the instillation of a hyperosmolar glucose-based solution, known as dialysate, into the peritoneal cavity via a permanently implanted catheter (Worsey et al., 2019).

Haemodialysis (HD) is the most common form of dialysis. This process involves diverting the patient's blood out of the body and into an external machine with a special filter, known as a dialyser or "artificial kidney" (Wilcox et al., 2022). Inside the dialyser, waste products and excess fluid are removed from the blood before it is returned to the body. Patients typically undergo this therapy at a dialysis centre three times a week for sessions lasting three to five hours, although home haemodialysis options are becoming more common (Al-Hilal et al., 2023). A vascular access, such as an arteriovenous (AV) fistula or graft, is surgically created, usually in the arm, to handle the high rate of blood flow required for the treatment (Sanjeev et al., 2024).

Kidney transplantation is considered the optimal treatment for most patients with ESKD, as it can offer a better quality of life and improved survival, compared to long-term dialysis. This surgical procedure involves placing a healthy kidney from either a deceased or a living donor into the recipient's body (usually in the lower abdomen) without removing the patient's own failed kidneys, unless they are causing specific medical problems (Cho et al., 2020). Following a successful transplant, the new kidney assumes the functions of filtering waste and regulating fluid balance. To prevent the body's immune system from attacking the new organ (rejection), recipients must take immunosuppressant medications for the life of the transplant (Thurlow et al., 2021).

2.2.3. Peritoneal Dialysis (PD) in the South African Context

Peritoneal Dialysis (PD) stands as a vital home-based renal replacement therapy (RRT) for individuals with End-Stage Kidney Disease (ESKD) globally (Johnson et al., 2020). Saxena and Gajjala, on the topic of urgent-start peritoneal dialysis, implicitly support the role of PD as a crucial therapy that can be initiated and maintained in a home setting. The concept of urgent-start PD further solidifies its flexibility and importance as an accessible renal replacement therapy for a broad range of patients with ESKD (Saxena et al., 2024).

In the South African context, where the burden of non-communicable diseases, including chronic kidney disease (CKD), is significant and healthcare resources are often constrained, PD offers a unique set of advantages and challenges (Moosa et al., 2020). One of the primary benefits of PD in resource-limited settings like South Africa is its cost-effectiveness, particularly when compared to centre-based haemodialysis (HD) in the long term (Smith et al., 2018b). The infrastructure requirements for establishing and maintaining PD programmes are considerably less extensive than those for HD units, which demand significant capital investment in machinery, water treatment facilities, and dedicated clinical space (Naicker, 2013). This makes PD a more accessible option for expanding RRT services, especially within the public healthcare sector, which serves most of the population (Smith et al., 2018b).

Peritoneal Dialysis significantly improves patient autonomy and quality of life. As a home-based treatment, it enables patients to administer their therapy in familiar surroundings, allowing more flexibility in fitting it into their daily routines (Luyckx et al., 2016). This reduces the need for frequent and often strenuous travel to dialysis centres. A notable benefit in South Africa is that geographic disparities and inadequate public transport infrastructure can present considerable barriers to accessing care (Jones & Brown, 2019). The ability to maintain employment or continue with family responsibilities often increases, leading to better psychosocial outcomes for patients (Davids et al., 2017). Additionally, PD is linked to better preservation of residual renal function compared to HD, which can have a positive impact on fluid balance and solute clearance (Johnson & Davies, 2020).

Despite its many benefits, the adoption and widespread use of PD in South Africa face significant challenges (Nephrology Society of South Africa, 2022). Peritonitis, a serious infectious complication of PD, remains a major concern. The rate of peritonitis can be affected by patient compliance with strict hygiene protocols, the cleanliness of their home environment, and access to clean water, all of which can be difficult to manage effectively in the various socioeconomic contexts across South Africa (Davids et al., 2017). Therefore, adequate patient education and continuous support are essential to reduce this risk, demanding a strong and well-trained nursing workforce (Department of Health, 2016).

Logistical challenges also have an impact on the optimal utilisation of PD in South Africa. The consistent supply chain for PD fluids and equipment, particularly in remote and rural regions, can be precarious. Issues such as transportation costs, storage facilities, and timely delivery can lead to treatment interruptions, compromising patient health outcomes (South African Renal Society, 2021). The availability of adequately trained healthcare professionals, including nephrologists and specialist PD nurses, is concentrated in urban centres, creating a disparity in access to quality care for patients in underserved areas (Naicker, 2013).

The historical preference and higher prevalence of HD in South Africa, partly due to established infrastructure and training, have also posed a challenge for PD growth. Financial models and reimbursement policies within both the public and private sectors have not always equally incentivised the initiation and maintenance of PD (Smith, 2018a). Addressing this requires policy reform and increased advocacy from professional bodies to ensure equitable access and funding for PD.

South Africa accounts for nearly 85% of all PD patients in the African continent. The public sector also offers a proportionately higher usage of PD, since there are constrained resources, compared to the private sector (Davidson & Van den Hemel, 2017). Peritoneal dialysis is more common in public-sector units, where 57% of patients started RRT with PD, largely because of limited haemodialysis slots and accessibility issues for rural patients (Adeniyi et al., 2020; Davies & Baker, 2016).

Peritoneal Dialysis offers a highly valuable and often preferable renal replacement therapy option within the South African context. Its cost-effectiveness, home-based

nature and potential to improve patient quality of life make it an ideal solution for expanding access to ESKD care in a resource-constrained environment (Thsehla et al., 2025). However, widespread adoption necessitates addressing critical challenges related to infectious complications, logistical complexities, and the need for comprehensive patient support and professional training. Continued collaboration between government, healthcare providers, and professional bodies like the South African Renal Society is essential to overcome these hurdles and fully realise the potential of PD in transforming the lives of South African patients with ESKD (South African Renal Society, 2021).

2.2.4 Navigating Peritoneal Dialysis in Gauteng's Public Sector: A Tale of Challenges and Opportunities

End-stage kidney disease (ESKD) poses a significant global health burden, demanding costly and lifelong renal replacement therapies (RRT) such as haemodialysis (HD) and peritoneal dialysis (PD) (Saran et al., 2023). In South Africa, and particularly within Gauteng's public health sector, this challenge is exacerbated by a confluence of socioeconomic disparities, a high prevalence of non-communicable diseases and strained public healthcare infrastructure (Gauteng Department of Health, 2020). Peritoneal Dialysis (PD), a home-based renal replacement therapy, offers a promising, yet complex solution, potentially alleviating the immense pressure on public health facilities while offering patients greater autonomy (Jones & Brown, 2019). This study explored the multifaceted challenges and the inherent opportunities associated with the implementation and expansion of PD within Gauteng's public health system.

Peritoneal dialysis (PD) represents a critical, but complex component of renal replacement therapy within Gauteng's public nephrology facilities. As a home-based treatment, it offers patient autonomy and significant cost savings, compared to in-centre haemodialysis (Zulu et al., 2019). However, its effective implementation is hampered by a series of systemic challenges, even as significant opportunities for its expansion and improvement exist (Makhema et al., 2023).

2.2.4.1 Challenges in Accessibility and Management for Peritoneal Dialysis

Public nephrology units in Gauteng are expected to operate under immense pressure from a high burden of ESKD driven by rising rates of hypertension and diabetes. One of the foremost challenges is the stringent rationing of chronic dialysis due to severe resource constraints. Facilities have a limited number of funded slots, meaning many medically eligible patients cannot access life-saving therapy (Mokgokong et al., 2023). This scarcity places immense pressure on patient selection for PD programmes.

A significant barrier to PD accessibility is the socioeconomic conditions of many patients. Successful PD requires a suitable home environment with access to clean running water, electricity for automated PD (APD), and adequate, hygienic storage space for dialysis supplies (Mokgokong et al., 2023). In a province with numerous informal settlements and widespread housing insecurity, many potential candidates are excluded from the process. Although home visits by nursing staff are a key part of the assessment, safety concerns and logistical constraints often limit their feasibility, creating a gap in patient support and monitoring (Chothia et al., 2022).

Many patients accessing the public sector come from low socioeconomic backgrounds, residing in informal settlements or overcrowded housing with limited access to clean water and sanitation (Malinga & Ndlovu, 2021). Maintaining the sterile environment crucial for PD at home, particularly preventing peritonitis, becomes incredibly challenging under these conditions. Issues such as illiteracy, low health literacy, and poor understanding of complex medical instructions can hinder adherence to strict PD protocols, leading to complications and treatment failure (Ndlovu et al., 2020). Transport challenges to follow-up appointments and the psychological burden of managing a chronic illness at home without robust community support also contribute to non-adherence. The supply chain for PD consumables remains a critical vulnerability, with intermittent shortages affecting patient care and adherence (Nephrology Society of South Africa, 2022).

The public sector faces a critical shortage of trained healthcare professionals, particularly nephrologists and specialist dialysis nurses (Hassen et al., 2021). A national study highlighted that South Africa has an insufficient number of nephrologists, with a significant disparity between the well-resourced private sector

and the overburdened public sector (Moosa et al., 2021). Another study by Hassen et al. (2021) highlights that there were only 2.5 nephrologists per million population in South Africa at that time, which are significantly below the median of 10.8 per million for upper-middle-income countries (Hassen et al., 2021). This shortage is further exacerbated by a marked maldistribution, with most nephrologists concentrated in the private sector serving a small percentage of the population (Hassen et al., 2021). This shortage has a direct impacts on the quality of PD training for patients and caregivers, ongoing clinical management, and the timely handling of complications like peritonitis. High rates of peritonitis not only lead to patient morbidity, but also contribute to technique failure, forcing a costly and disruptive switch to haemodialysis (Mokgokong et al., 2023). Intermittent supply chain issues for PD fluids and consumables can disrupt treatment, posing a significant risk to patient health and undermining confidence in the modality (Makhema et al., 2023).

2.2.4.2 Opportunities for Growth and Improvement in Peritoneal Dialysis

Despite hurdles such as socioeconomic, infrastructural and patient-related factors, substantial opportunities exist to enhance PD accessibility and management in Gauteng. The most significant driver is the modality's cost-effectiveness. Recent South African research confirms that PD is a more affordable therapy than haemodialysis, with a 2025 analysis showing its total discounted cost per patient over five years to be substantially lower (Thsehla et al., 2025). This financial advantage makes a compelling case for a "PD-first" policy, where PD is promoted as the initial treatment of choice for all medically suitable ESKD patients. Successfully implementing this policy could allow public funds to be stretched further, potentially increasing the total number of patients receiving renal replacement therapy (Department of Health, 2021).

Promoting a "PD-first" or "PD-favoured" policy presents a key opportunity to standardise and broaden access. Studies from Johannesburg units have shown that with careful patient selection, comprehensive training and strong support, a PD-first programme can deliver safe and effective outcomes, even in a low socioeconomic setting with a high prevalence of comorbidities such as HIV (Mokgokong et al., 2023). This illustrates that concerns about poorer outcomes in certain patient groups can be addressed effectively through a well-managed programme. Peritoneal Dialysis can alleviate the immense financial strain placed on the public health system. Once

patients are trained and stable, PD reduces the need for costly in-centre HD chair time, transport to facilities, and the associated staffing expenses (Department of Health, 2021). This frees up HD slots for patients who are medically unsuitable for PD, or those requiring acute dialysis, thereby optimising resource allocation within a constrained budget (Thsehla et al., 2025).

Peritoneal Dialysis empowers patients with a greater degree of autonomy and improved quality of life. Being able to perform dialysis at home offers flexibility, allowing patients to integrate their treatment better into their daily lives, maintain employment, and participate in social activities (Zulu et al., 2019). This enhances patient dignity and reduces the psychological burden associated with frequent hospital visits. PD also typically leads to better preservation of residual renal function compared to HD, which can contribute to better patient outcomes and fewer complications in the long term (International Society for Peritoneal Dialysis, 2020).

Technological advancements, such as Automated Peritoneal Dialysis (APD) cyclers, present an opportunity to simplify the treatment process, making it less intimidating for patients and potentially improving adherence, especially for those with lower literacy levels or physical limitations (Nxumalo & Dlamini, 2022). While these cyclers represent an upfront cost, their long-term benefits in terms of ease of use and reduced patient burden could justify the investment (Makhema et al., 2023).

Capacity building through targeted training programs for healthcare professionals, nurses, doctors and community health workers can expand the pool of individuals competent in PD management and patient support, ultimately scaling up the program. Policy support, recognising PD as a cornerstone of renal replacement therapy, coupled with strategic partnerships with non-governmental organisations and private-sector suppliers, could streamline the supply chain and enhance patient support networks (Mkhize & Gumede, 2021).

The journey of navigating peritoneal dialysis in Gauteng's public sector is undeniably complex, characterised by significant systemic and patient-level challenges. While significant hurdles related to resources, infrastructure and patient factors persist, the intrinsic advantages of PD, its cost-effectiveness, patient-centric nature, and potential for preserving residual renal function present compelling opportunities (Johnson &

Davies, 2020). Realising the full potential of PD will necessitate a concerted, multi-pronged effort involving increased budgetary allocation, robust human resource development, tailored patient education strategies, innovation in supply chain management, and strong policy frameworks (Modiba & Ngidi, 2017). By strategically addressing these areas, Gauteng can transform PD from a challenging alternative into a cornerstone of sustainable renal care, improving patient outcomes and alleviating the immense pressure on its public health system (Van der Walt & Du Plessis, 2018).

There is an opportunity to leverage community-based healthcare models. By training and empowering community healthcare workers to assist with basic monitoring, supply management, and identifying early signs of complications, the strain on specialist nurses could be alleviated (Jones & Brown, 2019). This would strengthen the support network for patients, improve adherence, and potentially reduce complication rates. Investing in patient education and empowerment is also crucial; well-informed patients are better equipped to manage their care, leading to improved outcomes and greater technique survival (Chothia et al., 2022).

By strategically addressing its inherent challenges while capitalising on its cost-effectiveness and patient-centred benefits, peritoneal dialysis can play a much larger and more sustainable role in meeting the growing demand for ESKD care in Gauteng's public health system.

2.2.5. Global Perspective of Peritoneal Dialysis

Globally, PD is recognised for its operational simplicity and cost-effectiveness. Peritoneal Dialysis offers a valuable therapeutic option for individuals with ESKD; its long-term implementation has been associated with various pathophysiological changes that can lead to adverse health consequences (Li et al., 2017). The worldwide prevalence of ESKD is rising, but the use of PD remains surprisingly low in many parts of the world. Globally, only about 11% of dialysis patients use PD, with the majority concentrated in a handful of countries like China, the USA, Mexico and Thailand (Li et al., 2020b).

This distribution is far from uniform. High-income countries in North America and Europe have seen modest growth in PD utilisation, often supported by "PD-first" or

"home-dialysis-first" initiatives aimed at improving cost-effectiveness and patient choice (Mehrotra, 2020; Himmelfarb et al., 2024). For instance, the United States has actively promoted home dialysis through policy changes, leading to a gradual increase in its uptake (Fotheringham & Mehrotra et al., 2023; USRDS, 2023).

In contrast, low- and middle-income countries (LMICs) face formidable barriers. A comprehensive global survey revealed that PD is available in only 28% of low-income countries, compared to nearly 100% of high-income countries (Bello et al., 2023). In many parts of sub-Saharan Africa and Southeast Asia, a "catastrophic expenditure" on dialysis is common, where patients and families bear the brunt of the cost (Htay et al., 2021a). Systemic issues such as a lack of trained nephrology teams, inconsistent supply chains for PD fluids, inadequate government funding, and a reimbursement structure that often favours in-centre haemodialysis are significant deterrents (Cho & Johnson, 2020). This creates a critical equity gap, leaving viable treatment out of reach for millions.

2.3 Malnutrition in End-Stage Kidney Disease and Peritoneal Dialysis Patients

Malnutrition in PD patients is a highly prevalent and complex issue, with estimates suggesting that up to 75% of dialysis patients experience some degree of nutritional compromise (Kalantar-Zadeh & Fougue, 2017). The term "Protein-Energy Wasting" (PEW) has been adopted to specifically describe the multifactorial syndrome of metabolic and nutritional derangements characteristic of PD patients (Ikizler & Kalantar-Zadeh, 2020). Malnutrition is characterised by a significant loss of body protein and energy stores, encompassing both protein and energy malnutrition. The prevalence of malnutrition is notably elevated in the advanced stages of CKD, specifically stages 4 and 5 (Kalantar-Zadeh & Fouque, 2020).

Patients undergoing peritoneal dialysis (PD) exhibit a significantly higher incidence of malnutrition compared to their counterparts receiving haemodialysis. This heightened susceptibility to malnutrition in the PD population can be attributed to a unique set of challenges inherent to this dialysis modality. These challenges include the loss of protein through the peritoneal effluent, metabolic disturbances stemming from chronic

inflammation, and the presence of gastrointestinal dysfunction (Hanna, 2020; NKF, 2023).

Malnutrition is a common and prevalent complication in PD patients, affecting up to 50% of the PD population (Kumar, 2020). In South Africa, where PD is an increasingly important treatment modality for ESKD, understanding the factors contributing to malnutrition is important to improve patients' outcomes and develop effective strategies to assess, prevent and manage malnutrition in this population (Sharma & Mehrotra, 2019).

2.3.1 Malnutrition in Peritoneal Dialysis (PD) Patients

Malnutrition, often termed protein-energy wasting (PEW), is a prevalent and serious complication in patients undergoing Peritoneal Dialysis (PD). It is a multifactorial syndrome characterised by a reduction in body protein and energy stores, leading to muscle wasting, reduced physical function, and poor overall health status (Gityamwi, 2020). Understanding its definition and specific terminology within this population is crucial for effective diagnosis and management (Mahan & Raymond, 2017).

Malnutrition refers to an imbalance in a person's intake of energy, protein, and other nutrients that leads to adverse effects on body composition, function and clinical outcomes (Mahan & Raymond, 2017). In the context of chronic kidney disease (CKD) and End-Stage Kidney Disease (ESKD) patients, including those on PD, this definition is often refined and specified by terms due to the unique pathophysiological mechanisms involved. The development of malnutrition in PD patients is multifactorial and complex, involving an interplay of various physiological and dialysis-related factors (Tian et al., 2017). Malnutrition is a prevalent comorbidity among peritoneal dialysis patients and has been found to cause malnutrition that affects a significant proportion of this population (Kittiskulnam et al., 2021).

The high prevalence of malnutrition in PD patients is attributed to multiple factors, including protein losses through the peritoneal membrane, chronic inflammation, and dietary restrictions (Kunin & Beckerman, 2022). The peritoneal membrane acts as a semipermeable barrier through which waste products and excess fluids are removed, but it also allows for the unintended loss of essential proteins, such as albumin and

amino acids (Tjong et al., 2023). Over time, this protein loss can contribute to a negative nitrogen balance, accelerating muscle breakdown and exacerbating malnutrition (Chan et al., 2024).

The causes of malnutrition in PD patients can lead to health consequences such as increased infection risk, because malnutrition compromises immune function, making patients more susceptible to infections, increased mortality risks, hospitalisation and morbidity, decreased quality of life, impaired wound healing, cardiovascular diseases, muscle weakness and frailty and cognitive impairment (Paniagua et al., 2023).

2.3.2 Prevalence and Aetiology of Malnutrition in Peritoneal Dialysis (PD) Patients

Malnutrition is a harmful condition in patients undergoing peritoneal dialysis (PD). It is a complex process driven by a confluence of interrelated factors that lead to a net loss of body protein and energy stores (Bello et al., 2022). Understanding the mechanisms is crucial for effective intervention, as well as the various factors that influence its progression and severity (Gusev et al., 2021). The aetiology of malnutrition in PD patients is multifactorial and includes:

2.3.2.1 Dialysis-Related Nutrient Losses

A primary and direct contributor to malnutrition in PD is the continuous loss of essential nutrients into the dialysate fluid. Protein and Amino Acid Loss during each PD exchange, significant amounts of protein (typically 5–15 grams per day) and amino acids (6–12 grams per day) are lost into the peritoneal fluid (Karupaiah et al., 2023a). This constant drainage creates a negative nitrogen balance, which causes the body to lose more protein than it takes in, leading to the breakdown of endogenous proteins, particularly muscle, to compensate. This can result in hypoalbuminemia (low albumin levels), a strong indicator of malnutrition and increased mortality risk (Mehrotra et al., 2016).

2.3.2.2 Decreased Nutrient Intake (Anorexia)

Anorexia, or loss of appetite, is highly prevalent in PD patients and significantly reduces the oral intake of protein and energy. Factors that contribute to anorexia

include the accumulation of uremic toxins in the blood, despite dialysis, which can directly suppress appetite and alter taste perception, making food less appealing (Carrero et al., 2018; Beto et al., 2022). Nutritional status and decreased nutrient intake in peritoneal dialysis patients are assessed using comprehensive tools like the Subjective Global Assessment (SGA), which considers clinical history, physical examination and appetite. It is preferred, because it is not significantly affected by fluid shifts, which are common in dialysis patients (Paniagua et al., 2023).

Chronic inflammation releases pro-inflammatory cytokines (e.g. TNF- α , IL-6) that have anorexigenic effects, leading to reduced food intake and increased resting energy expenditure (Ebert et al., 2021; Massironi et al., 2023). Gastrointestinal symptoms such as nausea, vomiting, abdominal fullness (due to dialysate volume) and constipation are other factors and can reduce appetite and food intake further (Ikizler et al., 2020).

Psychological Factors such as depression, anxiety, and the psychological burden of chronic illness and dialysis also contribute to anorexia (Ejiohuo et al., 2024; Mehrotra, 2020). Mental-health disorders are prevalent among PD patients and are often associated with decreased appetite and neglect of dietary recommendations (Paniagua et al., 2023). Addressing the psychological well-being of PD patients is therefore essential in mitigating the effects of malnutrition (Ejiohuo et al., 2024).

2.3.2.3 Metabolic Disturbances and Increased Catabolism

Peritoneal dialysis patients experience various metabolic derangements that promote protein breakdown and hinder protein synthesis. The kidneys' inability to excrete acid adequately leads to chronic metabolic acidosis, which is prevalent in PD. Metabolic acidosis directly stimulates protein catabolism, primarily through activation of the ubiquitin-proteasome pathway, leading to muscle wasting (Kovesdy, 2022b).

Systemic inflammation directly promotes a hypercatabolic state. Cytokines like TNF- α and IL-6 can activate muscle protein degradation pathways and inhibit protein synthesis, further exacerbating muscle loss. Inflammation also contributes to insulin resistance, hindering nutrient utilisation and promoting catabolism (Akchurin & Kaskel et al., 2015). Uraemia and inflammation often lead to insulin resistance, even in non-diabetic PD patients. This impairs the body's ability to utilise glucose and amino acids

effectively, contributing to protein breakdown and reduced anabolism (Mehrotra et al., 2016).

Various hormonal imbalances are observed in CKD and PD, contributing to the catabolic state. These include resistance to anabolic hormones like growth hormone (GH) and insulin-like growth factor-1 (IGF-1), as well as elevated levels of catabolic hormones like glucocorticoids. These imbalances impair muscle protein synthesis and promote degradation (Kovesdy, 2022b).

2.3.2.4 Peritoneal Glucose Absorption

Glucose in dialysate provides some calories; its absorption can contribute to a specific form of malnutrition. A significant amount of glucose is absorbed from the dialysate (up to 400–800 kcal/day or more), which can contribute to weight gain, but often in the form of fat mass rather than lean body mass (Konings, 2020). This can mask underlying muscle wasting, leading to a state of "sarcopenic obesity", where patients appear overweight, but are protein-malnourished, with reduced muscle mass (Bello et al., 2022). The absorbed glucose can also lead to a feeling of fullness, potentially suppressing oral food intake (Karupaiah et al., 2023b).

2.3.2.5 Inadequate Dialysis Adequacy

When dialysis is inadequate, the persistent accumulation of uremic toxins contributes to anorexia, inflammation and metabolic disturbances, creating a vicious cycle of worsening malnutrition (Johansson et al., 2017). The persistent presence of uremic toxins directly affects appetite. These toxins can interfere with the brain's appetite-regulating centres and cause gastrointestinal symptoms like nausea and a metallic taste in the mouth, leading to a reduced desire to eat (Johansson et al., 2017). A study by Ikizler et al. (2018) highlights that uremic toxins, such as indoxyl sulphate and p-cresyl sulphate, are key contributors to the anorexia observed in ESKD patients. This decreased food intake results in lower protein and calorie consumption, which is the initial step in the cycle of malnutrition (Ikizler et al., 2018).

Inadequate dialysis fails to remove pro-inflammatory cytokines, like interleukin-6 (IL-6) and tumour-necrosis factor-alpha (TNF- α), which are elevated in ESKD patients. The chronic presence of these inflammatory markers, a condition often termed "uremic

inflammation", contributes to a catabolic state, where the body breaks down muscle and other tissues for energy. This is further exacerbated by the uremic toxins themselves, which can activate inflammatory pathways (Osunbor et al., 2023). A review by Kalantar-Zadeh and Fouque (2017) emphasises that this chronic inflammation is a central driver of malnutrition, a severe form of malnutrition common in dialysis patients (Kalantar-Zadeh & Fouque, 2017).

Uremic toxins and inflammation together disrupt normal metabolism. They cause insulin resistance, meaning cells do not respond effectively to insulin, which impairs glucose and protein utilisation. This metabolic dysfunction, along with the catabolic effects of inflammation, leads to a breakdown of muscle proteins, known as muscle wasting or sarcopenia (Ruperez et al, 2022). According to literature by Kovesdy et al. (2018), this metabolic derangement is a key factor in the loss of muscle mass and physical function in ESKD patients. The body's energy balance is further disrupted, exacerbating the state of malnutrition.

The malnutrition resulting from this combination of anorexia, inflammation and metabolic disturbances further weakens the patient, making him more susceptible to infections and other complications. This, in turn, can intensify the inflammatory response, creating a feedback loop that accelerates the decline in nutritional status. The cycle becomes a critical barrier to patient well-being, increasing morbidity and mortality rates (Ruperez et al., 2022).

2.3.2.6 Comorbidities and Other Factors

Existing comorbidities common in PD patients, such as diabetes, cardiovascular disease and infections, can intensify the catabolic state and increase nutrient requirements, aggravating malnutrition (Beto et al., 2022). Avesani et al. (2020), highlight the multifactorial causes of malnutrition in CKD patients. It explicitly links chronic inflammation from comorbidities like cardiovascular disease and infections to a hypercatabolic state, which increases energy and protein requirements and aggravates malnutrition (Avesani et al., 2020). Age-related changes in metabolism, hormonal imbalances, and decreased physical activity contribute to muscle wasting, making it even more critical to ensure adequate protein and energy intake in elderly PD patients (Volkert et al., 2015).

Malnutrition in PD patients is a dynamic and complex process driven by a combination of dialysis-induced nutrient losses, reduced nutrient intake due to anorexia and gastrointestinal issues, and systemic metabolic derangements characterised by inflammation, metabolic acidosis, insulin resistance and hormonal imbalances (Ruperez et al., 2022). The absorption of glucose from dialysate further complicates the picture by promoting fat accumulation, while muscle mass may decline. These interconnected factors lead to a state of protein-energy wasting, having a negative impact on patient outcomes (Huang et al., 2023).

2.3.3 Consequences of Malnutrition and Clinical Outcomes in Peritoneal Dialysis (PD) Patients

Malnutrition is a significant concern in individuals undergoing peritoneal dialysis and is associated with a range of adverse outcomes (Kalantar-Zadeh et al., 2019). It is often multifactorial, stemming from a combination of dialysis-related factors, underlying comorbidities, and patient-specific issues (Johansson, 2017). Malnutrition can have serious risk factors and outcomes that can lead to increased mortality risks, hospitalisation, and decreased quality of life (Kovesdy et al., 2020). Malnutrition is also linked with increased infection risks, cardiovascular problems, muscle weakness and frailty (Kalantar-Zadeh et al., 2019). These effects not only affect the personal well-being of PD patients, but also have a significant burden on the healthcare system, due to higher medical costs and utilisation (Johansson, 2017).

A multitude of risk factors, ranging from inadequate intake to increased losses and metabolic disturbances, contribute to the development of malnutrition in PD patients. Recognising these risk factors and implementing proactive nutritional assessment and management strategies are crucial for improving the well-being and survival of individuals on peritoneal dialysis (Smith et al., 2018; Jones & Brown, 2019). Malnutrition has a profound and detrimental impact on patients undergoing peritoneal dialysis (PD). Its effects extend across various aspects of patient health, leading to increased morbidity, reduced quality of life and, ultimately, higher mortality rates (Ma et al., 2018; Huang et al., 2023).

2.3.3.1 Increased Mortality

Malnutrition is one of the strongest independent predictors of mortality in PD patients. Patients with a poorer nutritional status have a significantly higher risk of death. This is often linked to the exacerbation of other conditions and the body's diminished ability to withstand stressors (Lee et al., 2016). A systematic review and meta-analysis by Zhang et al. (2021) specifically investigated the risk factors for mortality in PD patients. The authors found that malnutrition is a significant predictor of mortality, even after accounting for other factors. This type of analysis provides a strong, evidence-based conclusion on the predictive power of malnutrition in PD patients (Zhang et al., 2021).

2.3.3.2 Higher Morbidity and Hospitalisation Rates

Malnourished PD patients experience an increased incidence of various complications, leading to more frequent and prolonged hospital stays (Chen et al., 2019). These complications include the following:

- Infections occur in patients with PD, where malnutrition compromises their immune system.
- Patients become more susceptible to infections such as peritonitis (an infection of the peritoneal membrane), which is a common and serious complication in PD.
- Recurrent infections further worsen nutritional status, creating a vicious cycle (Tian et al., 2017).
- Cardiovascular Disease (CVD) is multifactorial in PD patients; malnutrition is a significant contributor.
- It is linked to inflammation, oxidative stress, and dyslipidaemia, all of which accelerate atherosclerosis and increase the risk of heart disease, the leading cause of death in dialysis patients (Kovesdy, 2022b).
- Delayed Wound Healing caused by inadequate protein and energy stores impairs the body's ability to repair tissues, which can complicate surgical procedures (e.g. catheter insertion) and lead to chronic skin breakdown (Tian et al., 2017).

2.3.3.3 Reduced Quality of Life (QoL)

Loss of muscle mass and energy reserves due to malnutrition leads to profound fatigue, weakness and reduced physical functioning. This limits the patient's ability to perform daily activities, engage in social interactions, and maintain independence (Wang et al., 2024c). The physical limitations, chronic symptoms, and overall poor health associated with malnutrition can contribute to psychological distress, including depression and anxiety, further diminishing QoL (Sarikaya et al., 2025). Poor appetite and taste changes cause anorexia and altered taste perceptions make eating a challenge rather than a pleasure, affecting the enjoyment of food and potentially isolating patients socially (Wang et al., 2024c).

2.3.3.4 Impaired Functional Status

The loss of lean body mass, especially muscle, directly affects functional ability. This patient experiences weakness and muscle atrophy, making it difficult to carry out everyday activities, walk and stay balanced, which increases the risk of falls (Wright, 2019). The lack of energy and muscle weakness results in a more sedentary lifestyle, which can worsen muscle loss and lead to other health problems. Malnutrition is a key part of frailty syndrome, characterised by reduced physiological reserve and greater susceptibility to adverse health outcomes (Johansson, 2017).

2.3.3.5 Poor Response to Treatment and Increased Healthcare Burden

Malnourished patients often have a poorer response to ESAs (Erythropoiesis-Stimulating Agents) used to treat anaemia, requiring higher doses or alternative treatments (Babitt et al., 2012). The higher rates of hospitalisation, infections and need for more intensive medical interventions due to malnutrition contribute to a significant increase in healthcare costs (Chen et al., 2019).

2.3.3.6 Worsening Fluid and Electrolyte Imbalances

Severe malnutrition can indirectly worsen fluid and electrolyte imbalances due to impaired regulation and reduced compensatory mechanisms in a weakened state (Karupaiah et al., 2023b). Malnutrition often leads to hypoalbuminemia (low-serum albumin levels) due to reduced protein synthesis. Albumin is crucial for maintaining

plasma oncotic pressure. When albumin levels drop, this pressure decreases, causing fluid to shift from the bloodstream into the interstitial spaces, leading to peripheral oedema (Karupaiah et al., 2023b). This fluid shift makes it harder to manage fluid volume, potentially leading to volume overload and aggravating hypertension and heart failure.

2.3.3.7 Increased Healthcare Costs and Resource Utilisation

The higher rates of hospitalisation, readmissions, infections, and need for more intensive medical care in malnourished PD patients translate into a substantial economic burden on healthcare systems (Luyckx et al., 2016). Treating the complications of malnutrition often requires significant resources, including prolonged hospital stays, medications and specialised interventions.

Malnutrition in PD patients creates a vicious cycle of illness, exacerbating existing complications, compromising the body's ability to recover, and ultimately leading to a poorer prognosis (Smith et al., 2018). Its pervasive impact on mortality, morbidity, quality of life and functional status underscores the urgent need for comprehensive nutritional assessment and aggressive intervention in PD patients (Huang et al., 2023; Zhang et al., 2021; Ruperez et al., 2022). Therefore, addressing malnutrition is a cornerstone of comprehensive care for individuals on peritoneal dialysis.

2.3.4 Intervention and Management of Malnutrition in Peritoneal Dialysis (PD) Patients

Several strategies have been proposed to address malnutrition in PD patients, including dietary modifications, nutritional supplementation, and pharmacological interventions (Mentxakatorre et al., 2024). Dietary counselling and individualised nutritional plans are critical in ensuring that PD patients receive adequate protein and caloric intake while adhering to dietary restrictions (Karupaiah et al., 2023a).

Nutritional supplementation through oral protein supplements, amino acid-based formulations, and intradialytic parenteral nutrition (IDPN) has been explored to improve nutritional status in malnourished PD patients. However, adherence to

supplementation remains a challenge due to gastrointestinal discomfort and financial constraints (Costacurta et al., 2022).

Pharmacological interventions, such as appetite stimulants and anti-inflammatory agents, have also been investigated as potential strategies to mitigate malnutrition in PD patients (Hanna, 2020). However, further research is needed to determine their long-term efficacy and safety. Strengthening collaboration between nephrologists, dietitians and other healthcare professionals is essential for improving nutritional outcomes in PD patients (Kumar, 2020).

Managing malnutrition in PD patients requires a multidisciplinary approach focusing on optimising dialysis, addressing underlying causes, and providing nutritional support. Ensuring adequate clearance of uremic toxins is fundamental to improving appetite and reducing the catabolic state (Bazaev et al., 2018).

Peritoneal Dialysis patients require a higher protein intake than healthy individuals due to dialysate losses. Recommendations often suggest 1.2–1.3 g/kg of protein per day. High-quality protein sources like lean meats, poultry, fish, eggs and small amounts of dairy are encouraged (Ikizler et al., 2020; Dong, 2011). Energy requirements are typically 30–35 kcal/kg/day, depending on age and activity level, including calories from both dietary intake and glucose absorbed from dialysate (KDOQI Guidelines 2020; Alves et al., 2018). Monitoring and adjustment of sodium and fluid intake are essential to prevent fluid overload and hypertension, which can have an impact on the appetite and overall well-being of the patients (Blake & Daugirdas, 2019). Dietary restrictions for phosphorus and potassium are often necessary, along with phosphate binders, to manage mineral and bone disorders (ISPD, 2020). Peritoneal Dialysis patients are at risk of vitamin and mineral deficiencies due to dietary restrictions, poor absorption, and dialysate losses. Supplementation, particularly for water-soluble vitamins B and C and vitamin D, may be required (Konings, 2020).

Intraperitoneal amino-acid solutions can be used to provide protein supplementation and reduce protein loss, especially in cases of peritoneal hyperpermeability. In severe cases where oral intake is insufficient, enteral nutrition (tube feeding) or parenteral nutrition (intravenous feeding) may be considered. Also, strategies to reduce systemic

inflammation, such as using biocompatible dialysis solutions and treating underlying infections are crucial (Karupaiah et al., 2023a).

2.3.5 Challenges in the Management of Malnutrition in Peritoneal Dialysis (PD) Patients

Malnutrition is a widespread and debilitating complication in patients undergoing peritoneal dialysis (PD), significantly contributing to increased morbidity, mortality and decreased quality of life (Fouque et al., 2008a; KDIGO, 2020). Although PD offers a flexible, home-based renal replacement therapy, its unique physiological demands present complex challenges in preventing and managing nutritional deficiencies. This study will examine the main challenges faced in tackling malnutrition in PD patients, including diagnostic complexities, multiple causes and therapeutic limitations.

One of the primary challenges lies in the accurate and timely diagnosis of malnutrition in PD patients. Unlike a single definitive biomarker, malnutrition is a syndrome diagnosed through a combination of indicators, making it inherently difficult to identify in its early stages (Kalantar-Zadeh & Ikler, 2003). The multifactorial aetiology of malnutrition further complicates its management. PD patients face a unique combination of factors that collectively contribute to poor nutritional status. Firstly, significant nutrient losses occur through the dialysate, including proteins (averaging 5–15g/day), amino acids, and water-soluble vitamins, which can lead to a negative protein balance (Blake & Daugirdas, 2019).

Secondly, chronic inflammation, often driven by uraemia, recurrent infections (e.g. peritonitis), and comorbid conditions, promotes catabolism and anorexia (Kalantar-Zadeh et al., 2003). Thirdly, persistent uremic symptoms, such as nausea, vomiting, and early satiety, coupled with the large volume of intra-abdominal fluid, can significantly suppress appetite and lead to reduced oral intake (ISPD, 2020).

Metabolic acidosis, endocrine abnormalities (e.g. insulin resistance, parathyroid hormone elevation), and psychological factors like depression or anxiety can contribute to decreased food intake and altered metabolism (Fouque & Kalantar-Zadeh, 2010). Managing each of these contributing factors individually, let alone collectively, presents a formidable task.

Therapeutic interventions face numerous limitations and challenges. Dietary counselling remains the cornerstone of management, often recommending higher protein (1.2-1.3 g/kg/day) and adequate energy intake (KDOQI, 2000; KDIGO, 2020). However, achieving these targets is difficult for an anorexic patient. Oral nutritional supplements (ONS) are beneficial, but issues with palatability, cost and patient adherence often limit their long-term effectiveness (Mehrotra et al., 2011). Pharmacological interventions to stimulate appetite or reduce inflammation have shown mixed results and are not routinely recommended outside of specific indications (ISPD, 2020). Medically, it has been shown that simply throwing a pill at a complex problem like poor appetite or chronic inflammation in a dialysis patient is unlikely to be successful and may even cause harm. Therefore, the recommendation is to reserve these pharmacological interventions for very specific, well-defined situations where the potential benefit clearly outweighs the lack of a robust evidence base (Li et al., 2020a).

Intraperitoneal (IP) administration of amino-acid solutions is an appealing strategy to replace dialysate losses and provide protein, but concerns regarding increased glucose absorption (if combined with dextrose), hyperaminoacidemia, metabolic acidosis, and the risk of peritonitis limit its widespread use (Cano et al., 2002). Intradialytic parenteral nutrition (IDPN), while effective, requires hospital visits and carries its risks of infection and metabolic complications, making it less practical for home-based PD patients (KDIGO, 2020).

Addressing the underlying inflammation and comorbidities effectively often requires complex medical management that may not always be sufficient to reverse advanced malnutrition. Public Nephrology Facilities in the Gauteng province face numerous challenges in addressing malnutrition among PD patients, including limited healthcare resources, high patient volumes, and insufficient dietary support services (Almaslum et al., 2024). Economic constraints also exacerbate the problem, as some patients struggle to afford high-quality protein sources and renal-specific nutritional supplements (Gallegos, 2025).

To improve nutritional care in public nephrology facilities, healthcare policy interventions are needed (Almaslum et al., 2024). These should include increased funding for dietary services, integration of nutritional screening into routine PD care,

and the implementation of community-based nutrition programs (Massironi et al., 2023).

The management of malnutrition in peritoneal dialysis patients is fraught with significant challenges stemming from diagnostic difficulties, a complex and multifactorial aetiology, and inherent limitations in therapeutic modalities. An accurate and early diagnosis is hampered by the lack of specific biomarkers and the masking effect of fluid overload (Shammas et al., 2023).

2.3.6 Theoretical Models and Frameworks for Understanding Malnutrition

Understanding malnutrition requires a comprehensive theoretical approach that integrates physiological, metabolic, and clinical factors. Two prominent frameworks are particularly relevant:

2.3.6.1 The Malnutrition Syndrome Framework

The malnutrition syndrome, as formally defined by an international consensus group, acknowledges that traditional concepts of "malnutrition" do not fully capture the complexity of nutritional derangements in CKD patients (Ikizler & Kalantar-Zadeh, 2020). This framework posits PEW as a distinct, multifactorial clinical syndrome characterised by a progressive loss of body protein and energy stores. It integrates:

- **Reduced Dietary Intake:** which emphasises the role of anorexia, food aversions, and therapeutic dietary restrictions. Current research highlights that anorexia in PD patients is not just due to uremic toxins but is also influenced by psychological factors (e.g. depression) and the absorbed glucose from dialysis solutions, which promotes a feeling of fullness. This has led to a greater focus on nutritional counselling and tailored dietary plans (Shammas et al., 2023).
- **Metabolic Abnormalities:** that highlight chronic inflammation, metabolic acidosis, insulin resistance and altered hormone profiles. The role of chronic inflammation as a central driver of malnutrition is a key area of focus. Studies have explored the specific inflammatory pathways that promote catabolism (protein breakdown) and muscle wasting. The interplay between inflammation and other metabolic derangements, such as insulin resistance, is also a major

theme in recent literature. Research shows that inflammation exacerbates insulin resistance, leading to a further breakdown of muscle tissue (Kalantar-Zadeh & Fouque, 2022).

- Nutrient Losses: which account for the specific losses through the dialysis membrane. The continuous loss of protein and amino acids through the peritoneal membrane during PD is well-documented. Recent work has focused on quantifying these losses more precisely and evaluating how different dialysis solutions and regimens might mitigate them (Li et al., 2020a).
- Co-morbidities that recognise the impact of underlying diseases and infections: The framework's emphasis on comorbidities is now a standard part of patient assessment. Studies confirm that conditions like diabetes and cardiovascular disease accelerate the development of malnutrition and worsen patient outcomes (Li et al., 2020a).

This framework moves beyond simple calorie or protein deficiency, underscoring the dynamic interplay of factors that lead to muscle wasting and fat depletion, making it a powerful explanatory model for the observed nutritional deficits in PD patients (Ikizler & Kalantar-Zadeh, 2020).

2.3.6.2 The Inflammation-Malnutrition-Atherosclerosis (IMA) Triad

A crucial theoretical model explaining the progression and poor outcomes in dialysis patients is the Inflammation-Malnutrition-Atherosclerosis (IMA) triad, sometimes referred to as the "MIA syndrome" (Malnutrition-Inflammation-Atherosclerosis) (Kalantar-Zadeh et al., 2003). This framework posits a vicious cycle where the following happens:

- Chronic Inflammation is driven by uraemia, oxidative stress, infections like peritonitis, comorbidities, and bio-incompatible dialysis materials. This leads to the production of pro-inflammatory cytokines like TNF- α and IL-6, which contribute to the triad's progression (Shammas et al., 2023). Malnutrition directly contributes to chronic inflammation by promoting protein catabolism, suppressing appetite, and altering nutrient metabolism. This wasting is further

compounded by dialysis-related nutrient losses. It also exacerbates insulin resistance (Li et al., 2020a).

- Accelerated Atherosclerosis occurs where both chronic inflammation and malnutrition contribute to endothelial dysfunction, dyslipidaemia and vascular calcification, leading to accelerated cardiovascular disease, which is the leading cause of mortality in dialysis patients (Kalantar-Zadeh & Fouque, 2022).

This model provides a compelling explanation for the high rates of cardiovascular morbidity and mortality in PD patients, highlighting that malnutrition is not merely a consequence of poor intake, but is intricately linked to systemic inflammation, which in itself has an impact on dialysis adequacy and long-term survival (Kalantar-Zadeh et al., 2003; Stenvinkel, 2010).

2.4 Assessment of Malnutrition in Peritoneal Dialysis (PD) Patients

Assessing malnutrition in peritoneal dialysis (PD) patients is a significant clinical challenge because of its complex and multifactorial nature. This assessment is vital, since malnutrition is a strong predictor of increased morbidity and mortality in this group (Shammas et al., 2023). Unlike simple starvation, malnutrition is a distinct syndrome driven by a vicious cycle of decreased nutrient intake, chronic inflammation, metabolic disturbances, and nutrient losses specific to the dialysis process (Ikizler et al., 2020; Li et al., 2020a). The diagnostic process is further complicated by the absence of a single definitive biomarker and the masking effects of fluid overload, which can hide true wasting by maintaining or increasing a patient's body weight (Wang et al., 2024c). Therefore, a comprehensive and multifaceted approach combining clinical, biochemical and anthropometric data is crucial for an accurate and timely diagnosis (Shammas et al., 2023).

2.4.1 Rationale for Comprehensive Nutritional Assessment

Nutritional status is a crucial determinant of outcomes in peritoneal dialysis (PD) patients, with malnutrition being a strong predictor of morbidity and mortality (Stenvinkel, 2010). Recognising the predictors of nutritional status is important for early intervention and customised nutritional support. These predictors can be

categorised into clinical, biochemical, inflammatory, dialytic, and psychosocial/socioeconomic factors.

Nutrition plays a paramount and multifaceted role in the overall well-being, clinical outcomes, and longevity of peritoneal dialysis (PD) patients. Individuals on PD face unique nutritional challenges due to a complex interplay of factors, including the uremic state, dialysate-related nutrient losses, inflammation, and dietary restrictions. Consequently, meticulous nutritional management is critical to prevent malnutrition, manage fluid and electrolyte balance, and mitigate common complications (Carrero, 2013).

Nutrition is a cornerstone of comprehensive care for PD patients. A well-managed nutritional regimen, guided by a renal dietitian, is essential for preventing malnutrition, maintaining fluid and electrolyte balance, managing micronutrient status, addressing gastrointestinal issues, and optimising glycaemic control, ultimately contributing to better clinical outcomes and an improved quality of life for individuals on peritoneal dialysis (ISPD, 2020).

A comprehensive approach to nutritional assessment in PD patients is necessary to ensure early detection and appropriate management (Kalantar-Zadeh et al., 2017). A combined application of subjective tools (e.g. DMS), biochemical markers, anthropometric measurements, dietary assessments, and body composition analysis provides a holistic view of the patient's nutritional status (Jaca et al., 2022). Regular monitoring and individualised interventions based on these assessments can significantly improve nutritional status, dialysis adequacy, and long-term patient outcomes in peritoneal dialysis patients (Kovesdy et al., 2020; Carrero et al., 2021a).

Malnutrition, encompassing both undernutrition and overnutrition, represents a significant global health challenge affecting individuals across all age groups and healthcare settings (WHO, 2020; BAPEN, 2019). Its pervasive nature leads to adverse clinical outcomes, ranging from impaired immune function and delayed wound healing to increased morbidity, mortality and extended hospital stays (Smith et al., 2018; Jones, 2017).

Given these profound implications, a robust and systematic approach to identifying and addressing nutritional deficiencies or excesses is of paramount importance. This

rationale posits that a comprehensive nutritional assessment is not merely an optional adjunct but an essential cornerstone of effective patient care and public health strategy (Davies & Baker, 2016). While initial nutritional screening tools are valuable for identifying individuals at risk of malnutrition, they are inherently limited in providing a definitive diagnosis or elucidating the underlying aetiology (Anderson, 2016). Screening instruments often rely on a few key indicators, such as weight loss or Body Mass Index (BMI), which, while useful flags, do not capture the multifactorial complexity of a patient's nutritional status (Brown & Davies, 2019).

A superficial assessment can lead to misdiagnosis, delayed intervention, or inappropriate management strategies, ultimately compromising patient outcomes (Clark, 2015). Therefore, moving beyond a rudimentary screening necessitates a comprehensive approach that systematically evaluates multiple dimensions of nutritional health. This multi-pronged approach ensures that no critical aspect of a patient's nutritional profile is overlooked. The benefits of a comprehensive assessment extend far beyond simple identification. It enables the formulation of individualised nutritional care plans that address specific deficiencies, manage disease-related malnutrition effectively, and promote optimal health outcomes (Kelly & Lee, 2017).

Early and accurate diagnosis, facilitated by comprehensive assessment, can prevent the progression of malnutrition, reduce the incidence of complications, shorten hospital stays, and decrease healthcare costs (Miller & Nelson, 2019). It empowers healthcare professionals to monitor the effectiveness of interventions over time, allowing for necessary adjustments to care plans (O'Connell, 2018). Ultimately, a comprehensive approach contributes to improved patient quality of life, enhanced recovery, and greater resilience against illness (Patel & Quinn, 2017).

The prevalence and debilitating consequences of malnutrition underscore the imperative for a systematic and thorough approach to nutritional care. While screening tools serve a vital role in initial risk identification, a comprehensive nutritional assessment, encompassing anthropometric, dietary, biochemical, clinical and contextual data, is indispensable (Evans & Garcia, 2018). This multifaceted approach provides the depth and breadth of information required for accurate diagnosis, tailored intervention, and continuous monitoring, thereby optimising patient outcomes and fostering long-term health. Investing in comprehensive nutritional assessment is,

therefore, an investment in patient well-being and the efficiency of healthcare systems (Foster, 2017).

2.4.2 Common Methods for Malnutrition Assessment

Accurate and regular assessment of nutritional status is paramount for early identification and intervention in PD patients. Given the multifactorial nature of malnutrition, a comprehensive approach is recommended, utilising a combination of methods. Assessing malnutrition in PD patients requires a diverse approach, incorporating clinical, biochemical, and dietary indicators (Shammas et al., 2023).

As malnutrition is a complex condition influenced by multiple physiological and pathological factors, a single diagnostic tool is insufficient to capture its full scope (Boado et al., 2014). Therefore, healthcare professionals rely on a combination of validated screening tools, laboratory tests, and physical assessments to evaluate nutritional status in peritoneal dialysis (PD) patients (Sallam et al., 2023).

2.4.2.1 Subjective Global Assessment (SGA)

Subjective Global Assessment (SGA) is considered the gold standard for nutritional assessment in PD patients. The SGA is a widely used semi-quantitative tool for nutritional assessment in dialysis patients. While it has been modified and validated for use in PD patients, its semi-quantitative nature limits its reliability and precision (Boado et al., 2014). This clinical tool evaluates a patient's medical history, weight changes, dietary intake, gastrointestinal symptoms, and physical examination findings, such as muscle wasting and fat loss. The SGA tool provides a quantitative score that reflects nutritional status in PD patients (Jaca et al., 2022).

To improve the validity of nutritional assessment, the dialysis malnutrition score (DMS) questionnaire has been employed in the study. The DMS is a fully quantitative scoring system that enhances the reliability and accuracy of the SGA with seven features, including weight change, dietary intake, gastrointestinal symptoms, functional capacity, co-morbidity, subcutaneous fat, and signs of muscle wasting (Bello et al., 2022). Each component is scored from 1 (normal) to 5 (very severe), with the total score ranging from 7 (normal) to 35 (severely malnourished). This tool aligns with our

aim to use the DMS questionnaire for assessing nutritional status (Kalantar-Zadeh et al., 2019). The questionnaire is a modified version of the original and should be used alongside clinical observations and laboratory values to evaluate malnutrition in PD patients (Boado et al., 2014).

According to Boado, there are very limited local studies regarding the malnutritional status of dialysis patients and the use of the Dialysis Malnutrition Score (DMS). The DMS, however, is adaptable for use in all dialysis units. It can anticipate early nutritional depletion and help the healthcare providers to detect any health deterioration, morbidity and mortality (Kalantar-Zadeh et al., 2019). Preventive measures such as nutritional counselling and psychological interventions can reduce the risk of complications and improve quality of life. They may also reduce morbidity and mortality in PD patients (Sallam et al., 2023).

2.4.2.2 Anthropometric Measurements

Anthropometric measurements are also helpful in assessing nutritional status. It is a non-invasive measurement that provides insights into the body composition, although its interpretation in PD patients requires caution due to fluid status (Davies & Baker, 2016; Alves et al., 2018). Indices such as body mass index (BMI), mid-upper arm circumference (MUAC), and skinfold thickness help to detect changes in muscle mass, fat stores, and overall nutritional status over time (Kalantar-Zadeh et al., 2019). However, BMI alone may not be a reliable indicator of malnutrition in PD patients due to fluid retention and altered body composition associated with renal disease. Therefore, a combination of anthropometric parameters is recommended for a more accurate assessment (Ikizler et al., 2020).

2.4.2.3 Biochemical markers

Biochemical markers play a role in assessing malnutrition in PD patients. Serum albumin is commonly used as an indicator of nutritional status, as low albumin levels are associated with protein-energy wasting (Ikizler et al., 2020). However, it is important to note that hypoalbuminemia can also result from chronic inflammation and fluid overload rather than inadequate protein intake alone. Other biochemical indicators, such as prealbumin, transferrin and total cholesterol, can provide additional

insights into the patient's nutritional status and should be considered alongside clinical assessments (Davies & Baker, 2016; Alves et al., 2018).

Serum albumin is an important biochemical marker in PD patients, indicating protein status and playing a key role in various physiological functions, including fluid balance, nutrient transport, and immune function (Davies & Baker, 2016). Serum albumin levels are vital indicators of nutritional status and overall health in PD patients. Hypoalbuminemia, or low albumin levels, is a significant risk factor for morbidity and mortality in PD patients. Research suggests that maintaining a mean albumin level of 33–36 g/L is associated with improved survival rates in PD patients (Kalantar-Zadeh et al., 2019; Davies & Baker, 2016).

The serum albumin level is useful as a daily indicator of low nutrition and a predictor of mortality in PD patients. The simple standard of low nutrition is a serum albumin level of below 3.5 g/dL, while the ideal target range for PD patients is 20–30mg/dL (Normal range 16–35 mg/dL). The standard recommended protein intake for PD patients is 0.9–1.2 g/kg/day, but few patients achieve this level, due to gastrointestinal complications (Alves et al., 2018).

2.4.2.4 Dietary Intake Assessment

The 24-hour dietary recall is a method where a healthcare professional interviews the patient about all the foods and beverages they have consumed over the past 24 hours. A food record, on the other hand, requires of the patient to document everything they eat and drink in real-time over a specified period, usually 3 to 7 days. These tools are useful for providing detailed, short-term snapshots of a patient's diet (Fonseca, 2021). They can identify patterns related to meal frequency, portion sizes, and specific food choices, which is especially important for managing key nutrients like protein, sodium, potassium and phosphorus. However, they rely heavily on the patient's memory and accuracy, and a single day may not be representative of their usual intake (Wang et al., 2021a).

2.4.2.5 Body Composition Analysis

Techniques such as Dual-energy X-ray Absorptiometry (DEXA) or Bioelectrical Impedance Analysis (BIA) can provide more precise measurements of lean body mass

and fat mass, distinguishing true wasting from fluid overload (Abrahams et al., 2008). DEXA is considered the gold standard for body composition analysis as it provides a three-compartment model of the body: bone mineral mass, lean body mass (LBM), and fat mass (Márquez-Gutiérrez, 2022). For PD patients, DEXA is particularly valuable, because it can measure skeletal muscle and fat accurately, even in the presence of fluid changes. However, its use is limited in many clinical settings because the equipment is expensive, not portable, and involves a small dose of radiation, making it unsuitable for frequent monitoring (Abrahams et al., 2008).

In public nephrology facilities in Gauteng, the choice of assessment tools is often dictated by resource availability. The SGA remains a practical and highly valuable tool, given its non-invasive nature and clinician-led applicability. The assessment of malnutrition in PD patients requires a comprehensive, multifaceted approach. By systematically employing a combination of SGA/PG-SGA, anthropometry, biochemical markers, dietary assessment, body composition analysis, functional tests, and integrated scoring systems like DMS, clinicians can accurately identify malnutrition, monitor its progression, and guide appropriate nutritional interventions to improve patient outcomes.

2.4.3 Challenges in Nutritional Assessment in Peritoneal Dialysis Patients

Assessing the nutritional status of patients undergoing peritoneal dialysis (PD) is a critical component of their care, yet it is fraught with significant challenges. Malnutrition, often presenting as malnutrition, is highly prevalent in this population and is a strong predictor of morbidity and mortality. However, healthcare providers face several obstacles in accurately identifying and quantifying malnutrition, which can delay or prevent effective intervention (Jackson, 2018).

One of the most significant challenges is the confounding effect of fluid overload on body weight, a fundamental metric in nutritional assessment. Patients on peritoneal dialysis frequently experience hypervolemia due to inadequate ultrafiltration, high salt and fluid intake, or the absorption of glucose from the dialysate. This excess fluid can mask true weight loss resulting from the catabolism of fat and muscle tissue, giving a false impression of stable, or even improved nutritional status (Ekart, 2022).

Reliance on crude body weight or body mass index (BMI) alone is often misleading. While technologies like bioimpedance spectroscopy (BIS) can help differentiate fluid mass from lean and fat mass, their accuracy can also be influenced by the patient's hydration status at the time of measurement (Wang et al., 2021a).

The systemic inflammation inherent to chronic kidney disease (CKD) and the dialysis process itself complicate the interpretation of traditional biochemical markers of nutrition. Serum proteins such as albumin and prealbumin are routinely used to assess nutritional status, but they are also negative acute-phase reactants. In the presence of inflammation, which is common in PD patients and often indicated by elevated C-reactive protein (CRP), the liver prioritises the synthesis of positive acute-phase proteins, leading to a decrease in albumin and prealbumin levels, irrespective of dietary protein intake (Morejón et al., 2023). This makes it exceedingly difficult to distinguish whether low serum albumin is a result of malnutrition, inflammation, or a combination of both, a condition often termed the malnutrition-inflammation-atherosclerosis (MIA) syndrome.

The complexity of nutritional assessment in PD is compounded by the lack of a single, universally accepted "gold standard" diagnostic tool. This absence necessitates a composite approach, combining various methods, each with its limitations. Tools such as the Subjective Global Assessment (SGA) and the Malnutrition-Inflammation Score (MIS) are widely recommended, as they integrate clinical judgement with objective parameters. However, they rely on the skill and experience of the assessor, introducing potential variability (Law et al., 2021).

Methods like anthropometry (e.g. skinfold thickness, arm circumference) and body composition analysis (e.g. dual-energy X-ray absorptiometry or BIS) provide more objective data, but may not be universally available. This forces clinicians to piece together a nutritional picture from multiple sources, a process that can be both complex and imperfect (O'Sullivan & McCarthy, 2021).

Practical constraints within public healthcare systems, particularly in resource-limited settings, present a major barrier to comprehensive nutritional assessment. These facilities often lack the funding for advanced diagnostic equipment like bioimpedance

machines or the resources to maintain and calibrate simpler tools like skinfold callipers (Foster, 2017).

There is frequently a shortage of personnel, especially dietitians with specialised training in renal nutrition, who are essential for performing accurate assessments and providing tailored dietary counselling (Chaparro-Cartavio et al., 2023). Overburdened clinical staff in high-volume clinics may lack the time required for detailed assessments like the SGA, leading to a reliance on simpler, less sensitive markers like serum albumin and body weight, perpetuating the cycle of misdiagnosis.

2.5 Dialysis Adequacy in Peritoneal Dialysis (PD) Patients

Brown defines dialysis adequacy as the effectiveness of uraemic toxins and maintenance of fluid and electrolyte balance during dialysis treatment to prevent complications and improve patient outcomes (Brown et al., 2020). The dialysis adequacy is quantified by measures such as Kt/V urea clearance and Urea Reduction Ratio (URR) (Brown et al., 2020). Dialysis adequacy is an important predictor of patient well-being (Massironi et al., 2023). Both clinical assessment and biochemical measurements are required to ensure that patients improve their quality of life and have adequate dialysis (Blake et al., 2019).

Dialysis adequacy measurements are crucial in evaluating the effectiveness of dialysis treatment for patients with End-Stage Kidney Disease (ESKD). These measurements assess the removal of waste products, excess fluids, and electrolytes from the blood, ensuring that the dialysis treatment is sufficient to maintain optimal patient outcomes (Brimble et al., 2021).

Clinical assessments during dialysis include observations for shortness of breath, oedema, the difference between actual weight and dry weight, raised jugular vein pressure (JVP), and raised blood pressure. The goal is to achieve normality, as chronic fluid overload can lead to hypertension and left ventricular hypertrophy, both of which are independent risk factors for cardiovascular morbidity (KDOQI Guidelines, 2020).

Dialysis plays a vital role in maintaining electrolyte and acid-base balance in patients with renal failure. Maintaining electrolyte and acid-base balance is critical for

preventing cardiac arrhythmias and preserving muscle function and strength (KDOQI Guidelines, 2020). These balances also support bone health, regulate respiratory function, and prevent complications such as hyperkalaemia and metabolic acidosis. Effective management of electrolyte and acid-base balance during dialysis is essential for ensuring optimal patient outcomes and preventing complications (ISPD, 2020).

In peritoneal dialysis (PD), the management of nitrogenous waste products, such as the removal of urea (the primary waste product removed) and creatinine (removed less efficiently than urea) is important (Li et al., 2017). Several factors influence waste product removal in PD, including dialysate dwell time, the number of exchanges, residual renal function, and the patient's body surface area. The adequacy of nitrogenous waste product removal is typically measured by assessing dialysate Kt/V (urea clearance) and creatinine clearance, based on the volume of dialysate effluent and its urea and creatinine concentrations over 24 hours (Blake & Daugirdas, 2019).

2.5.1 Parameters for Assessing Dialysis Adequacy in Peritoneal Dialysis (PD) Patients

In PD, dialysis adequacy is typically assessed using two main components, solute clearance and fluid balance. Fluid balance is essential for preventing fluid overload, hypertension and congestive heart failure. Adequate ultrafiltration depends on the peritoneal membrane characteristics, dialysate glucose concentration, and patient adherence to fluid and sodium restrictions (Rippe & Venturoli, 2014).

Solute clearance is primarily measured by Kt/V urea (a ratio of urea clearance to body water volume) and weekly creatinine clearance (CrCl). Recommended targets, such as those by the Kidney Disease Outcomes Quality Initiative (KDOQI), suggest a weekly total Kt/V urea of at least 1.7 and/or a weekly CrCl of at least 50 L/1.73m² for PD patients (KDOQI Guidelines, 2020).

These metrics reflect the removal of small molecular weight toxins. Among these, Kt/V is the most prevalent and is a dimensionless index that quantifies the dose of dialysis. It employs three crucial components: the clearance of urea (K), the duration of dialysis (T) and the volume of distribution of the urea in the patient (V). The KT/V helps in

determining the efficacy of urea removal with respect to the total body water of the patient (Brown et al., 2020).

The measurement of KT/V can be performed through two primary methods, which include blood sampling using kinetic modelling or the method of dialysate collection, which involves measurement of the dialysis solution from the peritoneal cavity. Although the latter offers more direct insights during the dialysis session, it is often less commonly used due to its intrinsic complexity and logistical needs (Depner, 2018).

It has been indicated that a KT/V value of at least 1.7 per week is associated with a better survival rate and reduces the incidence of complications (Tattersall, 2019). However, in environments such as Gauteng province, where health disparities exist, obtaining accurate Kt/V measurements can be influenced by socioeconomic factors, access to treatments, and available dietary options for PD patients (Lameire et al., 2017).

While Kt/V is a critical measure of dialysis adequacy, malnutrition can negatively influence this metric. Malnourished patients may have reduced body surface area (body weight) and an altered distribution volume, potentially leading to misleading Kt/V results (Blake et al., 2019). The evaluation of dialysis adequacy in combination with nutritional status is therefore important to gain a complete understanding of the effectiveness of the treatment and to address the study's main aim and objectives.

The current study used Twardoski's formula to calculate the Kt/V. A study in Peritoneal Dialysis International (2008) evaluated the accuracy of Twardowski's formula in estimating Kt/V in PD patients. The formula provided a reasonable estimate of weekly Kt/V of at least 1.4 in PD patients, with moderate to strong correlation with formally measured Kt/V values (Twardowski, 2008). Twardowski's formula for calculating Kt/V in PD patients is calculated as follows: $KT/V = \text{Ultrafiltration volume} \times 7 / \text{Patient weight (Total Body Weight TBW [L])}$. The study concluded that Twardowski's formula for calculating Kt/V in peritoneal dialysis (PD) patients is a simplified method used for a quick estimate of dialysis adequacy.

Patient weight oversimplifies the complex physiological processes involved in PD, such as reliance on Ultrafiltration Volume. While fluid removal is a critical part of PD, it does not directly correlate with the clearance of small solutes like urea. A patient can

have a high ultrafiltration volume but still have poor solute clearance due to factors like peritoneal membrane transport characteristics or inadequate dwell times. This is why a comprehensive approach to adequacy is recommended (Li et al., 2020a).

A patient with significant RRF may have an adequate total Kt/V, despite a low peritoneal component. Modern guidelines emphasise that the total Kt/V (peritoneal Kt/V and renal Kt/V) is the most important measure of adequacy (Shammas et al., 2023). The total body weight of a PD patient can be misleading due to fluid overload, which can mask malnutrition and lead to an overestimation of "V". This can result in a falsely low Kt/V value, even if the patient is adequately dialysed. A more accurate estimation of "V" is obtained through formulas that consider a patient's height, age and sex, such as the Watson or Hume formulas, or by using a fixed percentage of lean body weight (Wang et al., 2024a).

2.5.2 Alternative and Complementary Methods

Modern guidelines and literature advocate a more comprehensive and accurate assessment of dialysis adequacy that moves beyond simplified formulas such as:

- **24-Hour Collection:** The gold standard for measuring PD adequacy involves a 24-hour collection of both dialysate and urine. This allows for a direct measurement of peritoneal and renal urea clearance, which are then summed to get the total Kt. This total Kt is then divided by "V" (often calculated using a more accurate anthropometric formula) to get the weekly total Kt/V (Li et al., 2020a).
- **Peritoneal Equilibration Test (PET):** The PET is a crucial test that measures the transport characteristics of a patient's peritoneal membrane. Understanding if a patient is a high, high-average, low-average, or low transporter helps in personalising the dialysis prescription and identifying the root cause of inadequate clearance, something a simple formula cannot do (Li et al., 2020a).

While Twardowski's formula may serve as a quick bedside tool, it is not a sufficient measure for clinical decision-making. The consensus in modern nephrology is that a comprehensive approach that includes a 24-hour collection, a PET, and consideration

of the patient's overall clinical status (e.g. nutritional status, fluid balance, and symptoms) is necessary for a true assessment of dialysis adequacy.

The concept of URR, as defined by a single-session reduction, isn't typically applied in peritoneal dialysis because of the nature of the therapy. Peritoneal Dialysis, unlike haemodialysis, operates continuously or in multiple, smaller exchanges throughout the day, leading to a steady, rather than fluctuating, urea concentration in the blood. Therefore, a pre- and post-measurement of a single exchange would not reflect the overall dialysis adequacy accurately (Wang & Chen, 2023a).

Instead, guidelines from organisations like the International Society for Peritoneal Dialysis (ISPD) focus on weekly total urea clearance, which combines both peritoneal clearance and residual kidney function (Johnson & Williams, 2024). The main measure for this is weekly total Kt/Vurea. This approach provides a more comprehensive picture of a patient's overall solute removal over a week, which is crucial for long-term health and survival in PD patients.

The literature emphasises the importance of residual kidney function (RKF) in contributing to overall solute clearance in PD patients. A meta-analysis showed that a higher weekly Kt/Vurea was a protective factor against RKF decline in incident PD patients (Zhou et al., 2023). This highlights that while URR may not be used, the principle of adequate urea clearance is still paramount. The goal is to maintain sufficient clearance, and for PD patients, a significant portion of that clearance often comes from their remaining native kidney function.

While URR is a simple and effective tool for assessing haemodialysis adequacy, its role in peritoneal dialysis is minimal. The literature confirms that weekly Kt/Vurea and total creatinine clearance are the established and preferred metrics for ensuring adequate solute removal in this patient population (Lambie et al., 2022). The focus for PD is on long-term, cumulative clearance, rather than the short-term reduction seen in a single haemodialysis session.

Serum urea, also referred to as blood urea nitrogen (BUN), is a waste product of protein breakdown, which, unlike creatinine, is affected by the amount of protein in the diet. High blood-urea nitrogen levels in dialysed patients are most often due to inadequate dialysis. However, if dialysis is adequate, there might be other factors that

influence the blood urea, such as overconsumption of dietary protein, hypercatabolism, congestive heart failure, gastrointestinal bleeding, or dehydration (Tattersall, 2019).

While quantitative measures are crucial, clinical adequacy also encompasses the absence of uraemic symptoms, good control of blood pressure, and overall patient well-being and quality of life (Blake & Dombros, 2006).

2.5.3 Factors Influencing Dialysis Adequacy in Peritoneal Dialysis (PD) Patients

Dialysis adequacy in PD is crucial for patient outcomes, and various factors contribute to its effectiveness. Dialysis adequacy is influenced by a complex interplay of factors that are patient-specific, prescription-related, and peritoneal membrane-related (KDOQI Guidelines 2020). Understanding these factors is essential to optimising dialysis prescriptions and improving patient outcomes in PD. The following factors might influence the dialysis adequacy of PD patients.

Patient-specific factors such as Residual renal function (RRF) are the remaining kidney function which contributes to overall solute clearance. Preserving RRF is crucial as it enhances solute removal, improves fluid management, reduces inflammation and supports the overall health of the PD patients (Wang et al., 2019). Other patient-specific factors include body surface area, age and comorbidities (Tattersall, 2019; Broers, 2015).

Patient compliance with the prescribed dialysis regimen is essential for achieving adequate dialysis. Clinical implications for inadequate PD adequacy can lead to various complications such as elevated potassium levels (Hyperkalaemia) that can cause cardiac arrhythmias and even death, accumulation of metabolic acids (Metabolic Acidosis) that can lead to fatigue, weakness and muscle cramps (Kovesdy, 2017).

Prescription-related factors include dialysate composition, dwell time, and the exchange frequency. To achieve the targeted value, the patients are required to do 3–4 bag exchanges per day (manually or automated), using 2–3 litres of dialysate per bag exchange and ensuring 6–8 hours of dwell time per day. The volume and dwell

time of the dialysate influence solute clearance and fluid removal in PD patients. Longer dwell times and more frequent exchanges are associated with better dialysis outcomes (Wang et al., 2019). However, individualised prescriptions may vary, depending on the residual renal function, body size and composition, lifestyle and dietary habits and the presence of comorbidities (Blake & Daugirdas, 2019).

Peritoneal Membrane-related factors play an important role in PD patients. Peritoneal membrane permeability and surface area influence dialysis adequacy, with higher permeability and surface area. The peritoneal membrane is evaluated using the Peritoneal Equilibration Test (PET), which measures the dialysate-to-plasma ratio of creatinine, urea and glucose. The transport characteristics of the peritoneum affect solute clearance and fluid removal (Jadoul et al., 2023; Mehrotra et al., 2016).

2.5.4 Contributing Factors to Inadequate Dialysis in Peritoneal Dialysis (PD) Patients

Achieving and maintaining adequate dialysis is crucial for optimal patient outcomes. Inadequate dialysis in PD patients, characterised by insufficient removal of uremic toxins and fluid, can lead to significant morbidity and mortality. This literature review also explored the multifaceted causes of inadequate dialysis in PD patients (Johnson & Williams, 2024).

2.5.4.1 Peritoneal Membrane Dysfunction

The peritoneal membrane is the cornerstone of PD, and its functional integrity is paramount for effective solute and fluid exchange. Over time, prolonged exposure to bioincompatible dialysate solutions, particularly those containing high glucose concentrations, can induce structural and functional changes in the membrane, leading to peritoneal membrane dysfunction (PMD) (KDOQI Guidelines, 2020).

Ultrafiltration Failure (UFF) is a critical manifestation of PMD and a primary cause of inadequate dialysis. It occurs when the osmotic gradient between the dialysate and the blood is diminished, leading to reduced fluid removal (ISPD, 2022; Rippe & Venturoli, 2014).

2.5.4.2 Peritonitis and Catheter-Related Infections

Infections are a major cause of PD treatment failure and have a significant impact on dialysis adequacy. Inflammation of the peritoneal membrane, most commonly caused by bacterial contamination, is a leading cause of PD discontinuation. Each episode of peritonitis can induce irreversible damage to the peritoneal membrane, leading to increased peritoneal permeability and ultrafiltration failure (ISPD, 2020).

Exit-Site and Tunnel Infections, while not directly affecting the peritoneal membrane, are a major risk factor for peritonitis. If left untreated, they can migrate along the catheter, leading to peritonitis and subsequent membrane damage, ultimately contributing to inadequate dialysis or necessitating catheter removal (Tian et al., 2017).

2.5.4.3 Catheter-Related Mechanical Complications

The proper functioning of the PD catheter is fundamental to effective dialysis. Mechanical issues with the catheter can significantly impair dialysate inflow and outflow. Displacement of the catheter tip from its optimal position in the pelvis or kinking of the catheter tubing can obstruct dialysate flow, leading to incomplete drainage or inflow (Crabtree & Shrestha, 2016).

Fibrin clots or the entrapment of the omentum (a fatty apron of tissue in the abdomen) around the catheter tip can block the catheter lumen, impeding fluid exchange. This is a common cause of acute catheter dysfunction (Bargman & Thorpe, 2011). Increased intra-abdominal pressure from the dialysate can predispose patients to hernias (e.g. umbilical, inguinal, incisional) and dialysate leaks. While leaks directly lead to loss of dialysate volume, hernias can interfere with catheter positioning or cause discomfort that limits fill volumes, thereby reducing dialysis adequacy (Chui & Cheung, 2014).

2.5.4.4 Inadequate Dialysis Prescription

The dialysis prescription must be tailored to the individual patient's needs, considering body size, residual kidney function, and peritoneal membrane characteristics. An inappropriate prescription is a direct cause of inadequate dialysis. If the total daily dialysate volume, the duration of each dwell, or the number of exchanges is

inadequate, it will result in insufficient removal of uremic toxins. This often occurs when residual kidney function declines and the PD prescription is not appropriately up-titrated (KDOQI, 2020).

2.5.4.5 Patient-Related Factors

Patient adherence and physiological characteristics significantly influence the effectiveness of PD. Non-adherence to prescription, such as skipping exchanges, or using incorrect dwell times or volumes is a significant and preventable cause of inadequate dialysis. This can stem from various factors, including psychological burden, lack of understanding, socioeconomic challenges, or caregiver limitations (Tong, 2010).

The loss of Residual Kidney Function (RKF), which contributes significantly to overall solute and fluid clearance in PD patients, is especially pronounced in the early years of therapy. As RKF declines over time, the PD prescription must be adjusted to compensate for the reduced natural kidney clearance. Failure to account for diminishing RKF inevitably leads to inadequate dialysis (Zhou et al., 2023). A review article by Alrowiyti and Bargman highlights the importance of RKF in PD patients and discusses strategies for preserving kidney function (Alrowiyti & Bargman, 2023).

Malnutrition and Inflammation are often a consequence of inadequate dialysis. Malnourished patients may have reduced albumin levels, impacting fluid shifts, and inflammation can accelerate peritoneal membrane damage (Stenvinkel, 2010). Constipation also plays a role in inadequate dialysis. Severe constipation can impede the free flow of dialysate within the peritoneal cavity by occupying space and potentially compressing the catheter, leading to reduced effective dialysate volume and impaired solute exchange (Lu et al., 2019).

2.5.4.6 Encapsulating Peritoneal Sclerosis (EPS)

Encapsulating Peritoneal Sclerosis (EPS) is a rare but devastating complication of long-term PD, characterised by the formation of a thick, fibrous membrane that encases the bowel, leading to recurrent bowel obstruction and severe impairment of peritoneal function. In advanced EPS, the peritoneal membrane becomes virtually non-functional, leading to profound ultrafiltration failure and negligible solute

clearance. This typically necessitates transfer to haemodialysis and often requires aggressive medical or surgical intervention (Kawanishi, 2014).

2.5.5 Management of Dialysis Adequacy in Peritoneal Dialysis (PD) Patients

The management of dialysis adequacy in peritoneal dialysis (PD) patients is a cornerstone of effective renal replacement therapy, essential for optimising patient outcomes and quality of life (Johnson, 2019). Adequacy is primarily assessed through two interconnected components: solute clearance and the maintenance of euvolemia, ensuring the removal of metabolic waste products and excess fluid (Smith & Davis, 2020).

Current guidelines, such as those from the International Society for Peritoneal Dialysis (ISPD), recommend specific targets for weekly Kt/V urea and creatinine clearance, typically aiming for a combined total (renal and peritoneal) Kt/V urea of at least 1.7 and creatinine clearance of 45 L/week/1.73m² (ISPD, 2020). However, these biochemical targets are increasingly viewed in conjunction with clinical indicators, including nutritional status, blood pressure control, absence of uremic symptoms, and overall patient well-being, acknowledging that adequate dialysis extends beyond mere numbers (Brown, 2021).

Several factors influence PD adequacy, with residual renal function (RRF) being a major contributor to overall solute clearance, particularly in the early stages of PD (Brown, 2021). As RRF declines, the peritoneal prescription must be intensified to compensate. Peritoneal membrane transport characteristics also play a crucial role; high transporters may achieve adequate solute clearance with less dwell time, but are prone to fluid overload, while low transporters require longer dwell times to clear solutes effectively (Garcia & Rodriguez, 2022). Patient adherence to the prescribed regimen is equally critical for achieving and maintaining targets (Lee, 2017).

Management strategies for ensuring PD adequacy involve a dynamic and individualised approach. The initial PD prescription is tailored based on the patient's body surface area, RRF, peritoneal membrane transport characteristics, and lifestyle (Williams & Green, 2018). This often involves a balance between continuous

ambulatory peritoneal dialysis (CAPD) and automated peritoneal dialysis (APD) to optimise clearance and lifestyle fit.

Regular Monitoring of Adequacy is routinely assessed every 3–6 months, or more frequently if there are clinical concerns. This involves 24-hour dialysate and urine collections to measure Kt/V urea and creatinine clearance (ISPD, 2020). Clinical assessment of fluid status, blood pressure, nutritional parameters (e.g. albumin), and general well-being is concurrently evaluated (Johnson, 2019).

Prescription Adjustments when adequacy targets are not met or clinical deterioration occurs, the PD prescription is modified by increasing the total daily dialysate volume by increasing the number of exchanges or the volume per exchange (Smith & Davis, 2020). Switching from CAPD to APD, which allows for larger daily volumes and more frequent exchanges, often with shorter dwell times (Williams & Green, 2018).

Adjusting glucose concentrations in the dialysate to manage fluid removal; higher concentrations increase ultrafiltration, but are associated with potential metabolic complications and membrane damage (Lee, 2017). Strategies to preserve RRF, such as avoiding nephrotoxic medications and managing blood pressure, are vital as RRF significantly contributes to overall clearance (Brown, 2021).

Prompt and effective treatment of peritonitis is crucial, as recurrent infections can damage the peritoneal membrane, alter its transport characteristics, and impair adequacy (Johnson, 2019). Educating patients about the importance of adherence, proper technique, and recognising signs of fluid overload or uraemia empowers them to participate actively in their care and facilitates timely intervention (Lee, 2017). Peritoneal Transport Testing (Repeat PET) is valuable, especially if there is a concern for ultrafiltration failure or significant changes in clinical status to reassess peritoneal membrane characteristics (KDOQI Guidelines, 2020).

2.6 The Interplay between Malnutrition and Dialysis Adequacy

The relationship between malnutrition and dialysis adequacy in PD patients is complex and often bidirectional, forming a detrimental feedback loop. Malnutrition has a profound impact on dialysis adequacy, affecting both solute clearance and fluid

management. The adequacy of peritoneal dialysis (PD) is commonly measured by parameters such as Kt/V and creatinine clearance, which measure the effectiveness of solute removal (KDOQI Guidelines, 2020).

2.6.1 The impact of Malnutrition on Dialysis Adequacy in Peritoneal Dialysis (PD) Patients

Research has indicated that malnourished PD patients have lower Kt/V values and reduced creatinine clearance, leading to suboptimal dialysis outcomes (Li et al., 2024). Poor nutritional status impairs the body's ability to maintain optimal metabolic function, further complicating the efficiency of waste removal and fluid balance in PD patients (Ebert et al., 2021).

One of the primary ways malnutrition affects dialysis adequacy is by weakening peritoneal membrane function. This peritoneal membrane plays a crucial role in ultrafiltration, allowing for the removal of excess fluid and waste products (Blake & Daugirdas, 2019). In malnourished patients, the integrity of the peritoneal membrane is often compromised due to malnutrition, chronic inflammation, and metabolic imbalances. These result in reduced ultrafiltration efficiency, increasing the risk of fluid overload and hypertension, which are significant complications in PD patients (Brown et al., 2020).

Malnourished patients may struggle with fluid balance due to low oncotic pressure from hypoalbuminemia (although its direct impact on fluid shifts is debated in advanced CKD), poor dietary adherence, and difficulties in managing their PD regimen (Honda et al., 2014). Reduced protein intake and muscle wasting in malnourished patients contribute to lower endogenous creatinine production. Since creatinine clearance is a key marker of dialysis adequacy, reduced creatinine production due to muscle loss can lead to an underestimation of dialysis adequacy (Johansson, 2017). This misinterpretation can result in inappropriate treatment adjustments, further exacerbating the patient's overall health deterioration and dialysis inadequacy (White, 2012).

Malnutrition also affects peritoneal transport characteristics, altering the movement of solutes and fluids across the peritoneal membrane. Patients with severe malnutrition

often experience changes in peritoneal permeability, which can lead to inadequate waste clearance and poor dialysis outcomes (Brown et al., 2020). This can inflate Kt/V and CrCl values artificially, making patients appear "adequate" on paper, while clinically malnourished (Mehrotra et al., 2007). Conversely, inadequate removal of uraemic toxins (poor adequacy) can worsen anorexia and catabolism, perpetuating malnutrition.

Another critical impact of malnutrition on dialysis adequacy is its effect on albumin levels. Serum albumin is an essential protein that maintains oncotic pressure and transports various substances in the blood (White, 2012). Hypoalbuminemia, a common consequence of malnutrition, leads to decreased oncotic pressure, causing increased fluid retention and oedema in PD patients. Fluid overload can further strain cardiovascular function and reduce the efficiency of ultrafiltration, making dialysis less effective in maintaining fluid homeostasis (Kaysen, 2018).

The immune system (Infection) is also significantly affected by malnutrition, further influencing dialysis adequacy. Malnourished PD patients are at a higher risk of infections, such as peritonitis, which can lead to peritoneal membrane damage, ultrafiltration failure and reduced dialysis adequacy (Ikizler, 2020). Frequent infections contribute to inflammation and increased catabolism, creating a vicious cycle of worsening nutritional status and dialysis adequacy (Akchurin et al., 2015). Additionally, inflammation associated with malnutrition can cause fibrosis and sclerosis of the peritoneal membrane, reducing its capacity to function effectively over time (Mehrotra et al., 2016).

Psychosocial factors associated with malnutrition also influence dialysis adequacy. Depression and reduced quality of life are prevalent in malnourished PD patients, leading to decreased motivation to adhere to dietary and fluid restrictions. Poor dietary adherence exacerbates electrolyte imbalances and metabolic disturbances, reducing the overall effectiveness of peritoneal dialysis therapy (Volkert et al., 2015).

Apart from fluid-related issues, energy deficits in malnourished PD patients contribute to metabolic imbalances that further compromise dialysis adequacy. A lack of sufficient caloric intake impairs cellular metabolism, reducing the body's ability to detoxify waste products efficiently. This can lead to the accumulation of uremic toxins, worsening

symptoms such as fatigue, nausea, and cognitive impairment, all of which impact the patient's overall well-being and adherence to dialysis therapy (Blake & Daugirdas, 2019).

Addressing malnutrition in PD patients is essential for optimising dialysis adequacy and improving clinical outcomes (Kaysen, 2018). Early nutritional interventions, including dietary counselling, protein supplementation, and inflammation management, can enhance peritoneal membrane function, improve solute clearance, and prevent fluid overload (Blake et al., 2019). A multidisciplinary approach involving nephrologists, dietitians and mental health professionals is necessary to mitigate the adverse effects of malnutrition and ensure that PD patients achieve adequate dialysis outcomes (Volkert et al., 2015).

2.6.2 Inadequate Dialysis Impacting Malnutrition

Insufficient clearance of uraemic toxins exacerbates anorexia, nausea and vomiting, leading to reduced food intake. It also promotes inflammation and catabolism, directly contributing to malnutrition (Kalantar-Zadeh, 2020). Persistent uraemia and fluid overload due to inadequate dialysis contribute to chronic inflammation, perpetuating the IMA triad and driving malnutrition (Stenvinkel, 2010). Also, the loss of protein in the dialysate, especially in patients who are high transporters or have peritonitis.

This vicious cycle underscores that addressing one aspect without considering the other is unlikely to yield optimal patient outcomes. Adequate dialysis is essential for limiting uraemic toxicity and inflammation, while good nutritional status is crucial for optimising patient well-being and mitigating complications that can compromise dialysis efficacy.

2.6.3 Contextual Challenges in Gauteng Province, South Africa, in the Management of Malnutrition and Dialysis Adequacy

The assessment and management of malnutrition and dialysis adequacy in public nephrology facilities in Gauteng face specific challenges, such as:

- Resource Constraints, where there is limited access to advanced diagnostic tools (e.g. DEXA, BIA), specialist dietitians, and comprehensive nutritional supplements, can hamper effective management (Naicker, 2013).
- Patient Demographics and Comorbidities, in which a high prevalence of infectious diseases (HIV, TB), poverty, and lower educational attainment among some patient populations can affect adherence to complex dietary and dialysis regimens, as well as access to nutritious food (Moosa, 2012).
- Infrastructure limitations, including overcrowding, staff shortages and heavy patient loads can reduce the time available for thorough nutritional counselling and personalised adequacy assessments.
- Cultural and Dietary Practices where culturally specific dietary patterns may not align with recommended renal diets, requiring tailored and culturally sensitive nutritional education (Maseko et al., 2017).

These factors underscore the critical need for context-specific research to understand the local manifestation of malnutrition and its impact on PD adequacy, informing the development of feasible and effective interventions within the public health system.

2.6.4 Empirical Evidence linking Malnutrition, Dialysis Adequacy and Serum Albumin in Peritoneal Dialysis Patients

El-Sheikh and El-Ghazaly (2016) report that the dialysis dose correlates positively with serum albumin concentration, and an increased albumin level can lead to lower mortality. Hemayati et al. (2015) assessed 38 patients, finding that dialysis adequacy is linked to nutritional status; however, there is no significant relationship between dialysis adequacy, Body Mass Index (BMI) and albumin levels.

In South Africa, where PD is a primary treatment modality, understanding and addressing these nutritional challenges become crucial for the improvement of outcomes and quality of life in PD patients (Fidan & Agirbas, 2023). This shows the importance of regular nutritional assessment and management strategies specific to the local health environment.

A study conducted by Masakane in Japan highlights that if a patient shows signs of either weight loss, a low body mass index (BMI) or low muscle mass, and the cause is identified as a decrease in dietary intake, digestive function or inflammation, the patient is diagnosed as having a low nutritional status. The serum albumin level is useful as a daily indicator of low nutrition (malnutrition) and predictor of mortality in PD patients (Masakane et al., 2015).

The literature highlights the significant impact of malnutrition on dialysis adequacy among PD patients, emphasising the need for early detection and intervention. Malnutritional assessment tools, dietary modifications, and supplementation strategies are critical components of PD patients' care (Satirapoj et al., 2017).

2.7 Theoretical Models and Frameworks for Understanding Malnutrition and Dialysis Adequacy in Peritoneal Dialysis

The management of patients on peritoneal dialysis (PD) is a complex interplay of clinical, psychological and social factors. Two of the most critical determinants of patient outcomes are nutritional status and dialysis adequacy. Malnutrition and inadequate dialysis, measured by solute clearance targets like Kt/V_{urea} , are strongly linked to increased morbidity, mortality and reduced quality of life (Vera et al., 2022).

2.7.1 The Socio-Ecological Model (SEM)

The Socio-Ecological Model (SEM) provides a comprehensive framework for understanding the multifaceted influences on these outcomes. Originally developed by Urie Bronfenbrenner, the SEM posits that an individual's behaviour and health are shaped by a series of nested, interacting environmental systems, ranging from immediate personal settings to broad societal policies (Glanz et al., 2010). Applying this model to PD patients helps to move beyond a purely biomedical perspective and illuminates the various leverage points for intervention. Below is an application of this model to malnutrition and dialysis adequacy in the PD patients. The levels of the SEM are the following.

2.7.1.1 Individual Level

Malnutrition and dialysis adequacy in (PD) patients are heavily influenced by factors at individual level, including a patient's personal knowledge, attitudes, skills and biological characteristics. A patient's ability to self-manage their complex treatment regimen, such as dietary adherence, fluid intake management, and proper execution of dialysis exchanges successfully, is directly linked to their health literacy and self-efficacy. Research indicates that low health literacy poses a significant barrier to effective self-management, as it can impede a patient's understanding of their prescribed diet, medication schedule, and signs of complications like peritonitis (Almutairi, 2021).

A patient's attitude and psychological state, such as the presence of depression or anxiety, are critical individual-level factors because these conditions can affect motivation and the ability to adhere to dietary and dialysis protocols negatively, leading to poor nutrition and inadequate dialysis (Kang, 2020). High self-efficacy, or the belief in one's capacity to succeed in self-managing their condition, is a strong predictor of positive outcomes, including better nutritional status and improved dialysis adequacy. Psychological distress can lead to a lack of motivation to perform dialysis exchanges correctly or consistently, thereby compromising dialysis adequacy (Palmer et al., 2021).

Clinical and biological factors, including comorbidities like diabetes and cardiovascular disease (CVD), are strongly associated with a heightened state of chronic inflammation in PD patients. This persistent, low-grade inflammation, often referred to as "malnutrition-inflammation-atherosclerosis" (MIA) syndrome, is a central driver of PEW (Kalantar-Zadeh, 2020). The inflammatory cytokines released, such as interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNF- α), directly promote muscle protein catabolism and inhibit protein synthesis, leading to muscle wasting and sarcopenia. These inflammatory mediators also have a significant anorexigenic effect, suppressing appetite and reducing nutrient intake, which further exacerbate the state of PEW (Carrero et al., 2020). The vicious cycle of inflammation leading to malnutrition and subsequently to further inflammation is a key feature of the clinical decline observed in these patients.

Residual renal function (RRF) is arguably one of the most important clinical determinants of patient outcomes in PD, influencing both nutritional status and solute clearance. Residual renal function (RRF) provides continuous, non-dialytic clearance of uremic toxins, which are known to contribute to systemic inflammation and suppress appetite. When RRF declines, the patient becomes more dependent on the peritoneal dialysate for clearance, leading to a rise in circulating uremic toxins and a worsening of uremic symptoms, including anorexia (Wang, 2020). The preservation of RRF is directly linked to better nutritional status, as it helps to maintain appetite and reduce the inflammatory burden on the body. Furthermore, RRF contributes to fluid and electrolyte balance, which can indirectly have an impact on nutrition by preventing volume overload and its associated complications, such as cardiac dysfunction, which can also impair appetite and lead to a catabolic state (Rong, 2022).

A patient's understanding of their condition, the rationale for dietary restrictions, and the significance of dialysis technique are essential. Low health literacy is linked to poorer adherence to both dietary advice and the PD prescription (Griva et al., 2020). Conversely, high self-efficacy, the belief in one's ability to manage their treatment, is a strong predictor of successful adaptation, improved nutritional intake, and adherence to the prescribed number and volume of exchanges (Griva et al., 2021a).

2.7.1.2 Interpersonal Level

This level examines how social relationships with family, friends and the healthcare team affect the patient's health behaviours. As PD is a home-based therapy, these relationships are particularly influential (Almeida, 2022).

Family and Social Support: The role of a supportive partner or family member is critical. They can assist with meal preparation that meets strict renal dietary requirements (e.g. high protein, low sodium/potassium/phosphate), which can be burdensome for the patient alone. Family members may also assist with the physical demands of PD exchanges, such as lifting bags and maintaining a sterile environment, which have a direct impact on adequacy and reduce the risk of peritonitis, a major cause of malnutrition and technique failure (Walker et al., 2021). A study by Tana (2019) found a significant correlation between the nutritional status of elderly outpatients and their caregivers' burden, suggesting that a patient's poor nutritional status is a major

contributor to caregiver stress. This highlights a crucial feedback loop: patient malnutrition increases the demands on the caregiver, which in turn elevates burden and can lead to a neglect of dietary tasks, further worsening the patient's nutritional state (Tana, 2019). Lack of support or caregiver burnout can have the opposite effect, leading to neglect of both diet and dialysis tasks.

Patient-Clinician Relationship: A strong, trusting relationship with the PD nurse, nephrologist and renal dietitian is paramount. Regular and effective communication helps in troubleshooting problems with dialysis technique, adjusting prescriptions to meet adequacy targets, and providing personalised dietary counselling. When patients feel heard and supported by their clinical team, their adherence to complex medical advice improves significantly (Teo et al., 2023). A study by Griva et al. (2020) found that interventions focused on strengthening patient self-efficacy through supportive clinician-patient communication were highly effective in improving both medication adherence and dietary habits in chronic kidney disease patients. This suggests that a trusting, collaborative relationship acts as a foundation for effective self-management, which is essential for long-term success on PD (Griva et al., 2020). The dietitian's role is especially crucial for navigating the challenges of poor appetite and complex dietary needs.

2.7.1.3 Organisational/Community Level

This level examines the significant impact of the healthcare system and wider community on a patient's health outcomes. The structure and policies of the dialysis clinic and the availability of local resources are not merely external factors; they directly shape the patient's experience and ability to manage their condition effectively. A patient's success on peritoneal dialysis is heavily influenced by the quality of care they receive from their clinic, as well as the support systems available in their local community, such as access to transportation, social services, and support groups (Cavanaugh, 2022). These organisational and community factors can either facilitate or hinder the patient's capacity to maintain treatment adherence, manage nutritional needs, and prevent complications like peritonitis.

Dialysis Unit Structure and Resources: The policies and resources of the dialysis clinic have a direct impact on patient outcomes. This includes staffing ratios (especially the

availability of a dedicated renal dietitian and PD nurse), the quality and frequency of patient training and re-training, and the adoption of modern technologies. For instance, the use of remote patient monitoring with automated peritoneal dialysis (APD) cyclers allows clinical staff to track treatment adherence and fluid status daily, enabling proactive intervention to prevent inadequate dialysis (Weinhandl et al., 2022).

Access to Care and Community Services: Geographic proximity to the dialysis centre for monthly check-ups can be a barrier. For patients living in remote areas, access to specialised care is limited. Community-level factors like the availability and affordability of appropriate foods (e.g. fresh produce vs. processed foods) and access to transportation services for clinic visits play a significant role (Johnson et al., 2023a). Food insecurity is a powerful predictor of malnutrition in the dialysis population and is mediated by community and socioeconomic context. A study by Ikizler (2020) highlights that food insecurity is independently associated with inflammation, a key driver of malnutrition and protein-energy wasting in individuals with chronic kidney disease (Ikizler, 2020). This suggests that the problem extends beyond individual dietary choices and is deeply rooted in systemic issues related to food access and socioeconomic status.

2.7.1.4 Public Policy/Societal Level

This highest level of the model represents the broadest context influencing the health and well-being of peritoneal dialysis (PD) patients. This level encompasses the overarching laws, economic systems, and societal norms that determine the allocation of resources and the structure of the healthcare system. These macro-level factors, such as healthcare financing policies and national dietary guidelines, do not directly interact with the patient, but instead create the environmental conditions that shape everything from access to care to the affordability of nutritious food (USRDS, 2023). Therefore, understanding the societal context is crucial for a comprehensive analysis of malnutrition and dialysis adequacy.

Healthcare Policy and Reimbursement: Government and insurer policies heavily influence the provision of dialysis care. Policies that favour home therapies like PD can lead to better funding, infrastructure and support systems. Critically, the reimbursement for oral nutritional supplements and the coverage of dietitian services

can determine whether a patient at risk of malnutrition receives these vital interventions (Vera et al., 2022). In many systems, these supplements are an out-of-pocket expense, creating a significant barrier for low-income patients.

Socioeconomic Determinants: Poverty, education level, and employment status are powerful determinants of health. Patients with lower socioeconomic status are more likely to experience food insecurity, live in housing unsuitable for sterile PD exchanges, and have lower health literacy (Johnson et al., 2023b). These systemic disadvantages create a cumulative burden that directly undermines a patient's ability to achieve adequate nutrition and dialysis. Research from Al-Jahdali (2022) further supports the notion that socioeconomic status has a significant impact on patient outcomes in peritoneal dialysis. The study demonstrated that patients with lower socioeconomic status, indicated by factors such as low income, limited education, and unemployment, had a higher incidence of peritonitis and greater rates of technique failure. These patients often face barriers like inadequate housing, which makes maintaining the sterile environment required for PD exchanges more challenging, thus increasing the risk of infection (Al-Jahdali, 2022). This systemic disadvantage, combined with lower health literacy, makes it difficult for patients to effectively navigate the complex self-care requirements of their treatment, creating a cyclical burden that leads to poorer health outcomes.

Cultural Norms: Cultural norms significantly influence how patients with PD manage their condition. Traditional beliefs about food and diet, which are deeply ingrained, can often clash with the strict dietary restrictions required for PD, such as those related to sodium, potassium, and phosphorus. For example, many traditional diets are rich in staples that are high in these minerals, making it difficult for patients to adhere to medical advice without abandoning culturally significant foods (Griva et al., 2020). A study by Kovesdy (2021) highlights that a lack of culturally sensitive dietary counselling can lead to poor adherence and, consequently, negative nutritional outcomes. This issue is compounded by cultural norms around illness, where some patients may rely on traditional remedies or community healers instead of strictly following medical prescriptions (Kovesdy, 2021). Additionally, cultural expectations regarding family responsibility can influence caregiving dynamics. While some cultures emphasise strong family support, which can be beneficial, this can also create a burden on family

members who may not have the resources or knowledge to provide the necessary care, leading to caregiver burnout and inadequate patient support (Almutairi, 2023).

The Socio-Ecological Model demonstrates that malnutrition and inadequate dialysis in PD patients are not isolated clinical failures, but are the result of a complex web of interacting factors at individual, interpersonal, organisational and policy levels. An effective approach to improving outcomes must therefore be multi-pronged. Interventions should not only target the patient with education and prescriptions, but must also strengthen family support systems, ensure dialysis units are well-resourced and patient-centred, and advocate public policies that reduce socioeconomic barriers to care. By addressing challenges across all these levels, healthcare systems can create an environment where PD patients have the greatest opportunity to thrive.

2.7.2 The Chronic Care Model (CCM)

End-Stage Kidney Disease (ESKD) treated with PD is the archetypal chronic condition, requiring lifelong, complex self-management from patients and proactive, coordinated support from healthcare providers. Two persistent challenges that have a significant impact on patient survival and quality of life are malnutrition (or protein-energy wasting) and failure to achieve dialysis adequacy targets (Kt/V_{urea}). Traditionally, healthcare has operated on a reactive, acute-care basis, which is ill-suited for managing these ongoing issues (Al-Jahdali, 2022).

The Chronic Care Model (CCM), developed by Edward Wagner and colleagues, offers a practical, evidence-based framework for redesigning healthcare to serve patients with chronic illnesses better. The model's central thesis is that improved patient outcomes are achieved when informed and activated patients interact with a proactive and prepared practice team (Griva et al., 2020). The CCM is structured around six interacting elements that guide the transformation of care. Applying this model to the PD population provides a clear roadmap for systematically addressing the drivers of poor nutrition and inadequate dialysis. Below is an application of this model to the specific challenges of PD care. The six core elements of the Chronic Care Model are:

2.7.2.1 Health System-Organisation of Health Care

This element highlights the importance of organisational leadership in prioritising high-quality chronic disease management. It requires a cultural shift away from crisis management towards planned, proactive care (Epping-Jordan, 2004). A health system committed to the CCM would visibly support its home dialysis programs. This includes protecting clinician time for patient education, funding essential multidisciplinary roles (like renal dietitians and social workers), and establishing quality improvement as a core mission (Ghantous et al., 2022). For instance, leadership might champion a "home dialysis first" initiative, ensuring the PD program is well-resourced to handle complex patients, thereby preventing burnout and improving outcomes. This top-level support is essential for creating an environment where proactive nutritional monitoring and dialysis prescription adjustments are the norm, not the exception (Ghantous et al., 2022).

2.7.2.2 Self-Management Support

This is the cornerstone of effective chronic care, especially for a self-administered therapy like PD. It involves empowering patients with the skills, confidence and knowledge to manage their condition. Instead of just handing a patient a diet sheet, self-management support involves collaborative goal setting. A dietitian might use motivational interviewing to explore a patient's barriers to eating and co-develop strategies, such as setting a realistic goal of trying one new high-protein recipe per week or incorporating an oral nutritional supplement at a specific time of day (Lambert et al., 2021). The focus is on building skills, such as reading food labels for protein, phosphorus and potassium to foster patient autonomy.

Effective training goes beyond the initial technical steps. It includes teaching patients how to troubleshoot common cyclor alarms, recognise signs of fluid overload or inadequate dialysis (e.g. fatigue, nausea), and understand when to contact the clinic. Structured education programs that incorporate problem-solving and build patient self-efficacy have been shown to improve adherence to the PD prescription (Griva et al., 2021b).

2.7.2.4 Decision Support

This element focuses on integrating evidence-based guidelines into practice to assist both clinicians and patients in making informed choices. To combat malnutrition, clinics can embed reminders and protocols based on the Kidney Disease Outcomes Quality Initiative (KDOQI) nutrition guidelines directly into the electronic health record (EHR). For example, an automatic alert could be generated for the dietitian when a patient's serum albumin level falls below a predetermined threshold (Teo et al., 2023). For dialysis adequacy, clinicians can use specialised software (e.g. PD Adequest) that models a patient's peritoneal transport characteristics (from a Peritoneal Equilibration Test) to recommend an optimal dialysis prescription, ensuring evidence-based adjustments rather than trial and error (Griva et al., 2020).

2.7.2.4 Delivery System Design

This involves restructuring the care team to facilitate planned, proactive and collaborative care. It is about defining roles and distributing tasks effectively among a multidisciplinary team. An effective delivery system moves beyond the traditional, brief physician visit. It utilises a core PD team, comprising a nephrologist, a specialised PD nurse, a renal dietitian, and a social worker, who conduct regular, planned case conferences to discuss high-risk patients (Cho & Johnson, 2022). The PD nurse might lead on adherence and technique monitoring, while the dietitian screens proactively for nutritional risk at every visit. This proactive, team-based approach ensures that subtle declines in nutritional status or dialysis clearance are identified and addressed early. Planned follow-up calls between clinic visits by the nurse can reinforce education and troubleshoot issues before they become critical.

2.7.2.5 Clinical Information Systems

Effective chronic care is impossible without the systematic use of patient data. This element emphasises leveraging technology to track patients, monitor outcomes, and support care coordination. A well-designed EHR or a patient registry can generate lists of all patients with declining weight or albumin levels, allowing the team to target interventions efficiently. Tracking patient-reported outcomes, such as appetite scores, can provide early warnings of impending malnutrition (Verkaik et al., 2023).

Most automated peritoneal dialysis (APD) cyclers now have remote patient monitoring capabilities. This technology allows the clinical team to see a patient's actual treatment data, including total therapy time, drain volumes, and skipped treatments, daily. This provides an objective measure of adherence and allows for timely intervention, a vast improvement over relying on patient self-reports during monthly visits (Weinhandl et al., 2022).

2.7.2.6 Community Resources

This element recognises that the clinic is not an island. Health is influenced by the community context, and the healthcare system must help patients connect with external resources. The care team should be knowledgeable about and actively link patients to community programs. For a patient facing malnutrition due to cost, a social worker can connect them to food banks, meal delivery services (e.g. Meals on Wheels), or government-assistance programs. To enhance self-management and combat social isolation, clinics can partner with patient-led peer support groups, where experienced PD patients can share practical tips on diet, travel, and coping with the demands of the therapy (Johnson et al., 2023a). A study by Lim (2022) found that peer support programs are highly effective in providing practical and emotional support for patients on peritoneal dialysis (PD). These groups allow experienced PD patients to share real-world advice on managing dietary restrictions, troubleshooting technical issues, and coping with the psychological burden of a chronic illness. By facilitating these connections, healthcare systems empower patients to learn from one another's lived experiences, which can significantly improve their confidence and adherence to treatment (Lim, 2022).

The Chronic Care Model provides a robust and practical framework for transforming PD care from a reactive model to a proactive, patient-centred system. By implementing these six elements systematically, PD programs can create an integrated structure of support that empowers patients and prepares clinical teams to manage the long-term challenges of malnutrition and dialysis adequacy effectively. This approach moves beyond simply treating complications as they arise and instead builds a system designed to prevent them, ultimately leading to better health, improved quality of life, and greater longevity for patients on peritoneal dialysis (Lin et al., 2025a; Gheorghe et al., 2025; Jia et al., 2024).

2.7.3 Biopsychosocial (BPS) Model

The Biopsychosocial (BPS) Model, first proposed by psychiatrist George Engel in 1977, was a revolutionary call to move beyond a purely biomedical understanding of illness. It posits that health and disease are the products of a dynamic and reciprocal interaction between biological, psychological and social factors (Guerrero-Castañeda & Flores-Morales, 2021). For a chronic, demanding condition like End-Stage Kidney Disease (ESKD) managed with peritoneal dialysis (PD), the BPS model offers a holistic and patient-centred framework for understanding critical outcomes like nutritional status and dialysis adequacy (Birkenfeld et al., 2024).

Unlike models that focus primarily on systems of care delivery, the BPS model focuses on the integrated nature of the patient's experience. It compels clinicians to see malnutrition and inadequate dialysis not as isolated physiological failures, but as complex syndromes emerging from the interplay of body, mind, and environment (Serrano-Mendoza et al., 2023). This analysis explores the drivers of malnutrition and dialysis adequacy in PD patients through the three interconnected domains of the BPS model.

2.7.3.1 *The Biological Domain*

This domain encompasses the physiological and pathological processes underlying the patient's condition. It is the traditional focus of medical practice. The biological drivers of malnutrition in PD are numerous, such as:

- Inflammation and Uraemia, in which the chronic inflammatory state and the accumulation of uremic toxins directly suppress appetite and increase protein catabolism (Carrero et al., 2020).
- Dialysate-Related Factors, where patients continuously absorb large amounts of glucose from the dialysate, which can induce feelings of fullness and contribute to metabolic disturbances.
- Significant amounts of protein (5–15 grams daily) and amino acids are lost into the spent dialysate, creating a high protein requirement that is difficult to meet (Mehrotra & Kalantar-Zadeh, 2022).

- Comorbidities, which coexist with other conditions like diabetes mellitus, gastroparesis and cardiovascular disease further exacerbate the metabolic burden and reduce nutrient intake (Canaud et al., 2022).

Dialysis adequacy (Kt/V_{urea}) is fundamentally a biological measure in which the Peritoneal Membrane Function transport characteristics of the individual's peritoneal membrane determine the efficiency of solute clearance. Patients who are "high transporters" clear small solutes quickly, but may struggle with fluid removal (ultrafiltration) on long dwells (Hwang, 2021). A recent study by Wang (2020) confirms this biological phenomenon, showing that peritoneal transport status is a critical determinant of both solute clearance and fluid balance in PD patients (Wang, 2020).

Residual Renal Function (RRF), occurs where the patient's remaining kidney function is a powerful contributor to total solute clearance. As RRF inevitably declines, the reliance on peritoneal clearance increases, requiring adjustments to the dialysis prescription (Blake & Daugirdas, 2023).

Physical Limitations in which the physical ability to perform exchanges, including manual dexterity and abdominal integrity (e.g. absence of hernias or leaks), are essential for the dialysis to be delivered effectively.

2.7.3.2 The Psychological Domain

This domain includes the patient's thoughts, emotions, behaviours and coping mechanisms. In a self-care modality like PD, the psychological state is a potent determinant of success. The link between psychological state and nutrition is direct. Depression and Anxiety are highly prevalent in PD patients and are major causes of anorexia (loss of appetite). The emotional burden of chronic illness can make the act of preparing and eating food feel overwhelming (Palmer et al., 2021).

Health Beliefs and Motivation occurs where the patient's belief in their ability to manage their diet (self-efficacy) and their understanding of why nutrition is important directly influence their dietary adherence. A sense of hopelessness or "illness fatigue" can lead to apathy towards diet.

Behaviour is the final common pathway for achieving adequate dialysis. Adherence where the psychological factors are the primary drivers of non-adherence, is therefore a major clinical challenge in managing PD patients. Depression can sap motivation, leading to skipped or shortened exchanges. Anxiety about performing the technique correctly can lead to avoidance behaviours (Griva et al., 2021a).

Cognitive Function, in which mild cognitive impairment is common in ESKD, can affect a patient's ability to remember and follow the complex, multi-step procedure of a sterile PD exchange correctly, thereby compromising the delivered dose of dialysis.

2.7.3.3 The Social Domain

This domain considers the patient's social and environmental context, including family, community, socioeconomic status, and culture. Socioeconomic status and food security are where a patient's income level has a direct impact on their ability to afford the high-protein, fresh-food diet required in PD. Food insecurity is a powerful and independent predictor of malnutrition in the dialysis population (Johnson et al., 2023b).

The presence of a supportive family or caregiver who can assist with grocery shopping and cooking can be the difference between a well-nourished and a malnourished patient. Conversely, social isolation can lead to irregular eating habits and depression.

The social domain significantly influences dialysis adequacy for patients on PD. A patient's home environment is a critical factor; a clean, private and stable living space is essential for performing safe PD exchanges. Inadequate or unsanitary housing increases the risk of peritonitis, a serious complication that not only impairs the efficiency of the dialysis, but can also lead to long-term technique failure (Al-Jahdali, 2022). Furthermore, while family support is generally beneficial, the issue of caregiver burden can compromise a patient's care. Excessive reliance on a single caregiver can lead to burnout, which in turn can increase the likelihood of errors during the PD exchange process. A stressed or exhausted caregiver may be more prone to compromising sterility, having a direct influence on dialysis adequacy and increasing the risk of infection (Almutairi, 2023). Relationship with the Healthcare Team is vital, because a strong, trusting relationship with the PD nurse and dietitian fosters open communication, allowing patients to report problems with adherence or technique without fear of judgement (Walker et al., 2021).

The Biopsychosocial Model provides a vital, holistic lens through which to view the challenges of malnutrition and dialysis adequacy in peritoneal dialysis patients. It reminds clinicians that the patient is more than their lab values or their dialysis prescription. Lasting success in managing this chronic illness requires an integrated approach that simultaneously addresses the patient's physiological derangements, their emotional and behavioural health, and their socioeconomic and environmental realities. By embracing this model, healthcare teams can move towards a more compassionate, comprehensive, and ultimately more effective form of care.

Malnutrition and dialysis adequacy are two inextricably linked pillars of care for peritoneal dialysis patients. Malnutrition is a highly prevalent and devastating syndrome driven by a complex interplay of reduced intake, increased catabolism, inflammation (as highlighted by the IMA triad), and nutrient losses, significantly affecting patient morbidity and mortality. Simultaneously, dialysis adequacy, reflecting the efficient removal of uraemic toxins and maintenance of fluid balance, directly influences patient well-being and, in turn, can be compromised by or contribute to malnutrition (Kalantar-Zadeh & Fouque, 2017; Huang et al., 2023; ISPD, 2020).

The KDOQI guidelines and the theoretical frameworks of malnutrition syndrome and the IMA triad provide a robust foundation for understanding these complex interactions. In the unique context of public nephrology facilities in Gauteng province, South Africa, the assessment of this relationship is particularly crucial due to resource limitations, a high burden of comorbidities, and socioeconomic challenges. Comprehensive assessment utilising tools like SGA, alongside appropriate biochemical and anthropometric measures, is essential for identifying patients at risk. Understanding the reciprocal relationship between malnutrition and dialysis adequacy is fundamental to developing holistic and effective management strategies aimed at improving the long-term outcomes and quality of life for PD patients in this challenging environment.

CHAPTER 3: METHODOLOGY

The present study investigated the impact of malnutrition on dialysis adequacy in PD patients. The study addressed four objectives: to assess the nutritional status of PD patients using the Dialysis Malnutrition Score (DMS) questionnaire and anthropometric assessment tools; to evaluate dialysis adequacy in PD patients through the Kt/v formula and Urea Reduction Ratio (URR); to identify the factors influencing dialysis adequacy in PD patients; and to explore the correlation between dialysis malnutrition, dialysis adequacy, and biochemical markers in PD patients. The study hypothesised that malnutrition affects dialysis adequacy in PD patients. This chapter describes the research methodology, such as the selected research ethical considerations, study design, study population, sampling techniques, data collection methods, and ensuring the study's rigour and credibility.

3.1. Ethical Approval

The proposal was approved by the Faculty Health and Environmental Sciences Research and Innovation Committee of the Central University of Technology (CUT) and the South African Medical Association Research Ethics Committee (SAMAREC). Approval number (SAMAREC) 280808016/046/2024 (Appendix K). All parts of the study were conducted according to internationally accepted ethical principles and guidelines.

Permission was also granted by the hospital's authorities from SBAH (Appendix I) and Helen Joseph Hospital (Appendix J) to conduct the research and access patient records. The researcher committed to non-disclosure about the identity, the information or any other data of the patients enrolled in the study. The researcher committed that the collected data were for no other purpose than the specified objectives of the study, and all data would be kept confidential and anonymous.

3.2. Study Population

The study was conducted on PD patients with End Stage Kidney Disease (ESKD), in two public nephrology facilities, who participated voluntarily in the study. The study

was conducted in the Gauteng province of South Africa at the Steve Biko Academic Hospital (SBAH) and the Helen Joseph Hospital. A purposive sampling method was used, which involved participants who met the inclusion and exclusion criteria of the study. The study recruited a total of 81 adult patients (31 female and 50 male) (Figure 3.1) and this was done with the sample size calculation as per Appendix L.

3.2.1 Inclusion Criteria

- All PD patients were either on CAPD or APD.
- All patients participated voluntarily in the study and signed an informed consent document.
- Age group: ≥ 18 years and older.
- Patient had been receiving treatment for at least three months.

3.2.2 Exclusion Criteria

- Haemodialysis patients.
- Hospitalised patients within a month before data collection.
- Patients > 60 years of age.
- Known malnourished patients (diagnosed).
- Non-compliant patients.

3.2.3 Sample Size

According to the statistician, a sample size of 175 participants was sufficient to achieve the 95% confidence interval. However, a limitation of the study was that SBAH had a total of 44 PD patients, of whom 39 accepted to participate in the study. Helen Joseph had 52 patients, and only 42 patients accepted to participate in the study. Therefore, the total sample size was 81, comprising both male and female participants aged between ≥ 18 and ≤ 60 years, all currently receiving PD treatment. No withdrawals were reported throughout the duration of the study. The calculation equation of the

sample size is attached in Appendix L. Figure 3.1 below illustrates the recruitment of participants from two different PD units.

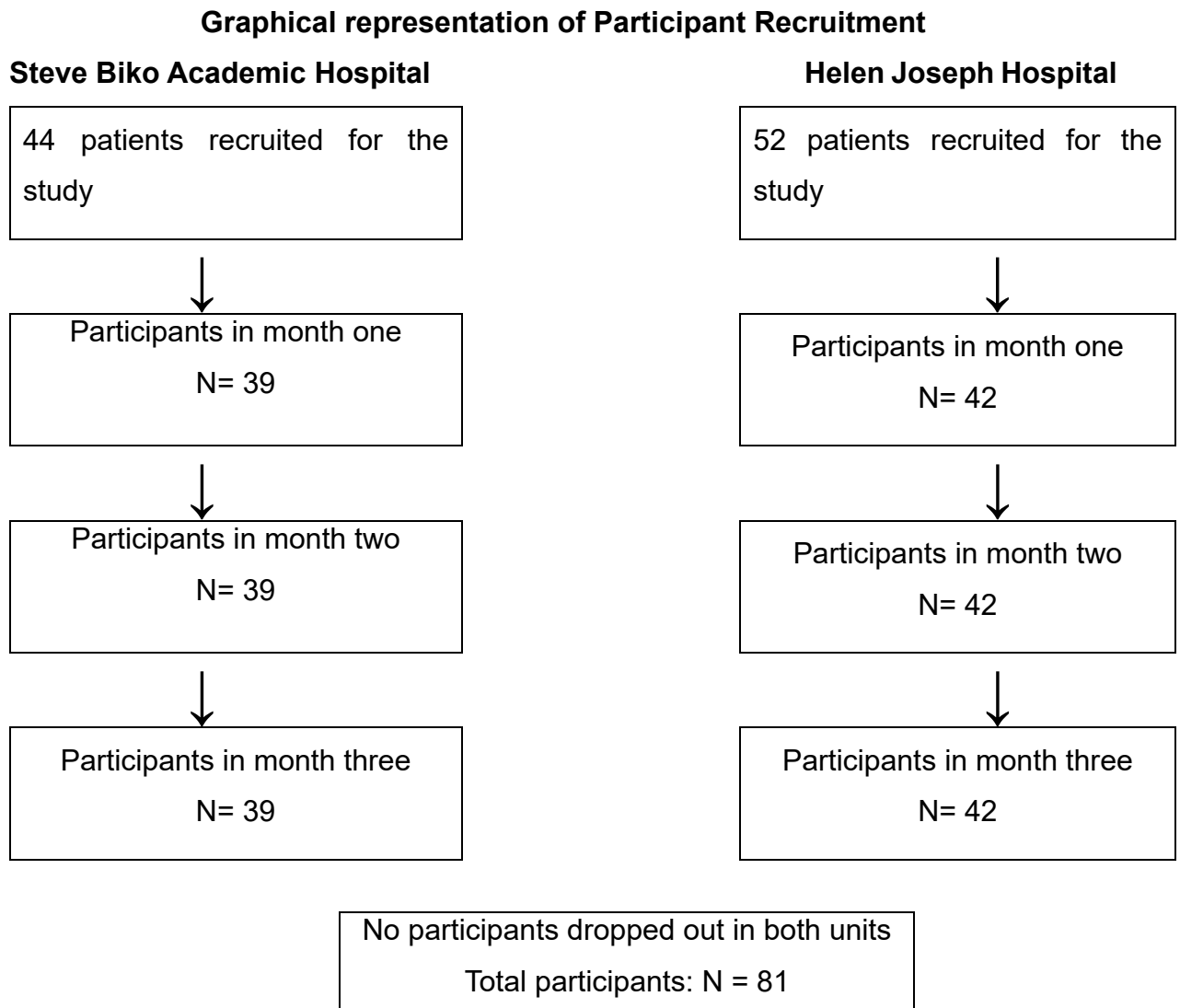


Figure 3.1: Participants' Recruitment

3.3 Study Design

A prospective longitudinal descriptive design was used, where data were collected from the two different public nephrology facilities in the Gauteng Province over a period of three months. The Dialysis Malnutrition Score (DMS) questionnaire (Appendix B) was used to determine the nutritional status, and the Kt/V formula (Appendix N) was used to determine dialysis adequacy. The study used quantitative data to determine the malnutritional status and dialysis adequacy of the PD patients. The study consisted

of three visits (Appendix D), which were scheduled 30 days after each visit for a period of three months.

3.4 Data Collection

The data collection sheet was used by the researcher to record the necessary data as outlined below. The data collection tools included the DMS questionnaire and patients' dialysis files. The data obtained included the patients' anthropometric measurements details for dialysis adequacy (Kt/V were calculated), and the biochemical markers (serum albumin, urea and creatinine). A registered dietician (Appendix H) was consulted after the measurements and calculations for malnutritional status had been done to ensure validity with the results achieved.

3.5 Equipment and Tools for Evaluation

To evaluate the malnutritional status and dialysis adequacy of patients undergoing PD, this research employed a multifaceted approach utilising a combination of specialised tools (such as Seca scale, metric tape measure, Harpenden calliper) and methods (DMS questionnaire, blood results).

3.5.1 Patient Information and Informed Consent Document (ICD)

All patients in the PD units from both facilities were recruited to participate in the study; however, the inclusion and exclusion criteria of the study were considered. Patients who did not meet the requirements for the study were excluded from the study. Patients were asked to sign the ICD voluntarily before study procedures could commence. The study procedures were explained, and patients had the opportunity to ask questions before they signed the ICD. The patients were also informed about the financial implications (no reimbursement) of the study. It was explained to the patients that they had the right to withdraw from the study at any time without any explanation. Patients were given the ICD (Appendix A) to complete when they agreed to participate in the study. In this study, no participants felt the need to withdraw after they had signed the consent to participate (no fallout).

3.5.2 Data Collection Sheet

A data collection sheet was used for recording data (Appendix C), which included information on gender, race, age, duration of PD, type of PD solution, and number of exchanges per day. Anthropometric assessment measurements, which included weight and height that was used to calculate the BMI, MUAC, TSF and AMA were also measured with each visit. Dialysis adequacy results using the Kt/V formula was recorded on the data sheet. Biochemical blood results (serum albumin, urea and creatinine) from the dialysis file were collected over three months.

3.5.3 Dialysis Malnutrition Score (DMS) Questionnaire

The Dialysis Malnutrition Score (DMS) questionnaire developed by Kalantar-Zadeh et al. (2001) was used to establish the nutritional status of the participant (Appendix B). The DMS was actually a modification of the subjective global assessment (SGA). Using the 7-point SGA aligns with the current international gold standard for comprehensive nutritional assessment in dialysis patients (Ikizler et al., 2020). The first part of the DMS included the patient's medical history (5 questions), including weight change, dietary intake over the past two weeks, gastrointestinal symptoms lasting longer than two weeks, and functional capacity of daily tasks. The second part of the DMS included a physical examination (2 questions), in which the loss of subcutaneous fat and the presence of muscle wasting were assessed. The variables were scored individually (1 to 5 each question), and the total of these scores (0 to 35) was used to determine the overall malnutrition rating of the participants, categorised as normal (0-5), mild (6-10), moderate (11-15), severe malnutrition (16-20) and very severe malnutrition (21-35).

3.5.4 Anthropometric Measurements

Body mass index (BMI) was calculated using the body weight (kg) and height (m) was measured using the Seca scale (seca GmbH, Germany). The height in centimetres (cm) was taken (Appendix E). The BMI was calculated using the weight in kg divided by height in metres (BMI= weight (kg)/height (m)²). Body mass index (BMI) was

classified into three categories: normal (18.5–24.9 kg/m²), overweight (25–29.9 kg/m²) and obese (≥ 30 kg/m²) (Appendix F).

Mid-Upper Arm Circumference (MUAC) were measured using a metric tape measure (Hoechstmass, Germany) at the midpoint between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna of the dominant arm. A flexible tape measure was wrapped around the midpoint of the upper arm, ensuring the tape was not too tight or too loose.

The Triceps Skinfold Thickness (TSF) was measured using a Harpenden calliper (HSB-BI; Baty International, United Kingdom). Measurement was taken by identifying the midpoint of the triceps muscle on the back of the upper arm. Using the thumb and index finger, the skinfold at the marked site was pinched, ensuring to grasp the skin and subcutaneous fat. The thickness of the skinfold was measured in millimetres (mm) using the calliper.

Arm-Muscle Area (AMA) was calculated from MUAC and TSF measurements (Appendix M). The AMA was determined from the upper-arm anthropometric measurements, MUAC and TSF (Álvarez-Córdova et al., 2024).

3.5.5 Biochemical Markers and Clinical Analysis

Blood results, including serum albumin, plasma urea and creatinine for the measure of solute clearance, were analysed by the National Health Laboratory Services (NHLS) at the hospitals and the blood results were retrieved in the participant's dialysis file over a period of 3 months. Due to limited resources, Peritoneal urea clearance (Kt) was not calculated, as the value of urea in the 24-hour dialysate sample was needed. The hospital was not able to admit the participant due to limited resources (hospital beds).

Dialysis adequacy measurements (Kt/V) were performed using Twardowski's formula (Twardowski, 2008) (Appendix N). The formula provided a Kt/V of 1.4 in PD patients, with a moderate to strong correlation with formally measured Kt/V values. Because of resource limitations, the updated formula recommended by the KDOQI Guidelines could not be utilised. Data (Ultrafiltration volume and Total body weight) were collected

over three months, with each visit occurring after a month. All visits for the 3-month period were conducted on the participants scheduled follow-up dates. The findings were discussed during the visits, as necessary.

3.6 Statistical/Data Analysis

Data from the data collection sheets were captured electronically by the researcher in Microsoft Excel, and data analysis was done by the registered Biostatistician (Appendix O). Analysis was done using Statistical Analysis System (SAS) Version 9.4. Descriptive statistics, namely frequencies and percentages, were calculated for categorical data (e.g. gender, age, ethnicity) and means and standard deviations or medians and percentiles were calculated for numerical data (e.g. weight, height, laboratory results, number of visits). The Shapiro-Wilk test for normality investigates if numerical data follows a normal distribution. Specifically, the Chi-Square test was used to compare frequencies or percentages between groups (gender, race, BMI, DMS). For paired data, the paired T-test or Signed Rank test was used to compare mean or median differences (age, MUAC, serum creatinine), and for unpaired data, the independent T-test or Mann-Whitney U-test was used to compare mean or median differences between groups (duration, TSF, AMA, serum albumin, serum urea). Correlation analysis was used to assess the correlation between variables. A significance level (p) of 0.05 was used in this study.

3.7 Quality Assurance

To ensure the validity and reliability of the research findings, a rigorous quality assurance framework was established and followed throughout the study. This framework involved implementing strict procedures for data collection, management, and analysis to minimise potential errors and bias. A data management plan was created to ensure data integrity, with procedures for double-entry of data and regular checks for completeness and accuracy. The study aimed to produce robust and trustworthy results that could withstand scientific scrutiny and contribute meaningfully to the body of knowledge.

3.7.1 Good Clinical Practice

All clinical work conducted under this protocol was subjected to the GCP guidelines (The Principle of ICH GCP & Stenvinkel). The declaration of Helsinki's basic principle number 3 states that research should be conducted only by scientifically qualified people and under the supervision of adequately qualified people (World Medical Association, 2018). Three fundamental ethical principles were followed throughout the study: respect for persons, beneficence, and justice. Privacy, anonymity and confidentiality were maintained throughout the study.

3.7.2 Safety Variables

The study was completely safe; no adverse effects resulted from the study. The blood results that were used in the study were derived from the standard unit protocols and were recommended by the South African Renal Society (SARS) as guidelines for optimal care of patients on Chronic dialysis in South Africa. No additional blood testing was done.

3.7.3 Participants' Confidentiality

The researcher ensured to comply with the POPI Act, as well as to protect and de-identify participants' personal information during the study. Consent had to be obtained before the collection of data, as highlighted in the Informed Consent document. All participants received a study code that was clearly distinguished between the two study sites. This code was used to de-identify participant data during and after the study to protect confidentiality during publications or presentations

All information obtained during the study was strictly confidential. The study data were coded so that they would not be linked to the participant's name. The participant's identity was not revealed while the study was being conducted or when the study was reported in scientific journals. The records were kept at the Hospital's Nephrology department and would be archived for five years. None of the information that were collected will be shared with any other person without the participant's permission. The ethics committee will have access to the data for audit purposes.

3.8 Financial Implications

No financial implications were expected from the participants, as they were seen when they visited the hospital during their routine monthly follow-ups. Participants were not reimbursed for participating in the study, as stipulated in the informed consent. The biochemical bloods were part of the routine monthly bloods, and no additional bloods were taken.

CHAPTER 4: RESULTS

This chapter presents a comprehensive account of the findings derived from analysing the data collected in line with the study's objectives. It details the results of both descriptive and inferential analyses, concentrating on the associations between dialysis malnutrition, dialysis adequacy and biochemical markers. When relevant, the findings are presented in tables and figures to provide clarity and facilitate understanding.

Furthermore, the chapter is structured to deliver the results in an organised manner, starting with an evaluation of demographics (gender, race, age, duration, type of solution). It then proceeds to the analyses related to the primary goals, such as (malnutritional status, anthropometrics, dialysis adequacy and biochemical markers). Finally, we analysed the correlations with dialysis adequacy for the set goals.

The statistical analysis was followed by the Shapiro-Wilk test, which was performed to investigate the distribution of continuous data. The interpretation of the p-value was as follows:

If $p < 0.05$, the variable does not follow a normal distribution, and the data are skewed, then the report on the median and interquartile range (IQR) is provided. If $p \geq 0.05$, the variable follows a normal distribution, and the data are not skewed, then the report on the mean (M) and standard deviation (SD) is reported. To compare the proportions between the two dialysis adequacy groups, the Chi-Square test/Fisher's exact test was used. The interpretation of the p-value is as follows: If $p < 0.05$, then there is a statistically significant difference between the proportions of the categories. If $p \geq 0.05$, then there is no significant difference between the proportions of the categories.

4.1 Evaluation of Demographics

4.1.1 Graphical Representation of the Gender Distribution

A total of 81 male and female participants were enrolled in the research study. Of those 81 participants, 50 were male (61.73%) and 31 were female (38.27%). The parameters

of the gender distribution are displayed in Figure 4.1 below.

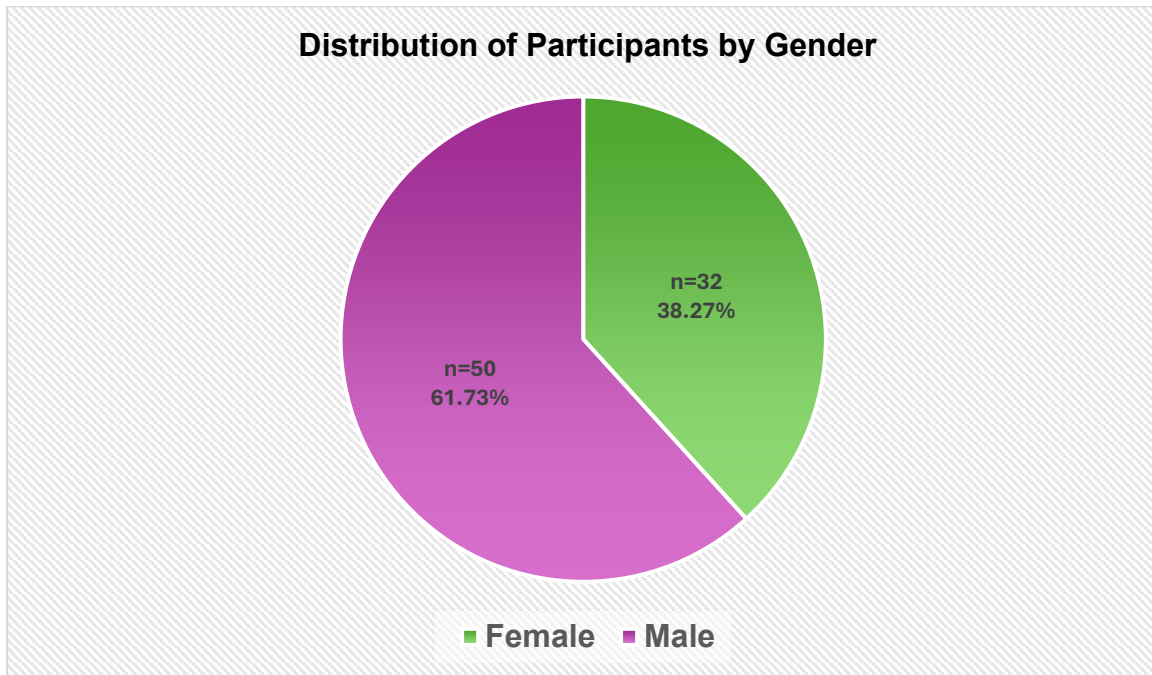


Figure 4.1: Distribution of Participants by Gender

4.1.2 Graphical Representation of the Race Distribution

Most participants were Black (72.84%), followed by Coloured (14.81%), White (8.64%), and Indian (3.70%) persons. The parameters for race distribution are displayed in Figure 4.2.

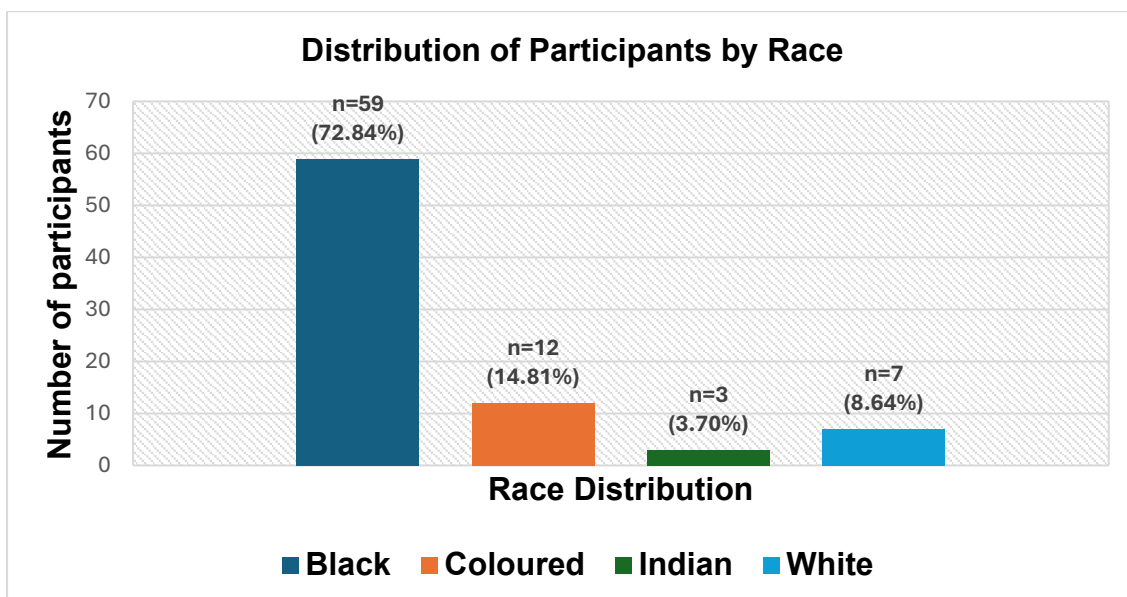


Figure 4.2: Distribution of Participants by Race

4.1.3 Graphical Representation of the Age Distribution

The participants' ages ranged from 20 to 71 years. The distribution of age was assessed for normality using the Shapiro-Wilk test. According to the Shapiro-Wilk test for normality, the distribution of the age of the participants follows a normal distribution ($W=0.973$, $p=0.0838$). The mean age was 45.3 years and $SD=11.9$ years. The parameters for age distribution are displayed in Figure 4.3.

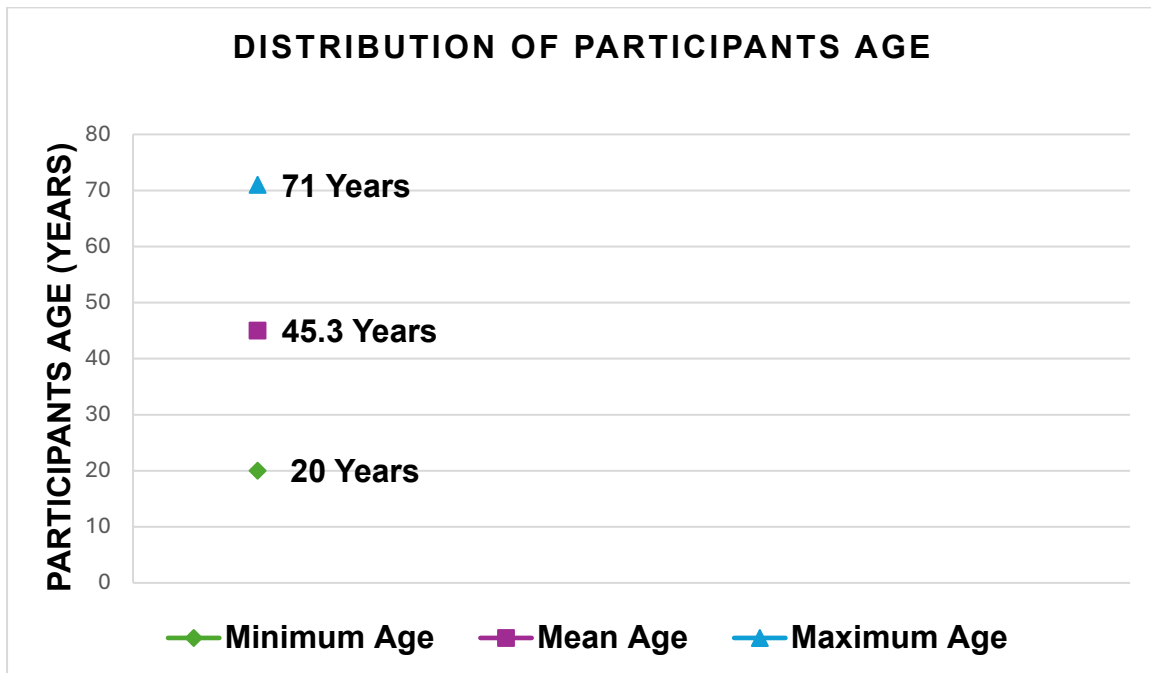


Figure 4.3: Distribution of Participants' Age

4.1.4 Graphical Representation of the Duration on Peritoneal Dialysis

The duration of PD for the 81 participants was assessed for normality using the Shapiro-Wilk test. The results displayed in Figure 4.4 indicated that the data were not normally distributed ($W=0.781$, $p<0.001$). The median duration of PD was 36 months, with an interquartile range from 16.0 to 60.0 months. The duration of PD ranged from a minimum of 3.0 months to a maximum of 240 months. This indicates that half of the participants had a PD duration between 16 and 60 months.

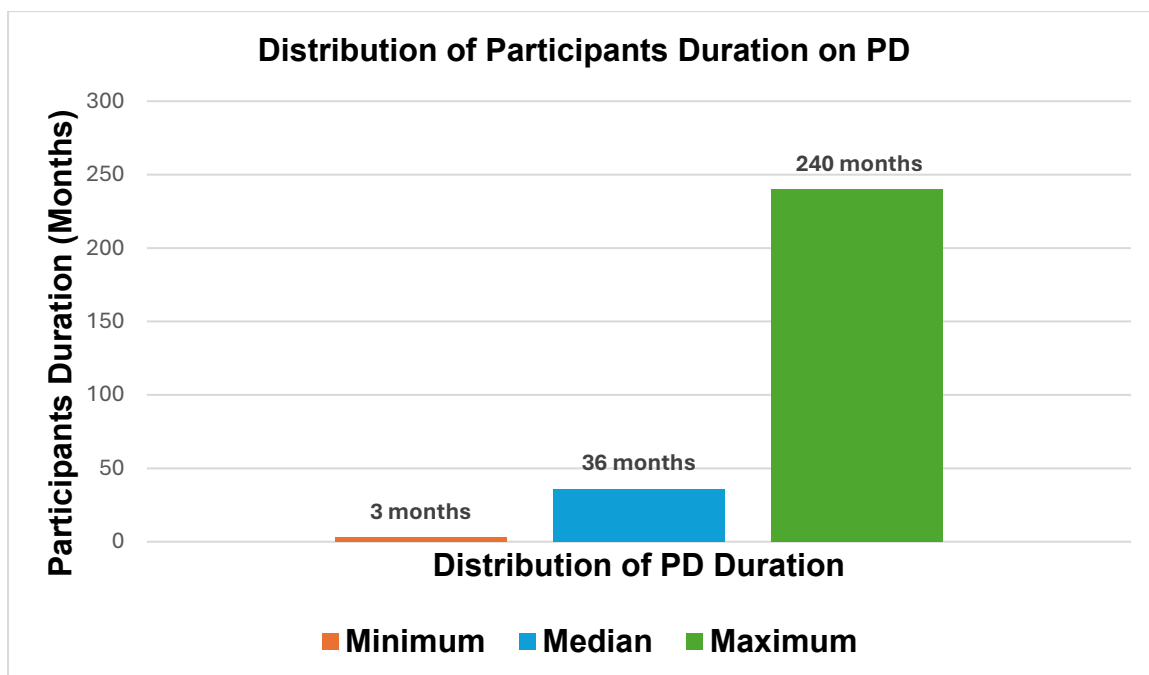


Figure 4.4: Distribution of Participants' Duration on PD

4.1.5 Graphical Representation of Peritoneal Dialysis Solution

The data displayed in Figure 4.5 show the participants who used the Single and Combined PD solution. The observed data on the Single solution show the majority of participants were using Dineal 1.5% PD solution (33.33%), followed by Dineal 1.5% and Dineal 2.5% PD solution (22.22%), Dineal 2.5% PD solution (19.75%), Dineal 2.5% and Extraneal PD Solution (18.52%), Dineal 1.5% PD solution and Extraneal PD Solution (4.94%). One participant was on 3 solutions (1.23%). None of the participants was on Dineal 4.25% PD Solution.

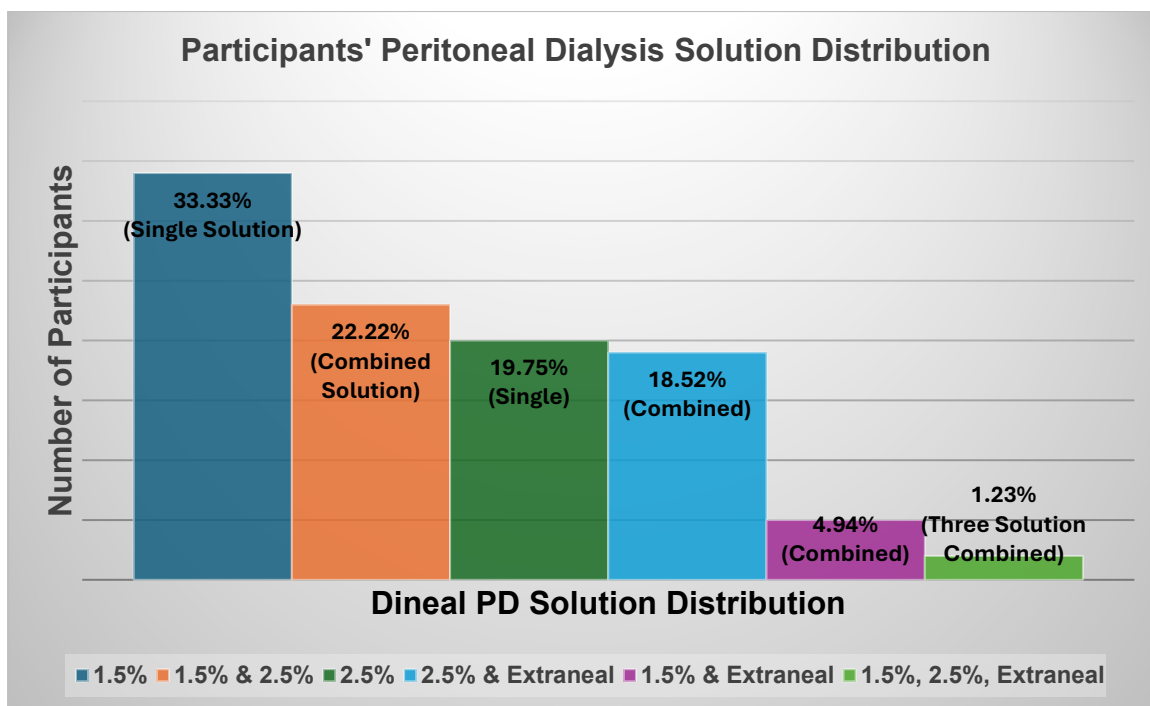


Figure 4.5: Participants' Peritoneal Dialysis Solution Distribution

4.2 Evaluation of Malnutritional Status

The results of the three visits for DMS are displayed in Figure 4.6 below. Of the 81 participants, the participants displayed very severe malnutrition (score 21–30) (18.52%), severe malnutrition (score 16–20) (34.57%), moderate malnutrition (score 11–15) (32.10%), and mild malnutrition (6–10) (14.81%).

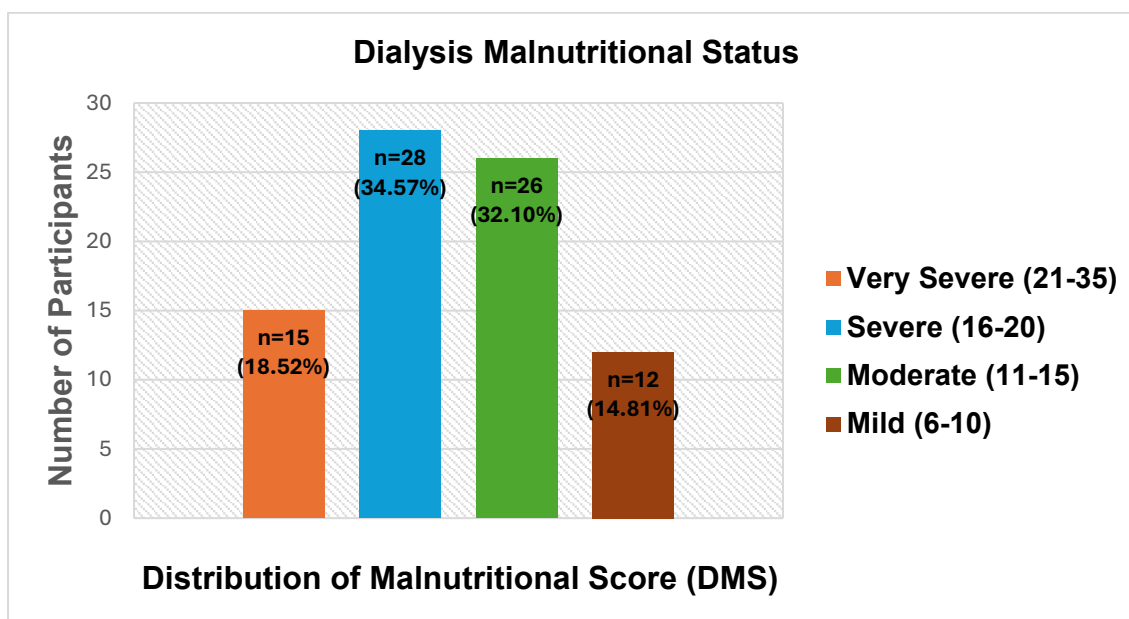


Figure 4.6: Dialysis Malnutritional Status

4.3 Evaluation of Anthropometric Measurements

4.3.1 Evaluation of the Body Mass Index (BMI)

A total of 81 male and female participants' anthropometric measurements were taken over 3 months. The distribution of the participants' BMI was assessed using the Shapiro-Wilk test for normality. According to the Shapiro-Wilk test for normality the distribution of the BMI of the participants followed a normal distribution ($W=0.979$, $p=0.193$). As such, the data are appropriately summarised by the mean and standard deviation. The mean BMI was 25.56, and the SD was 4.64 (Table 4.1).

4.3.2 Evaluation of the Weight (Total Body Weight)

The Shapiro-Wilk test for normality on the participants' weight data showed that the data were consistent with a normal distribution ($W=0.987$, $p=0.564$). Therefore, the mean and standard deviation were appropriate for describing the data. The mean weight was 71.86 kg, with a standard deviation of 15.23 kg (Table 4.1). This indicates that the participants' weights were distributed symmetrically around the mean, with a spread of approximately 15.23 kg.

4.3.3 Evaluation of the Height

The distribution of the participants' height was assessed for normality using the Shapiro-Wilk test, which indicates that the height data are consistent with a normal distribution ($W=0.990$, $p=0.809$). Accordingly, the data are summarised using the mean and standard deviation. The mean height of the participants was 167.58 cm (SD=9.22 cm) (Table 4.1).

4.3.4 Representation of Mid-Upper Arm Circumference (MUAC)

The Shapiro-Wilk test for normality of the participants' (MUAC) results indicates that the data are consistent with a normal distribution ($W=0.972$, $p=0.071$). Accordingly, the mean and standard deviation are the appropriate measures to describe the central tendency and dispersion of the data. The mean MUAC was 31.83 cm, and the SD was 5.93 cm (Table 4.1).

Table 4.1: Clinical Parameters of patients (n=81) BMI, Weight, Height & MUAC

Variables	Means	Standard Deviations(SD)
BMI (kg/m ²)	25.56	4.64
Weight (kg)	71.86	15.23
Height (cm)	167.58	9.22
MUAC (cm)	31.83	5.93

4.3.5 Graphical Representation of Triceps Skin Folds (TSF)

The distribution of the participants' triceps skinfold (TSF) measurements was assessed using the Shapiro-Wilk test for normality, which indicated that the data were not normally distributed ($W=0.966$, $p=0.030$). Consequently, the TSF data are presented using the median and interquartile range (IQR). The median TSF was 23.00 mm, with an IQR from 20.00 mm to 31.00 mm (Table 4.2). The TSF values ranged from a minimum of 8.00 mm to a maximum of 42.00 mm. This indicates that 50% of the participants had a TSF measurement between 20.00 mm and 31.00 mm.

4.3.6 Graphical Representation of Arm Muscle Area (AMA)

The distribution of the participants' arm muscle area (AMA) measurements was assessed using the Shapiro-Wilk test for normality, which indicated that the data were not normally distributed ($W=0.867$, $p<0.001$). Consequently, the AMA data are presented using the median and interquartile range (IQR). The median AMA was 14.30 cm², with an IQR from 5.60 cm² to 32.00 cm² (Table 4.2). The AMA values ranged from a minimum of 0.01 cm² to a maximum of 92.00 cm². This indicates that 50% of the participants had an AMA measurement between 5.60 cm² and 32.00 cm².

Table 4.2: Clinical Parameters of patients (n=81) TSF and AMA

Variables	Median	Interquartile Range (IQR)
TSF (mm)	23.00	20.00–31.00
AMA (cm ²)	14.30	5.60–32.00

4.4 Graphical Representation of Dialysis Adequacy: Adequate Dialysis versus Inadequate Dialysis

Our findings show that within our population, we continue to have 38.27% of patients who had inadequate dialysis ($Kt/V < 1.4$), and 61.73% of the participants had adequate dialysis ($Kt/V > 1.4$). Figure 4.7 shows the distribution of dialysis adequacy.

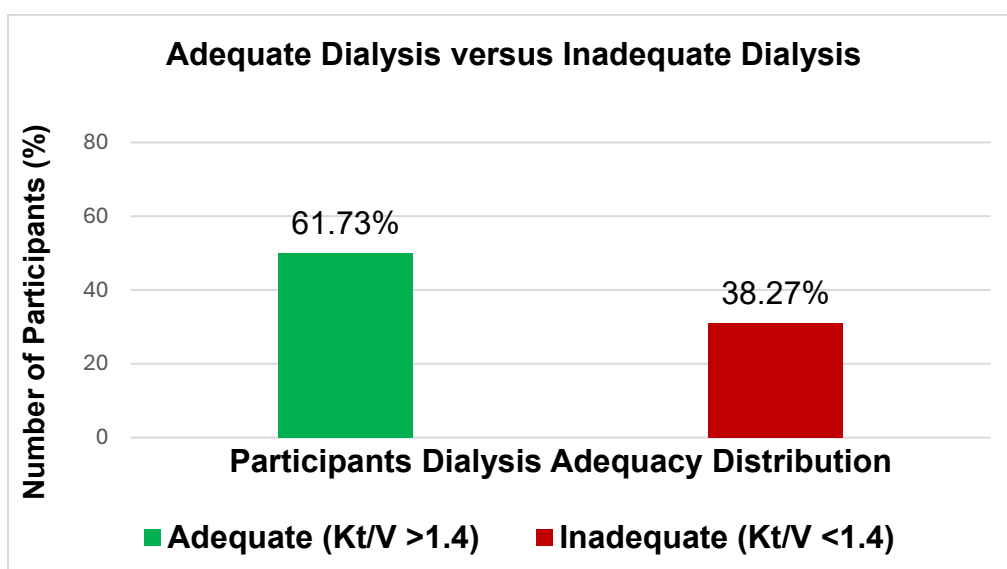


Figure 4.7: Adequate versus Inadequate Dialysis

The distribution of the participants' Kt/V measurements was assessed using the Shapiro-Wilk test for normality; the results indicated that the data were not normally distributed ($W=0.909$, $p < 0.001$). Consequently, the Kt/V data are presented using the median and interquartile range (IQR). The median Kt/V was 1.40, with an IQR from 1.20 to 1.70 (Table 4.3). The Kt/V values ranged from a minimum of 1.00 to a maximum of 2.70. This indicates that 50% of the participants had a Kt/V measurement between 1.20 and 1.70.

Table 4.3: Clinical Parameters of patients (n=81) Kt/V

Variables	Median	Interquartile Range (IQR)
Kt/V	1.4	1.20 -1.70

4.5 Evaluation of Biochemical Markers

4.5.1 Graphical Representation of Serum Albumin

The distribution of the participants' serum albumin levels was assessed using the Shapiro-Wilk test for normality. The results indicated that the data were not normally distributed ($W=0.965$, $p=0.026$). Consequently, the albumin data are presented using the median and interquartile range (IQR). The median albumin level was 34.00 g/L, with an IQR from 30.00 g/L to 37.00 g/L (Table 4.4). The albumin levels ranged from a minimum of 18.67 g/L to a maximum of 44.67 g/L. This indicates that 50% of the participants had an albumin level between 30.00 g/L and 37.00 g/L.

4.5.2 Graphical Representation of Serum Urea

The distribution of the participants' serum urea levels was assessed using the Shapiro-Wilk test for normality. The results indicated that the data were not normally distributed ($W=0.956$, $p=0.007$). Consequently, the serum urea data are presented using the median and interquartile range (IQR). The median urea level was 20.47 mmol/L, with an IQR from 17.07 mmol/L to 25.37 mmol/L. The urea levels ranged from a minimum of 9.27 mmol/L to a maximum of 39.13 mmol/L (Table 4.4). This indicates that 50% of the participants had a urea level between 17.07 and 25.37 mmol/L.

Table 4.4: Clinical Parameters of patients (n=81) Serum Albumin & Urea

Variables	Median	Interquartile Range (IQR)
Serum Albumin (g/L)	34.00	30.00–37.00
Serum Urea (mmol/L)	20.47	17.07–25.37

4.5.3 Representation of Serum Creatinine

The distribution of the participants' creatinine levels was assessed for normality using the Shapiro-Wilk test. The results showed that the data are consistent with a normal distribution ($W=0.981$, $p=0.257$). Accordingly, the data are summarised by the mean and standard deviation. The mean creatinine level was 1 046.10, with a standard deviation of 391.10 (Table 4.5).

Table 4.5: Clinical Parameters of patients (n=81) Serum Creatinine

Variables	Means	Standard eviations(SD)
Seum Creatinine ($\mu\text{mol/L}$)	1046.10	391.10

4.6 Correlations of Dialysis Adequacy and Demographics

4.6.1 Dialysis Adequacy versus Gender Distribution

Results representing the correlation between dialysis adequacy and gender are displayed in Figure 4.8 below. Of the 81 participants, 50 had adequate dialysis of ≥ 1.4 (22 female, 22 male) and 31 had inadequate dialysis of ≤ 1.4 (9 female, 22 male). According to the Chi-Square test, the correlation between dialysis adequacy and gender was not statistically significant ($p = 0.1779$). This result was also confirmed using Fisher's Exact test ($p=0.2406$).

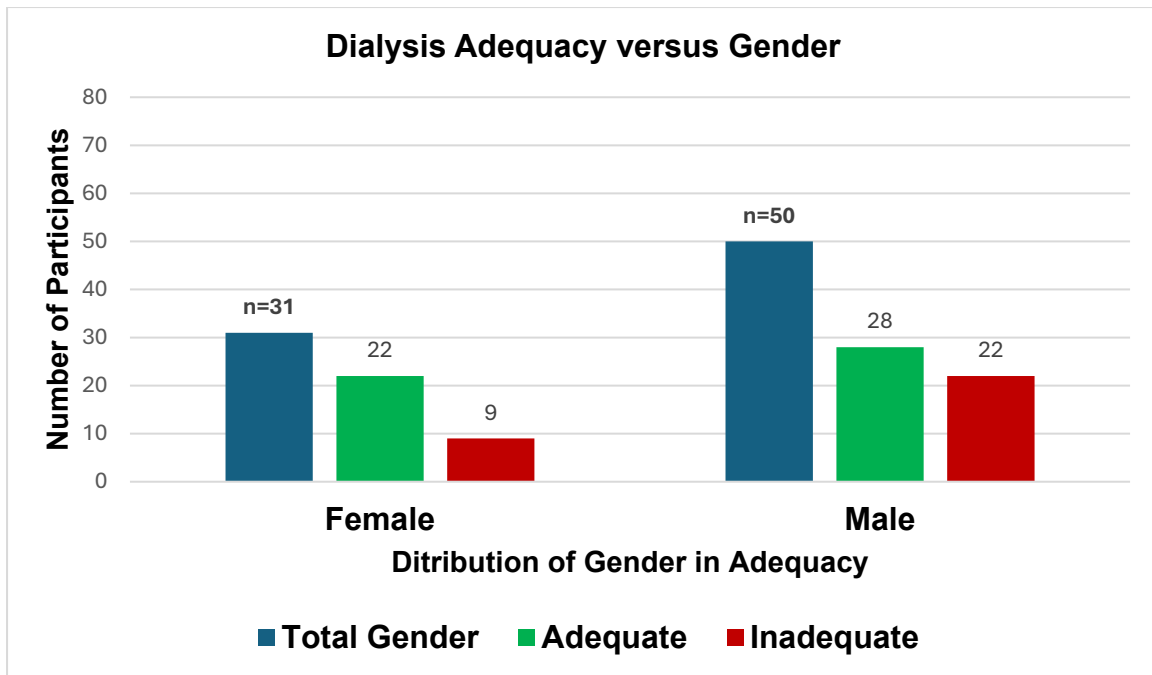


Figure 4.8: Dialysis Adequacy versus Gender

4.6.2 Dialysis Adequacy versus Race Distribution

Results representing the correlation between dialysis adequacy and race are displayed in Figure 4.9 below. From the Fisher's exact test, the correlation between dialysis adequacy and race was not significant ($p=0.8754$). This test was also confirmed using the Chi-Square test ($p=0.7934$).

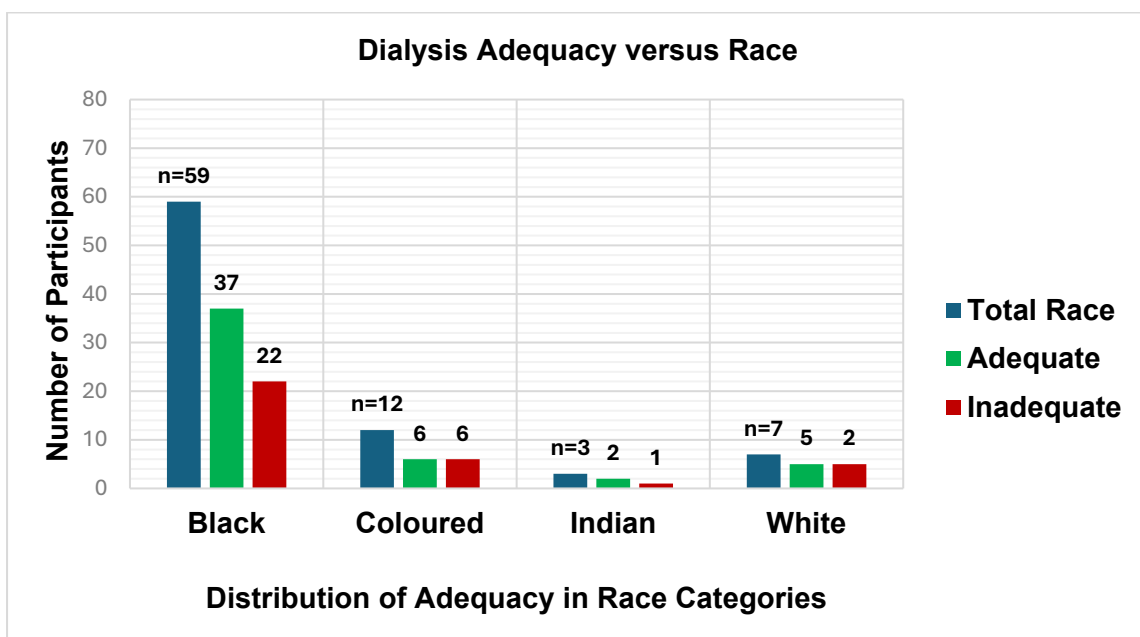


Figure 4.9: Dialysis Adequacy versus Race

4.6.3 Dialysis Adequacy versus Age Distribution

Results representing the correlation between dialysis adequacy and age are displayed in Table 4.6 below. From the paired T-test, the correlation between dialysis adequacy and age was significant ($p=0.0033$). There was a significant difference between the mean values of the groups. A significant effect was observed.

Table 4.6: Correlation between Age and Dialysis Adequacy

Variables	N	Minimum Years	Maximum Years	Mean (Years)	Standard Deviation (SD)
Adequate >1.4	50	20.0	68.0	42.3	12.2
Inadequate <1.4	31	28.0	71.0	50.2	9.8

4.6.4 Dialysis Adequacy versus Duration on Peritoneal Dialysis

Results representing the correlation between dialysis adequacy and duration on PD are displayed in Table 4.7 below. From the Mann-Whitney U-test, the correlation between dialysis adequacy and duration was not significant ($p=0.0997$). This test was also confirmed using the Chi-Square test ($p=0.0987$). There was no significant difference between the median values of the categories.

Table 4.7: Correlation between Duration and Dialysis Adequacy

Variables	N	Minimum (Months)	Maximum (Months)	Median (Months)
Adequate >1.4	50	3.0	240.0	36.5
Inadequate <1.4	31	3.0	144.0	24.0

The table below is a summary of the Demographics Results, highlighting the p-value and its significance.

Table 4.8: Summary of Demographic Results

Variables	p-value	Significant (p < 0.05) Not Significant (p. 0.05)
Gender	0.1779	p > 0.05
Race	0.8754	p > 0.05
Age	0.0033*	p < 0.05
Duration	0.0997	p > 0.05

4.7 Correlation of Dialysis Adequacy and Malnutritional Status

The parameters comparing dialysis adequacy to malnutrition displayed in Figure 4.10 proved to be not significant. From the Chi-Square test, the correlation between dialysis adequacy and malnutritional status (DMS) was not significant (p=0.9714).

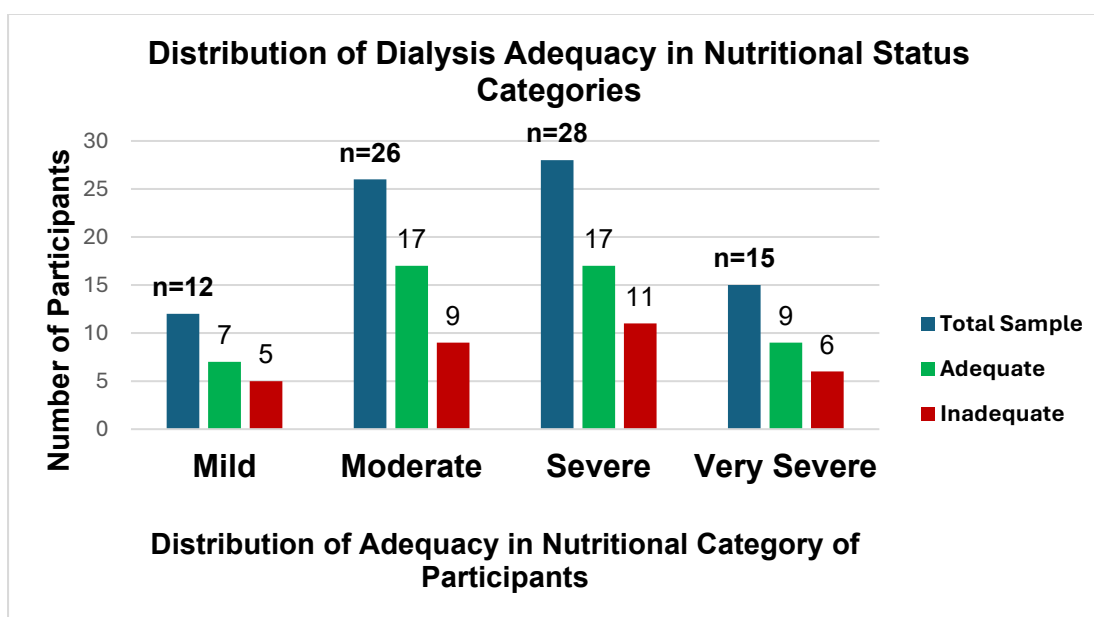


Figure 4.10: Distribution of Dialysis Adequacy in Nutritional Status Categories

4.8 Correlation of Dialysis Adequacy and Anthropometric Measurements

4.8.1 Dialysis Adequacy versus Body Mass Index (BMI)

The parameters comparing dialysis adequacy to BMI displayed in Figure 4.11 proved to be significant. From the Fisher's exact test, the correlation between dialysis

adequacy and BMI is significant ($p=0.0001$). This test was also confirmed using the Chi-Square test ($p=0.0001$).

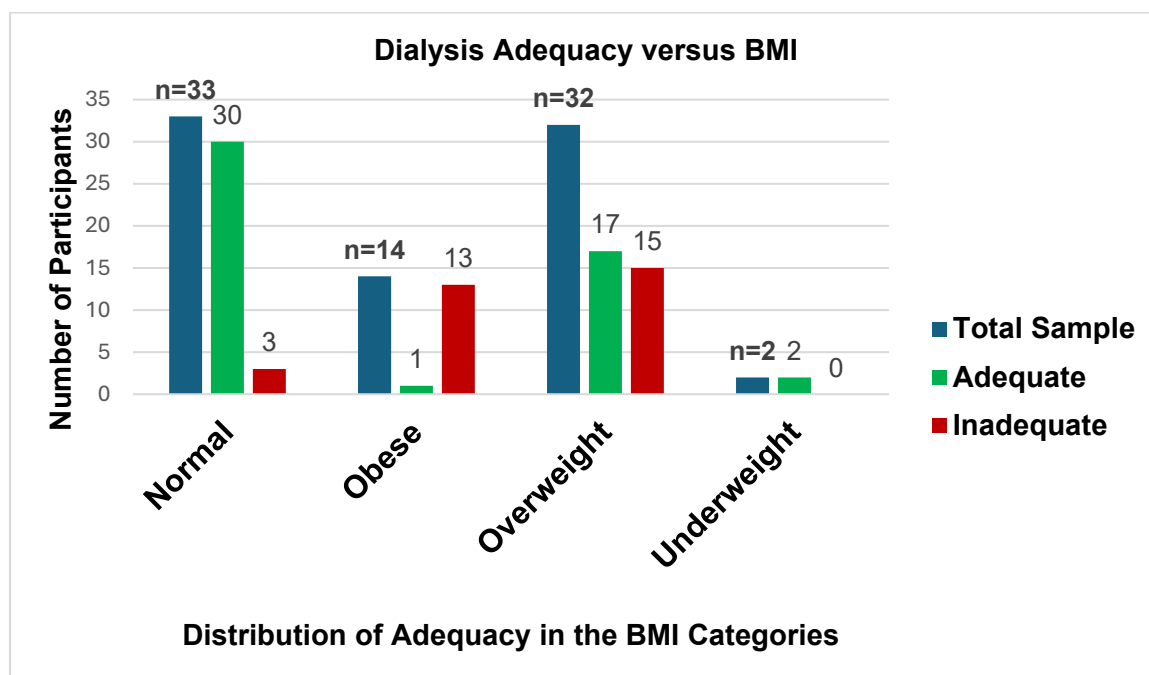


Figure 4.11: Dialysis Adequacy versus BMI

4.8.2 Dialysis Adequacy versus Mid Upper Arm Circumference (MUAC)

The parameters comparing dialysis adequacy to MUAC proved to be not significant. Results are displayed in Table 4.9 below. From the independent T-test, the correlation between dialysis adequacy and MUAC was not significant ($p=0.1203$). This test was also confirmed using the Chi-Square test ($p=0.1637$).

Table 4.9: Correlation between MUAC and Dialysis Adequacy

Variables	N	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation (SD)
Adequate > 1.4	50	21.00	46.00	31.02	6.35
Inadequate < 1.4	31	24.00	44.00	33.13	5.00

4.8.3 Dialysis Adequacy versus Triceps skin folds (TSF)

The parameters comparing dialysis adequacy to TSF and AMA proved to be significant. Results are displayed in Table 4.10 below. From the Mann-Whitney U-test,

the correlation between dialysis adequacy and TSF is significant ($p=0.0006$). This test was also confirmed using the Chi-Square test ($p=0.0006$).

Table 4.10: Correlation between TSF and Dialysis Adequacy

Variables	N	Minimum (mm)	Maximum (mm)	Median (mm)
Adequate > 1.4	50	8.00	40.0	21.00
Inadequate < 1.4	31	10.00	42.00	31.00

4.8.4 Dialysis Adequacy versus Arm Muscle Area (AMA)

The parameters comparing dialysis adequacy to AMA proved to be significant. Results are displayed in Table 4.11 below. From the Mann-Whitney U-test, the correlation between dialysis adequacy and AMA is significant ($p=0.0006$). This test was also confirmed using the Chi-Square test ($p=0.0006$).

Table 4.11: Correlation between AMA and Dialysis Adequacy

Variables	N	Minimum (cm ²)	Maximum (cm ²)	Median (cm ²)
Adequate > 1.4	50	0.01	85.52	9.90
Inadequate < 1.4	31	0.40	92.00	29.90

The table below is a summary of Anthropometric Results, highlighting the p-value and its significance.

Table 4.12: Summary of Anthropometric Results

Variables	p-value	Significant (p < 0.05) Not Significant (p. 0.05)
BMI	*0.0001	p < 0.05
MUAC	0.1203	p > 0.05
TSF	*0.0006	p < 0.05
AMA	*0.0006	p < 0.05

4.9 Correlation of Dialysis Adequacy and Biochemical Markers

4.9.1 Dialysis Adequacy versus Serum Albumin

The parameters comparing dialysis adequacy to serum albumin are displayed in Table 4.13. From the Mann-Whitney U-test, the correlation between dialysis adequacy and Serum Albumin is significant (p=0.0057). This test was also confirmed using the Chi-Square test (p=0.0056).

Table 4.13: Correlation between Seum Albumin and Dialysis Adequacy

Variables	N	Minimum (g/L)	Maximum (g/L)	Median (g/L)
Adequate > 1.4	50	18.67	44.67	32.50
Inadequate < 1.4	31	22.67	43.00	35.33

4.9.2 Dialysis Adequacy versus Serum Urea

The parameters comparing dialysis adequacy to serum urea are displayed in Table 4.14. From the Mann-Whitney U-test, the correlation between dialysis adequacy and Serum Urea was not significant (p=0.5897). This test was also confirmed using the Chi-Square test (p=0.5863).

Table 4.14: Correlation between Serum Urea and Dialysis Adequacy

Variables	N	Minimum (mmol/L)	Maximum (mmol/L)	Median (mmol/L)
Adequate > 1.4	50	9.27	38.67	19.93
Inadequate < 1.4	31	11.87	39.13	21.40

4.9.3 Dialysis Adequacy versus Serum Creatinine

The parameters comparing dialysis adequacy to serum creatinine are displayed in Table 4.15. From the independent T-test, the correlation between dialysis adequacy and Serum Creatinine was not significant ($p=0.4704$). This test was also confirmed using the Chi-Square test ($p=0.4975$).

Table 4.15: Correlation between Serum Creatinine and Dialysis Adequacy

Variables	N	Minimum ($\mu\text{mol/L}$)	Maximum ($\mu\text{mol/L}$)	Mean ($\mu\text{mol/L}$)	Standard Deviation (SD)
Adequate > 1.4	50	283.33	1767.67	1070.99	375.65
Inadequate < 1.4	31	346.67	1881.33	1005.96	417.98

The table below is a summary of Biomarker Results, highlighting the p-value and its significance.

Table 4.16: Summary of Biochemical Results

Variables	p-value	Significant ($p < 0.05$) Not Significant ($p \geq 0.05$)
Serum Albumin	0.0057	$p < 0.05$
Serum Urea	0.5897	$p > 0.05$
Serum Creatinine	0.4704	$p > 0.05$

CHAPTER 5: DISCUSSION

This study aimed to assess the prevalence of malnutrition and its association with dialysis adequacy in adult patients undergoing peritoneal dialysis at public nephrology facilities in the Gauteng province. The objectives were set to assess the malnutritional status of the PD patients using the DMS questionnaire and anthropometric measurements to determine dialysis adequacy using the Kt/V formula, to determine the factors influencing dialysis adequacy and lastly to determine the correlation between dialysis adequacy, dialysis malnutrition and biochemical markers in PD patients.

A dialysis malnutrition score (DMS) questionnaire was used to determine the malnutritional status and dialysis adequacy using Kt/V was calculated to determine dialysis adequacy. Anthropometric measurements and biomarkers were recorded. The data distributions and correlations of different parameters were searched, and findings were discussed as follows.

5.1 Evaluation of Demographics

5.1.1 Gender Distribution

According to the present study of 81 participants, the gender distribution showed a higher percentage of males at 61.73% compared to females at 38.27%. The provided gender distribution suggests that a majority of the peritoneal dialysis (PD) patients in our study population are male. Our findings are similar to general epidemiological trends in end-stage kidney disease (ESKD), where men generally show a faster progression to ESKD (Ricardo, 2020). Similar studies, such as that of Gao et al. (2021), with a larger cohort of a 266 sample population, found a comparable gender distribution, with a slightly higher proportion of males at 50.8% and females at 49.2% in their cohort of CAPD patients. Consequently, Nerbass et al. (2025) report a higher percentage of females at 52% compared to males at 48% patients on peritoneal dialysis in Brazil. Contrary to our findings, a study by Song et al. (2021) shows that being male is an independent risk factor for inadequate dialysis.

5.1.2 Race Distribution

Our results showed a higher percentage of Black patients (72.84%), compared to patients of other races within our study population. Similar findings by Sunnyraj et al. (2023) show Black African patients as predominant. This reflects the demographics of the public-health sector it serves. Based on the South African Renal Registry (2022), Black individuals make up the largest percentage of patients on Kidney Replacement Therapy (KRT) in South Africa, despite significant disparities in access and prevalence rates per million population across ethnic groups. A similar study by Mashego et al. (2023) shows that there is no statistically significant ($p=0.142$) correlation between race and dialysis adequacy. The study also found that Black African ethnicity is associated with a reduced mortality hazard, which is an interesting, related finding (Mashego et al., 2023).

Contrary to our findings, a study by Trinh et al. (2017) shows that race is a statistically significant ($p<0.05$) factor in peritoneal dialysis outcomes. The study findings should consider culturally specific dietary habits across the Black, Coloured, White and Indian groups, as these can have an impact on adherence to the high-protein, high-calorie and potassium/phosphate-restricted PD diet. Tailored dietary counselling is often required.

5.1.3 Age Distribution

In our study cohort, the mean age was relatively young on average (45.3 years). Similarly, a study by Rhee et al. (2021) reports the mean age and standard deviation, ranging from 19 to 81 years. Contrary to this finding, a prospective observational cohort study by Zhou et al. (2022) indicates a higher median age of 57.0 years compared to our mean of 45.3 years and further shows that the data are not normally distributed in this patient population.

Younger patients generally have higher energy and protein needs due to a more active lifestyle, greater lean-body mass, and higher basal metabolic rates, compared to elderly patients. The recommended dietary intake for PD patients under 65 years is 35 kcal/kg/day (compared to 30-35 kcal/kg/day for those over 65), and 1.2–1.3

g/kg/day of protein (Carrero et al., 2023). A younger cohort may require more intensive nutritional counselling to meet these high demands.

5.1.4 Duration on Peritoneal Dialysis

Our results showed a median duration of 36 months, representing a significant period of constant nutrient drain. Similarly, a retrospective study by Guo et al. (2022) shows a median of 38.0 months, with the IQR ranging from 15.0 to 68.0 months. However, Chen et al. (2023a) report different findings that show a standard deviation value of 20.3 months, smaller than our results.

The PD process itself causes continuous protein and amino acid losses (up to 5–15 grams of protein per day), which accumulate over years and contribute significantly to negative nitrogen balance and muscle wasting (Carrero et al., 2020). The continuous exposure to glucose-rich dialysate over several years can induce chronic inflammation and impair appetite and dietary intake, further exacerbating malnutrition (Carrero et al., 2020).

Furthermore, our study findings showed that the correlation between dialysis adequacy and duration was not statistically significant. Other studies, such as the one by Zhuang et al. (2023), show that PD duration is not a significantly independent predictor of all-cause mortality. A lack of a significant correlation with a major outcome like mortality aligns with the study finding that duration is not significantly correlated with dialysis adequacy. Contrary to our study finding, a study by Alsolami et al. (2022) found a statistically significant ($p < 0.001$) negative correlation between the duration of peritoneal dialysis and dialysis adequacy. Their study findings conclude that longer duration on PD is significantly associated with a decrease in technique survival.

5.1.5 Peritoneal Dialysis Solution

In our study cohort, the majority of the patients used Dineal 1.5% and 2.5% PD solution. This was critical for reporting on the nutritional status, particularly concerning glucose exposure, ultrafiltration and energy balance. Patients on PD absorb a significant amount of dextrose (typically 100–200 g) daily from the dialysate, contributing 350–700 non-nutritional kilocalories to their daily intake (Carrero et al.,

2021b). While malnutrition is a major concern, the caloric absorption can lead to overweight or obesity, especially in the younger cohort identified previously. The fact that none of the participants was on the 4.25% PD solution is a notable finding. The 4.25% Dineal solution is the highest concentration and is primarily used to achieve maximum ultrafiltration (fluid removal) in patients, with little to no Residual Kidney Function (RKF) or severe fluid overload.

The use of Extraneal in combination with Dineal 2.5% solutions is a positive clinical practice with nutritional benefits. Extraneal is typically used for the long-dwell exchange (e.g. overnight). Its large molecular weight provides sustained ultrafiltration with minimal absorption, compared to dextrose (Carrero et al., 2021b). The finding should emphasise that the use of a combination of lower dextrose concentrations is a strategy employed by the public facility unit to optimise ultrafiltration while managing the chronic metabolic burden associated with dextrose.

A study by Alsolami et al. (2022) found similar findings regarding the use of various peritoneal dialysis (PD) solutions. While the study does not provide a specific breakdown of percentages for each solution, it validates the use of both single and combined solutions and discusses the preference for specific types.

5.2 Evaluation of the Malnutritional Status

According to the present study, a majority of our patients were malnourished, 34.57% were severely malnourished, and 18.25% were very severely malnourished. This means half of our cohort exhibited significant malnutrition. The high prevalence in this study showed that malnutrition is rampant. Patients in public facilities may have limited access to the high-quality, high-protein foods necessary to meet the increased protein needs (1.2 to 1.3 g/kg/day) recommended for PD patients (Lin et al., 2025a). Similarly, a prospective study by Hassan et al. (2024) reports a high prevalence of malnutrition in their dialysis cohort of 238 patients; 37% of the population were classified as malnourished (mild (14.81%), and moderate/severe/very severe (85.19%). The mean nutritional status falls squarely into the severe malnutrition range (16–20), indicating a highly compromised nutritional state for the average patient.

In our study, the parameters comparing dialysis adequacy to malnutrition proved to be not statistically significant. Similarly, a multicentre study by Al-Khazraji et al. (2025) reports a high malnutrition prevalence of 47.5% in their PD cohort, which shows there is no significant association between the delivered dialysis dose (weekly Kt/V) and nutritional status. On the contrary, a study by Li et al. (2022), reports a significant positive correlation between total weekly Kt/V and nutritional status (SGA score) in their PD cohort. They conclude that achieving the Kt/V target is significantly associated with better nutritional outcomes, emphasising the continued importance of clearance in supporting a patient's nutritional state.

5.3 Evaluation of the Anthropometric Measurements

5.3.1 Evaluation of the Body Mass Index (BMI)

Our results showed a mean BMI of 25.56, which is significant, as it places the average patient in the overweight category (BMI 25.0–29.9 kg/m²) according to World Health Organization (WHO) standards. In the general population, a high BMI is a risk factor for mortality. However, in patients with End-Stage Kidney Disease (ESKD), a higher BMI (often in the overweight or low-obese range) is paradoxically associated with better survival and is considered a protective phenomenon known as reverse epidemiology or the "obesity paradox" (Carrero et al., 2021b). The mean BMI of 25.56 suggests that, on average, the cohort may have a survival advantage compared to undernourished PD patients (BMI < 18.5 kg/m²) or those with a lower BMI (Mehrotra et al., 2021).

Similarly, a study by Chen et al. (2025) found that BMI is a strong and highly significant predictor of achieving adequate dialysis (defined as total weekly Kt/V \geq 1.7). Other studies, such as the one by Zhang et al. (2023), found a significant association between being overweight/obese and a higher risk of technique failure. The authors conclude that nutritional status (specifically, high BMI) is an independent predictor of inadequate dialysis, which align directly with the study finding of a significant correlation between dialysis adequacy and BMI.

Contrary to our study, Al-Obaidi et al. (2025b) found that after adjusting for residual renal function and prescribed dialysate volume, BMI is no longer a statistically

significant and independent predictor of dialysis adequacy, suggesting that BMI may be a confounder rather than an independent predictor. Subsequently, a study by Saha et al. (2022) indicated that BMI and dialysis adequacy were not significantly correlated in the cohort of peritoneal dialysis (PD) patients. This concludes that while BMI is a crucial nutritional marker, it does not serve as a primary predictor of dialysis adequacy in the PD population.

5.3.2 Evaluation of the Weight

In our study cohort, the results indicated a weight gain. Weight gain on PD is often attributed to the absorption of dextrose (sugar) from the dialysis solution, which can lead to an increase in body fat. While obesity itself is associated with adverse outcomes in dialysis patients, a small amount of weight gain due to improved nutrition is often viewed positively, contrasting the severe risk associated with weight loss. (Imam et al., 2021). Other studies, such as the one by Chen (2022) on obesity, weight gain, and fluid overload in peritoneal dialysis (PD) patients supports the finding that weight gain and distribution are common in this population. The findings found the mean weight gain after one year of PD was 1.34 kg with a normal distribution.

A study by Zhang et al. (2023) shows that overweight status is significantly associated with technique failure, which contradicts the finding that weight data are normally distributed and does not correlate directly with outcomes. The finding implies that the finding may not be perfectly symmetrical, with a significant number of overweight participants leading to a non-normal distribution in a different population.

5.3.3 Evaluation of the Height

Our results shows the mean height of 167.58 cm (SD=9.22 cm). The results are not statistically significant, which indicates that the height data are consistent with a normal distribution. Height is a fundamental anthropometric measure that is usually normally distributed in most populations, including patient groups, and it is used to calculate body mass index (BMI) to assess nutritional status.

Similarly, a study by Alsolami et al. (2022) shows a mean height of 167.5 cm and a standard deviation (SD) of 10.2 cm, non-significant findings for height as a predictor

of outcomes, indicating that height data in their cohort were likely normally distributed. Contrary to our findings, a study by Zhang et al. (2023) found a significant association between overweight/obese status and technique failure. The distribution of these variables may not be as uniform as in the findings of the study, or height, when combined with other factors, can have a significant impact on dialysis adequacy.

5.3.4 Evaluation of Mid- Upper-Arm Circumference (MUAC), Triceps skin folds (TSF) and Arm-Muscle Area (AMA)

5.3.4.1 Mid Upper Arm Circumference (MUAC)

The results in our study cohort showed that the variable followed a normal distribution and the data were not skewed; consequently, the mean and standard deviation. The relatively high mean MUAC within our study suggests that, despite the risks of malnutrition from the disease and dialysis, the average patient has managed to preserve a good amount of muscle mass.

Our study showed no correlation between dialysis adequacy and MUAC (not significant). The MUAC does not influence dialysis adequacy as measured by standard metrics like Kt/V or Urea Reduction Ratio (URR) directly. Instead, MUAC is a highly valuable anthropometric indicator of nutritional status and body composition, which has an indirect correlation with dialysis adequacy and patient outcomes. Better nutritional status, indicated by a higher MUAC, is often associated with better dialysis adequacy and improved survival (lower mortality risk) in dialysis patients and better health-related quality of life. Conversely, reduced MUAC is an indicator of malnutrition, which is highly prevalent in dialysis patients (Mahzari & Khalkhali, 2022).

Similarly, a prospective study by Ganesan et al. (2025) found that MUAC was not significantly correlated with the total weekly Kt/V at baseline, showing it was highly predictive of patient mortality. Furthermore, Ganesan et al. (2025) confirm the independence of these measures, finding no significant correlation between MUAC and total weekly Kt/V ($p=0.176$), reinforcing the consensus that MUAC is a measure of nutritional risk requiring dietary intervention, rather than an outcome directly improved by adjusting the dialysis dose.

Conversely, Al-Khafaji et al. (2025) report a significant positive correlation between MUAC and total weekly Kt/V ($p=0.005$), suggesting that MUAC acts as a predictor of adequacy by proxy, as better muscle mass often reflects improved overall health, fluid management, and residual kidney function, which collectively boost the total clearance. This finding is contradicted by Tellez et al. (2024b) in a multivariate analysis, who identified lower MUAC as an independent and statistically significant predictor of failing to meet the Kt/V target, arguing that low muscle mass can indirectly have an impact on the achievement of clearance goals. However, a study by Zhang et al. (2023) shows that nutritional status, including measures of body composition, is a significant predictor of technique failure, a proxy for dialysis adequacy.

5.3.4 Triceps skin folds (TSF)

The results in our study cohort showed that the variable does not follow a normal distribution; the data were skewed, and the median and inter-quartile range were reported. The minimum value of 8.00 mm confirms that at least one participant is severely energy deficient, indicating high heterogeneity in energy reserves. This group (TSF below 10 mm) represents the most severely malnourished and catabolic patients who require urgent nutritional support. The maximum TSF of 42.00 mm (representing very high fat stores) indicates the presence of obese patients within the cohort. While they have high energy reserves, this state is associated with chronic inflammation, which is a driver of the Malnutrition-Inflammation Complex Syndrome (MICS), increasing risks for cardiovascular events and mortality (Mehrotra et al., 2021; Carrero et al., 2021b).

In correlation with dialysis adequacy, the TSF was significant ($p=0.0006$), a simple and non-invasive measure of subcutaneous fat, as a useful indicator of dialysis adequacy. This is a crucial finding, because it suggests that nutritional status, as reflected by TSF, is directly linked to the effectiveness of the dialysis treatment. It could mean that patients with better nutritional status (higher TSF) may have better dialysis adequacy, or vice versa. Similarly, a study by Wang et al. (2025a) shows a significant correlation between TSF and the achieved Kt/V dose, which concludes that TSF serves as an independent predictor of adequate dialysis clearance, with patients in the lowest TSF quartile facing a higher risk of inadequate dialysis. Subsequently, Sadek et al. (2025b)

show a significant independent association between TSF and the achievement of the total weekly Kt/V target, showing that TSF is a crucial marker for overall metabolic and fluid status, which ultimately influences the ability of the patient to achieve and maintain adequate small-solute clearance.

Conversely, Li et al. (2025a) report that, despite examining TSF, they found no statistically significant correlation between TSF and weekly total Kt/V, suggesting that TSF is an independent measure of nutritional status and a poor predictor of the clearance dose achieved. Han et al. (2022) also report differing results, where peripheral anthropometric measurements, including TSF, are not independently associated with the achievement of adequate Kt/V in a large PD cohort. They suggest that central markers of inflammation and protein metabolism are more predictive of clearance success than fat reserves alone.

5.3.4.3 Arm Muscle Area (AMA)

The findings of the median Arm Muscle Area (AMA) of 14.30 cm² (with an Interquartile Range (IQR) of 5.60 to 32.00 cm²) are the most critical step for assessing malnutrition, as AMA is a direct and specific estimate of somatic protein/skeletal muscle reserves (Carrero et al., 2021a). The median AMA of 14.30 cm² is a strong indicator of significant muscle depletion in the central 50% of the cohort when compared to healthy population reference standards, which are typically much higher (AMA often ranges from 20 cm² to over 50 cm² for healthy adults, depending on sex) (Ma et al., 2018). The AMA median of 14.30 cm² is not normal and suggests that this group is severely malnourished/muscle depletion. A low IQR value confirms that the majority of the patients are in a state of muscle wasting.

Low AMA is strongly associated with frailty, reduced quality of life, hospitalisation, and mortality. This low median AMA directly contradicts the previous findings of a high mean Body Mass Index (BMI) and high median Triceps Skin Fold (TSF). This contrast reveals a high prevalence of sarcopenia (muscle loss) and, specifically, sarcopenic obesity, where patients appear obese or have adequate fat reserves (based on BMI/TSF), but are actually severely depleted in terms of vital muscle reserves (Carrero et al., 2021a).

In our study cohort, the results showing the correlation between dialysis adequacy and AMA are significant. These further reveal that the nutritional status of our patients contributed to adequacy. The Kt/V measures solute clearance, and AMA measures the patient's somatic protein stores (muscle mass). In chronic dialysis patients, especially those with malnutrition, low muscle mass (low AMA) is a stronger predictor of negative outcomes than the Kt/V value itself. This creates a paradox: a patient who is severely malnourished (low AMA) may receive adequate or even high Kt/V, but this does not reflect true metabolic adequacy. The high Kt/V simply reflects the fact that they have a small volume to clear, not that they are receiving an adequate dose for their metabolic needs. The significant relationship aligns with the findings of Al-Obaidi et al. (2025a), who report a highly significant positive correlation between AMA and total weekly Kt/V. The median AMA is 21.5 cm², thereby confirming AMA's role as a strong, independent predictor of achieving the required dialysis clearance dose. Furthermore, Gong et al. (2021) show a significant independent predictor of dialysis inadequacy. This directly supports the study finding of a significant correlation between a measure of muscle mass and dialysis adequacy. The study concludes that a patient's nutritional status is crucial for maintaining adequate dialysis.

In contrast, a retrospective study by Han et al. (2022) involving a large PD cohort found that AMA is not independently associated with the achievement of adequate Kt/V, suggesting that Kt/V success is influenced more by central metabolic and inflammatory markers than by peripheral muscle mass. Further opposing evidence is provided by Li et al. (2025a), who specifically report that AMA does not correlate significantly with total weekly Kt/V, emphasising the conclusion that AMA is a vital prognostic marker, but not a direct determinant of small-solute clearance. Another study by Alsolami et al. (2022), found that the arm-muscle area is not a significant predictor of technique or patient survival, which directly opposes our study findings. Their study concludes that other factors, such as age and comorbidities, are more important predictors of patient outcomes.

5.4 Evaluation of the Dialysis Adequacy: Adequate Dialysis versus Inadequate Dialysis

According to our findings, 61.73% of the patients had adequate dialysis, while 38.27% had inadequate dialysis. Our results indicate that a significant percentage of patients did not receive adequate PD clearance as per the Kt/V calculation we had utilised. Our significant number of patients not achieving adequate PD clearance as per the Kt/V guidelines (38.27%) require urgent interventions. Each of the 31 patients with inadequate dialysis needs an urgent clinical assessment to determine the cause of failure (Blake et al., 2020).

Similarly, Sadek et al. (2025a) report a statistically non-normal distribution ($p=0.002$) and feature a median Kt/V of 1.62, further corroborating the difficulty in achieving ideal adequacy and the resulting left-skewed data pattern. Other studies, such as the one by Alsolami et al. (2022), found similar results to our study that directly support that Kt/V data may not be normally distributed, which concludes that patient characteristics, including obesity, are significantly associated with a higher risk of technique failure.

Conversely, Tellez et al. (2025) report that the total weekly Kt/V distribution was statistically normal and achieved a high median Kt/V of 1.88, demonstrating that effective dose optimisation can counteract the tendency toward skewed, inadequate clearance. Furthermore, Wang et al. (2024a) report a near-normal Kt/V distribution with a median clearance of 1.75, directly opposing our finding by confirming that protocolized dose adjustments can shift the distribution successfully to be adequate and symmetrical.

5.5 Evaluation of the Biochemical Markers

5.5.1 Evaluation of the Serum Albumin

The reported albumin levels provide a critical insight into the nutritional status of the peritoneal dialysis (PD) patients in the public facility unit. Albumin is widely considered a key marker of nutritional status and a strong predictor of morbidity and mortality in dialysis patients, although it is also influenced by inflammation and volume status. Hypoalbuminemia is a powerful, independent predictor of poor clinical outcomes in PD

patients. A median level of is associated with higher mortality and increased peritonitis risk (Inflammation) (Wu et al., 2025; Li et al., 2021; Lameire et al., 2020).

Our results show a significant prevalence of malnutrition within this PD cohort. A median of 34g/L means that the dialysis units must prioritise routine nutritional assessment (such as the DMS) and intervention strategies (dietary protein and energy intake goals) for a large portion of their patient population. The findings indicate an urgent need for the public facility dialysis units to implement a robust, multidisciplinary approach to nutritional care, as recommended by international guidelines.

According to the present study, the correlation between dialysis adequacy and serum albumin showed to be significant ($p=0.0057$). Similarly, a study by Li et al. (2022) reports a median serum albumin of 34.5 g/L and demonstrates a significantly positive correlation between total weekly Kt/V and serum albumin, suggesting that achieving better clearance contributes to maintaining improved plasma protein status. Subsequently, Chen et al. (2025) report that their serum albumin data were statistically non-normally distributed with a median of 33.8 g/L and confirm a highly significant independent correlation between total weekly Kt/V and serum albumin, validating the strong relationship between small-solute clearance and patient nutritional status. Another study by Jones (2024) report a significantly positive correlation between serum albumin levels and peritoneal dialysis adequacy (Kt/V) in a cohort of patients. The results suggest that better nutritional status (higher albumin) is associated with more effective dialysis.

In contrast, Tellez et al. (2024a) found no significant correlation between Kt/V and serum albumin ($p=0.280$), suggesting that nutritional status and dialysis clearance are independent goals in well-managed patients. Furthermore, Li et al. (2025b) found that while the median serum albumin was 36.0 g/L, Kt/V was not an independent predictor of serum albumin levels after controlling for inflammation and comorbidities. Their findings support the hypothesis that albumin levels are primarily dictated by systemic inflammation, linking with dialysis dose, non-significant. A study by Zhang et al. (2023) found that serum albumin levels are a significant predictor of dialysis outcomes, which is the opposite of the finding of a non-normal distribution.

5.5.2 Evaluation of the Serum Urea

In our study cohort, the median urea level of 20.47 mmol/L (IQR 17.07 to 25.37 mmol/L) was observed. It is primarily an assessment of dialysis adequacy and, indirectly, protein intake, through the estimation of Protein Nitrogen Appearance (PNA). While acceptable urea targets vary based on dialysis vintage and residual kidney function (RKF), a median urea of 20.47 mmol/L suggests that the average patient in this public facility dialysis unit is achieving a level of adequate dialysis clearance. Current guidelines emphasise the need for adequate small solute clearance (measured by Kt/V 1.4) to maintain patient well-being and nutritional status (Carrero et al., 2023).

Uncontrolled high urea levels are a sign of inadequate clearance, which drives the catabolic and inflammatory state of uraemia, directly contributing to malnutrition and anorexia. The median urea level in our study suggests the overall burden of uraemia was managed for the central cohort. Higher steady-state urea levels often correlate with higher protein intake. Conversely, low urea levels can be a sign of low protein intake and severe anorexia/malnutrition, even if dialysis is adequate (Mehrotra et al., 2021).

The wide range of urea levels (9.27 mmol/L minimum to 39.13 mmol/L maximum) indicates severe heterogeneity and distinct risk groups. The extremely low value (9.27 mmol/L) for a dialysis patient is highly concerning, which may indicate severe malnutrition or low protein intake, good RKF and inadequate dialysis sampling (sample was taken immediately post-dialysis). The high value (39.13 mmol/L) suggests two possibilities, a non-adherence/inadequate dialysis and very high protein intake.

According to the present study, the correlation between dialysis adequacy and serum urea was not statistically significant ($p=0.5797$). Similarly, a study by Li et al. (2022) report a non-normal distribution for serum urea ($p=0.005$) with a median of 21.1 mmol/L, finding no significant correlation between total weekly Kt/V and serum urea ($p=0.355$), suggesting that urea levels are more indicative of protein intake than dialysis clearance effectiveness. Supporting that, Chen et al. (2025) found that serum urea data were non-normally distributed and reported no significant correlation between the baseline serum urea level and total weekly Kt/V ($p=0.421$) after

accounting for protein catabolism. The median urea level was 19.5 mmol/L (IQR 16.8–24.8 mmol/L), which emphasises the role of dietary intake in setting the baseline urea concentration.

Conversely, Wang et al. (2024b) report that the serum urea distribution was statistically normal and showed a highly significant inverse correlation between total weekly Kt/V and serum urea ($p < 0.001$), emphasising that a higher achieved clearance dose is directly associated with lower steady-state urea concentrations. Supporting the physiological relationship, Li et al. (2025b) found that the distribution of serum urea was near-normal ($p = 0.065$) and confirms that total weekly Kt/V is an independent and highly significant predictor of serum urea, which suggests that adequate small-solute clearance is essential for achieving optimal biochemical control. However, Jones (2024) report opposite findings, showing a significantly positive correlation between serum albumin levels (a key nutritional marker) and dialysis adequacy in their study. This contrasts with our finding for serum urea, suggesting that while some markers may not correlate, others do.

5.5.3 Evaluation of the Serum Creatinine

Our results show the mean creatinine level of 1 046 $\mu\text{mol/L}$ ($\text{SD} = 391.10$). Creatinine is the best biochemical marker for assessing muscle mass and the severity of malnutrition in this population (Carrero et al., 2021a). Creatinine is a byproduct of muscle metabolism; its serum level, when adjusted for dialysis adequacy and residual kidney function (RKF), is a strong indicator of the body's lean body mass (LBM) or muscle mass (Mehrotra et al., 2021).

According to our study findings, the correlation between dialysis adequacy and serum creatinine was not statistically significant ($p = 0.4704$), which shows that a patient's serum creatinine level alone is not a reliable indicator of dialysis adequacy. Creatinine can be influenced by factors other than dialysis clearance, such as muscle mass and diet. A study by Li et al. (2025c) found that the serum creatinine was statistically normally distributed with a mean of 985.5 $\mu\text{mol/L}$. They further report no significant correlation between total weekly Kt/V and serum creatinine, concluding that RRF is the primary predictor of creatinine concentration. Supporting the non-significant correlation, Wang et al. (2025b) found that the serum creatinine distribution was near

normal ($p=0.081$) with a mean of $1080.5\mu\text{mol/L}$ and determined that total weekly Kt/V is not an independent predictor of serum creatinine, suggesting that creatinine concentration reflects muscle mass and production rate more than the prescribed clearance dose.

On the contrary, Wang et al. (2024b), studying long-term PD participants, found that serum creatinine was statistically non-normally distributed ($p=0.009$) and, more significantly, showed a highly significant inverse correlation between total weekly Kt/V and serum creatinine. This suggests that clearance strongly dictates creatinine levels when RKF is minimal. Supporting the physiological inverse relationship, Sadek et al. (2025a) report that serum creatinine distribution was non-normal and confirm that total weekly Kt/V is an independent and highly significant negative predictor of serum creatinine concentration, validating the importance of clearance in managing baseline uremic toxin levels.

CHAPTER 6: CONCLUSION

This study addressed all set objectives successfully, providing essential insights into the clinical status of this vulnerable population.

The malnutritional status using the DMS questionnaire for our study confirmed a high prevalence of malnutrition; more than half of the patients displayed severe or very severe malnutrition. The dialysis adequacy using Kt/V in our study showed that 61.73% of patients achieved the minimum PD clearance (Kt/V 1.4). In addressing the factors influencing dialysis adequacy, the study found that among the demographic factors, age was identified as a significant factor correlating with adequacy. Younger patients (20–68 years) had adequate PD as compared to older patients (28–71 years); this was statistically significant. Other demographics, such as gender, race, and duration of PD, were not statistically significant predictors of dialysis adequacy.

Three key anthropometric components of malnutrition, BMI ($p=0.0001$), Triceps Skin Fold (TSF) ($p=0.0006$), and Arm-Muscle Area (AMA) were statistically significant and correlated with dialysis adequacy. This suggests that metrics reflecting lean body mass and somatic protein stores are strong predictors of a patient's ability to achieve adequate PD. Furthermore, serum albumin demonstrated a significant correlation with Kt/V, being statistically significant, whilst serum urea and creatinine did not demonstrate a statistically significant correlation with dialysis adequacy.

Our analysis from the DMS-defined malnutritional status was not linked to dialysis adequacy. In our study, the specific indicators of body composition (BMI, TSF, AMA) and serum albumin were strong predictors of successful peritoneal dialysis adequacy. Our study shows that there is a statistically significant association between age, selected anthropometric measures (BMI, TSF, AMA) and adequacy (Kt/V) within our sample population. Larger sample populations, longer time frames and PET analysis would provide clarity to our findings.

6.1 Recommendations

We conclude that interventions such as residual kidney function decline, peritonitis, poor technique, or membrane changes, and modifying patients' prescription (e.g.

higher volume exchanges, more exchanges, or switching to Automated Peritoneal Dialysis (APD) could provide support in maximising higher Kt/V in PD patients. Further research is recommended to investigate the observed significant correlation between age and dialysis adequacy to ensure optimal and potentially individualised PD prescription strategies for different age groups.

6.2 Limitations of the Study

While providing valuable insights, a larger sample size and PET analysis would be preferred in our PD population in public facilities in Gauteng.

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CHAPTER 8: APPENDICES

APPENDIX A: PATIENT INFORMATION AND INFORMED CONSENT DOCUMENT

STUDY TITLE: The assessment of malnutrition on dialysis adequacy of peritoneal dialysis patients at public nephrology facilities in Gauteng province

PRINCIPAL INVESTIGATOR: Mrs N.L. Setjje

SUPERVISOR: Prof. P.H. Mfengwana

Patient

You are invited to participate in a research study that forms part of my formal studies. This information document will help you to decide if you would like to participate. Before you agree to take part, you should fully understand what is involved. You should not agree to take part unless you are completely satisfied with all aspects of the study.

WHAT THE STUDY IS ALL ABOUT

The study will be conducted on patients with kidney failure using Peritoneal Dialysis (PD) as the treatment. Peritoneal Dialysis is one of the main treatment options for kidney failure offered to patients with kidney disease. The treatment involves solute and fluid exchange in the stomach (peritoneal membrane), allowing for the elimination of waste products from the body. The treatment has adverse health effects and consequences, such as malnutrition, which occurs in 30–50% of the patients.

Patients who suffer from kidney failure have a significant chance of developing a condition caused by not getting the right amount of nutrients and dialysis treatment that are needed for health, or develop malnutrition, which can contribute to the patients' health status. Malnutrition and poor dialysis are risk factors for hospitalisation and death of PD patients. Therefore, identification of causes, assessment, and management of malnutrition in patients receiving PD treatment is important. The study aims to determine the significance of dialysis malnutrition on dialysis adequacy of peritoneal dialysis patients on PD treatment, and to be able to detect early malnutrition and poor dialysis to prevent complications related to dialysis dose.

WHAT YOU WILL BE REQUIRED TO DO IN THE STUDY

The study will consist of Visit 1 (Day 0), Visit 2 (Day 30), and Visit 3 (Day 60). All visits will be conducted in your normal follow-up dates with the renal clinic; therefore, no extra travelling is required.

Visit 1 (Day 0)

- The researchers will introduce themselves to you and clearly explain what the study is all about by going through the details of this patient information document.
- If you agree to participate in this research study, you will be required to sign this document before starting the study.
- Using a semi-structured interview form, information on your age, race, gender, BMI, weight, and duration of PD treatment will be collected.
- There is a Dialysis Malnutrition Score (DMS) questionnaire and anthropometric (physical features) assessment that will be done to determine your nutritional status, and you will be required to answer questions on your nutritional habits.
- The researcher will ask the questions and fill in the answers for you.
- The researcher will also collect information from your dialysis file (monthly blood results) and fill them in on the data sheet formulated by the researcher.
- The information that will be collected (pre- and post-urea and creatinine, albumin) from the files will also be used to calculate the adequacy of dialysis (Kt/V).
- The date for the appointment will be the same as your monthly follow-up at the renal unit.
- Visit 2 will be scheduled 4 weeks (30 days) after Visit 1.
- There will be no specific requirements from you; you will follow the same routine as your previous appointments.

Visit 2 (Day 30)

- The results of the nutritional status and dialysis adequacy will be discussed.

- Depending on the results of the status, you will be advised accordingly, for example, the dietician will be recommended to assist with the nutritional (diet) plan for intervention and on adequacy, the renal staff will adjust the treatment accordingly.
- The questions from the previous visit will be repeated (same as in Visit 1).
- The same information as from Visit 1 will be collected to compare the changes.

Visit 3 (Day 60)

- The same information as from Visit 2 will be collected to compare the changes.

ANY CONDITIONS THAT MAY EXCLUDE YOU FROM THE STUDY

You will be excluded from the study:

- If you were hospitalised within a month when the study beginning.
- If you are known or have been diagnosed with malnutrition.
- If you are above 60 years of age.
- If you have not been on dialysis treatment for the past 3 months.
- If you are not compliant with your PD treatment.

CAN ANY OF THE STUDY PROCEDURES RESULT IN PERSONAL RISK, DISCOMFORT, OR INCONVENIENCE

There will be little discomfort or inconvenience adjusting to the nutritional plan and recommendations that need to be conducted or implemented in the dialysis treatment. Your medical aid will not have to pay for any expenses.

POTENTIAL BENEFITS THAT MAY COME FROM THE STUDY

The study might not directly benefit the patients; however, the study findings might benefit the scientific community in identifying dialysis malnutrition and offer dialysis support in Renal Units.

FINANCIAL COMPENSATION OR INCENTIVE FOR PARTICIPATING IN THE STUDY

The research study is self-funded; therefore, patients will not receive any kind of remuneration to take part in the study. Participation in this study is completely voluntary.

YOUR RIGHTS AS A PATIENT IN THE STUDY

Your participation in this study is entirely voluntary. You have the right to withdraw at any stage without any penalty or future disadvantage whatsoever. You do not have to provide the reasons for your decision. Your withdrawal will in no way influence your continued care and relationship with the healthcare team.

CONFIDENTIALITY AND ANONYMITY IN THE STUDY

All information obtained during this study is strictly confidential. The study data will be coded so that it will not be linked to your name. Your identity will not be revealed while the study is being conducted or when the study is reported in scientific journals. The records will be kept at the Hospital's Nephrology department for 5 years and the CUT Department of Biomedical Sciences for 5 years. All information that has been collected will not be shared with any other person without your permission.

RESEARCHER'S QUALIFICATIONS

I am a Clinical Technologist (B-Tech Degree) in Nephrology from the Central University of Technology, doing my master's degree. I have 19 years' experience in the field, and this study will be used to complete my master's degree in clinical technology in Nephrology.

ETHICS APPROVAL

The Protocol of this clinical trial was submitted for approval to the South African Medical Association Research Ethics Committee (SAMAREC), a research ethics committee registered with the National Health Research Ethics Council. Written approval has been granted by SAMAREC for the conduct of the trial. The study has been structured per the Guidelines on Clinical Trials and Ethics in Health Research, published by the Department of Health and the Declaration of Helsinki (last updated October 2013), adopted by the World Medical Association (WMA), as well as the

Guidelines for Good Clinical Practice in the Conduct with a Human Patient in South Africa (3rd edition, 2020), which deals with the recommendations guiding doctors in biomedical research involving human patients. Copies of these documents may be obtained from the study doctor, should you wish to review them.

If you have any questions about the study or your rights, at any time, or think you have experienced an injury or reaction to the study medication, you should contact your study doctor. Study doctor/Principal Investigator: [Dr P.H. Mfengwana]. If you have questions about your rights as a research patient, you may contact: The South African Medical Association Research Ethics Committee (SAMAREC) PO Box 74789 Lynwood Ridge 0040 Tel: 012 481 2082 Email: samarec@samedical.org

WHOM TO CONTACT FOR ADDITIONAL INFORMATION REGARDING THE STUDY

- The Primary Investigator, Mrs N.L. Setjie, can be contacted during office hours on 012 314 0632.
- The study supervisor from Central University of Technology, Prof. H. Mfengwana, can be contacted on 051 507 3576 during office hours.

DECLARATION: CONFLICT OF INTEREST

I hereby declare that I have no personal interest, direct or indirect, in the matter addressed in the submission, and I did not purposefully and unlawfully favour or prejudice anyone in the composition of the submission. There will be internal funding towards the study from the Central University of Technology. I certify that the submission is original work and is not under review at any other publication.

INFORMED CONSENT

I hereby confirm that I have been adequately informed by the researcher about the nature, conduct, benefits, and risks of the study. I have also received, read, and understood the above written information. I am aware that the results of the study will be anonymously processed into a research report. I understand that my participation is voluntary and that I may, at any stage, without prejudice, withdraw my consent and participation in the study. I had sufficient opportunity to ask questions and, of my own

free will, declare myself prepared to participate in the study. I am aware that I shall receive a signed and dated copy of this Informed Consent Document.

_____	_____	_____
Patient's Name	Date	Patient's Signature
_____	_____	_____
Researcher's Name	Date	Researcher's Signature
_____	_____	_____
Witness Name	Date	Witness Signature

APPENDIX B: DIALYSIS MALNUTRITION SCORE (DMS)

A. Patients-related medical history:

1. Weight change (overall change in past 6 months)				
1	2	3	4	5
no weight change or gain	minor weight loss (<5%)	weight loss 5 to 10%	weight loss 10 to 15%	weight loss >15%
2. Dietary intake				
1	2	3	4	5
no change	sub-optimal solid diet	full liquid diet or moderate overall decrease	hypo-caloric liquid	starvation
3. Gastrointestinal symptoms				
1	2	3	4	5
no symptoms	nausea	vomiting or moderate GI symptoms	diarrhea	severe anorexia
4. Functional capacity (nutritionally-related functional impairment)				
1	2	3	4	5
none (improved)	difficulty with ambulation	difficulty with normal activity	light activity	bed/chair-ridden with no or little activity
5. Co-morbidity				
1	2	3	4	5
dialysis <12 months and healthy otherwise	dialysis 1-2 years or mild co-morbidity	dialysis 2-4 years or age >75 or moderate co-morbidity	dialysis >4 years or severe co-morbidity	very severe multiple co-morbidity

B. Physical Exam:

1. Decreased fat stores or loss of subcutaneous fat (below eyes, triceps, biceps, chest)				
1	2	3	4	5
no change		moderate		severe
2. Signs of muscle wasting (temple, clavicle, scapula, ribs, quadriceps, knee, interosseous)				
1	2	3	4	5
no change		moderate		severe

C. Malnutrition Score: (sum of all numbers)

The first part of the SGA/DMS:

Compromised the patient history, which includes weight change, dietary intake relative to normal over the past two weeks, gastrointestinal symptoms lasting longer than two weeks, and functional capacity.

The second part of the SGA/DMS:

A physical examination, where the loss of subcutaneous fat in four different areas (shoulders, triceps, chest, and hands), the presence of muscle wasting and the presence of oedema in various areas (hands, sacrum and/ or feet) were assessed. The variables are individually scored, and the sum of the scores is used for the overall rating of the patient's nutritional assessment, classified as normal, mild, moderate or severe undernutrition. Scores are as follows:

- 0–5 normal nutrition
- 6–10 mild malnutrition
- 11–15 moderate malnutrition
- 16–20 severe malnutrition
- 21–30 very severe malnutrition

Anthropometric measurement:

Body mass index (BMI)

Body weight (kg) and height (cm) will be calculated using the Seca scale after complete drainage of the last bag exchange. The BMI will be calculated using the weight in kg divided by height in square metres. Body mass index (BMI) will be classified into three categories:

- normal (18.5–24.9 kg/m²)
- overweight (25–29.9 kg/m²)
- obese (≥ 30 kg/m²)

Mid-upper arm circumference (MUAC) (cm)

The MUAC will be measured using a metric tape measure at the midpoint between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna of the dominant arm.

Triceps skin fold (TSF) thickness (mm)

The TSF will be measured to the nearest 0.1 mm, taking the average of three measurements on the posterior aspects of the dominant arm, over the triceps muscle and at the midpoint line determined for the MUAC using a Harpenden calliper.

Arm muscle area (AMA) (mm)

The AMA will be determined from the upper arm anthropometric measurements, MUAC and TSF.

APPENDIX C: DATA COLLECTION SHEET

All personal data will be coded for study purposes.

Patient Code: _____

Demographics:

Gender: _____ Race: _____ Age (years): _____

Duration on PD Treatment (months): _____

Type of PD solution: _____

Assessment:

	VISIT 1	VISIT 2	VISIT 3
DATE			
Weight (kg)			
Height (cm)			
BMI (kg/m ²)			
Mid-upper Arm circumference (MUAC) (cm)			
Triceps skin fold (TSF) (mm)			
Arm muscle area (AMA) (mm)			
Serum Albumin (g/L)			
Urea (mmol/L)			
Creatinine (mmol/L)			
Kt/v (greater than 1.7)			
URR (>65%)			

DMS DATA COLLECTION SHEET

QUESTIONNAIRE		VISIT 1	VISIT 2	VISIT 3
Date				
A	Patient-related medical history:			
1	Weight change			
2	Dietary Intake			
3	Gastrointestinal symptoms			
4	Functional capacity			
5	Co-morbidity			
B	Physical Exam:			
6	Decreased fat store/loss of Subcutaneous fat (triceps, biceps)			
7	Signs of muscle wasting			
C	Total Score:			

Malnutritional Scores categorized as follows:

- 6–10 mild malnutrition
- 11–15 moderate malnutrition
- 16–20 severe malnutrition
- 21–30 very severe malnutrition

SEMI-STRUCTURED INTERVIEW QUESTIONS:

1. Gender
2. Race
3. Age
4. Duration on PD
5. Type of PD solution

APPENDIX D: MEASUREMENT METHOD

VISIT 1 (DAY 0)

- Introduce the research patient to the researcher and explain the purpose of the study and what will be expected of the patient.
- An Information and Informed Consent Document will be given to the research patient to read.
- Participation is voluntary and research patients will be required to give written consent before any procedures will be conducted.
- Using a semi-structured interview, information on the patient's age, race, gender and duration of PD will be collected on the data collection sheet (Appendix C).
- An DMS and Anthropometric measurement (Appendix B) will be done on patient and be completed by the researcher on the data sheet.
- The latest blood results will be collected from the patients file and will be recorded on the data collection sheet formulated by the researcher.
- The assessment results that determine the nutritional status and dialysis adequacy results will be discussed with the patients in the next visit.
- Visit 2 will be scheduled 30 days after Visit 1.

VISIT 2 (DAY 30)

- The assessment and adequacy results will be discussed with the patients.
- Nutritional plan and dialysis treatment improvement or recommendation based on the results will be discussed with the patient.
- An experienced dietician will be consulted to assist with the nutritional advice if the assessment result needs intervention.
- The DMS and anthropometric measurements will be repeated.
- Monthly Blood results (Urea, Creatinine, Serum Albumin) will be retrieved from the patient's files.

- The data collection sheet will be completed by the researcher.
- The visit will be scheduled 30 days after Visit 2.

VISIT 3 (DAY 60)

- The assessment results will be discussed and compared with the results from Visit 2.
- The researcher will observe the nutritional status and dialysis adequacy difference from Visit 2.
- The researcher will thank the patients for participating in the study.

APPENDIX E: MEASURING HEIGHT USING A STADIOMETER

- Ensure the floor surface is even and firm.
- Have the patient remove shoes and stand up straight with heels together, and with heels, buttocks and shoulders pressed against the stadiometer.
- Arms should hang freely with palms facing thighs.
- Measure with the patient standing tall, looking straight ahead with the head upright and not tilted backwards.
- Make sure the patient's heels stay flat on the floor.
- Lower the measure on the stadiometer until it contacts the top of the head.
- Record standing height to the nearest centimetre.

MEASURING CALF CIRCUMFERENCE

- The patient should be sitting with the left leg hanging loosely or standing with their weight evenly distributed on both feet.
- Ask the patient to roll up their trouser leg to uncover the calf.
- Wrap the tape around the calf at the widest part and note the measurement.
- Take additional measurements above and below the point to ensure that the first measurement was the largest.
- An accurate measurement can only be obtained if the tape is at a right angle to the length of the calf.

MEASURING ARM CIRCUMFERENCE

- Locate and mark the midpoint of the sternal notch with the pen.
- Ask the patient to place the left arm in a horizontal position.
- Check that the patient's arm is horizontal and in line with the shoulders.
- Using the tape measure, measure the distance from the mark on the midline at the sternal notch to the web between the middle and ring fingers.
- Check that the arm is flat and the wrist is straight.
- Take reading in cm.

APPENDIX F: BODY MASS INDEX

20	19	18	18	17	17	16	16	15	15	14	14	14	13	13	12	12		45
21	20	19	19	18	17	17	16	16	16	15	15	14	14	13	13	13		47
21	21	20	19	19	18	18	17	17	16	16	15	15	15	14	14	13		50
22	22	21	20	20	19	19	18	17	17	17	16	16	15	15	14	14		52
23	23	22	21	21	20	19	19	18	18	17	17	16	16	15	15	15		54
24	24	23	22	21	21	20	20	19	18	18	17	17	16	16	16	15		57
25	25	24	23	22	22	21	20	20	19	19	18	18	17	16	16	16		59
26	26	25	24	23	22	22	21	21	20	19	19	18	18	17	17	16		61
27	26	26	25	24	23	23	22	21	21	20	20	19	18	17	17	17		63
28	27	27	26	25	24	23	23	22	21	21	20	20	19	18	18	18		66
29	28	27	27	26	25	24	23	23	22	22	21	20	20	19	19	18		68
30	29	28	27	27	26	25	24	24	23	22	22	21	20	19	19	19		70
31	30	29	28	27	27	26	25	24	24	23	22	22	21	20	20	19		72
32	31	30	29	28	27	27	26	25	24	24	23	22	22	21	21	20		75
33	32	31	30	29	28	27	27	26	25	24	24	23	22	21	21	21		77
34	33	32	31	30	29	28	27	27	26	25	24	24	23	22	22	21		79
35	34	33	32	31	30	29	28	27	27	26	25	24	24	23	22	22		82
36	35	34	33	32	31	30	29	28	27	27	26	25	24	24	23	23		84
37	36	35	34	33	32	31	30	29	28	27	26	26	25	24	24	23		86
38	37	36	35	33	32	31	31	30	29	28	27	26	26	25	24	24		88
39	38	37	35	34	33	32	31	30	30	29	28	27	26	26	25	24		91
40	39	37	36	35	34	33	32	31	30	29	29	28	27	26	26	25		93
41	40	38	37	36	35	34	33	32	31	30	29	28	28	27	26	26		95
42	41	39	38	37	36	35	34	33	32	31	30	29	28	28	27	26		98
43	42	40	39	38	37	36	34	33	32	32	31	30	29	28	27	27		100
44	43	41	40	39	37	36	35	34	33	32	31	31	30	29	28	27		102
45	43	42	41	39	38	37	36	35	34	33	32	31	30	30	29	28		104
46	44	43	42	40	39	38	37	36	35	34	33	32	31	30	29	29		107
47	45	44	43	41	40	39	38	36	35	34	33	33	32	31	30	29		109
48	46	45	43	42	41	40	38	37	36	35	34	33	32	31	31	30		111
49	47	46	44	43	42	40	39	38	37	36	35	34	33	32	31	30		114
	150	152.5	155	157.5	160	162.5	165	167.5	170	172.5	175	177.5	180	182.5	185	187.5	190	

Underweight ($\leq 18 \text{ kg/m}^2$)
 Weight Appropriate ($18.5\text{-}24.9 \text{ kg/m}^2$)
 Overweight ($25\text{-}29.9 \text{ kg/m}^2$)
 Obese ($\geq 30 \text{ kg/m}^2$)

APPENDIX G: REQUEST FOR PERMISSION LETTERS

Enquiries: Mrs N.L. Setjie

Contact No: 072 288 1769/084 915 4452

May 2024

Dear Sir/Madam

RE: PERMISSION TO CONDUCT RESEARCH AT STEVE BIKO ACADEMIC HOSPITAL (RENAL UNIT)

My name is Nelly Lerato Setjie, a Clinical Technologist in Nephrology working at 1 Military Hospital for the past 19 years. I am currently pursuing my master's degree in clinical technology in Nephrology at the Central University of Technology. I am seeking permission to conduct my research study at your hospital in the Renal Unit.

The title of the study will be "The assessment of malnutrition on dialysis adequacy of peritoneal dialysis patients at public nephrology facilities in Gauteng province". The reason I am seeking permission to conduct my study at your hospital is that 1 Military Hospital does not have a PD unit.

The research will be Quantitative by nature, where data will be collected from patients' files, an assessment will be done, and patients will have to answer a questionnaire regarding their nutritional status. Only individuals known to the PD unit who adhere to the inclusion criteria will be approached to participate.

Participation in this study is completely voluntary. Patients will sign an informed consent document (ICD) before they are allowed to participate. If, for any reason, they would like to withdraw during the study, they are free to do so without any negative consequences.

Confidentiality will be upheld by de-identifying the patients' particulars by giving them a study code. The patients' names will not be mentioned in any research publication or presentation. The necessary permissions will be sought from the Research Ethics Committee, and all parts of the study will be conducted according to Internationally accepted Guidelines such as Helsinki 2013.

The research study is self-funded and therefore patients will not receive any kind of remuneration to take part in the study.

Please find attached the following documents:

- I. Research Proposal
- II. Report on the evaluation committee from CUT
- III. Confirmation letter from CUT
- IV. CV of the Researcher

Please let me know if you require any additional information regarding the research study.

Your positive consideration in this regard will be appreciated.

N.L. Setjie

Chief Clinical Technologist Nephrology 1 Military Hospital

Enquiries: Mrs N.L. Setjie

Contact No: 072 288 1769/084 915 4452

May 2024

Dear Sir/Madam

**RE: PERMISSION TO CONDUCT RESEARCH AT HELEN JOSEPH HOSPITAL
(RENAL UNIT)**

My name is Nelly Lerato Setjie, a Clinical Technologist in Nephrology working at 1 Military Hospital for the past 19 years. I am currently pursuing my master's degree in clinical technology in Nephrology at the Central University of Technology. I am seeking permission to conduct my research study at your hospital in the Renal Unit.

The title of the study will be "The assessment of malnutrition on dialysis adequacy of peritoneal dialysis patients at public nephrology facilities in Gauteng province". The reason I am seeking permission to conduct my study at your hospital is that 1 Military Hospital does not have a PD unit.

The research will be Quantitative by nature, where data will be collected from patients' files, an assessment will be done, and patients will have to answer a questionnaire regarding their nutritional status. Only individuals known to the PD unit who adhere to the inclusion criteria will be approached to participate.

Participation in this study is completely voluntary. Patients will sign an informed consent document (ICD) before they are allowed to participate. If, for any reason, they would like to withdraw during the study, they are free to do so without any negative consequences.

Confidentiality will be upheld by de-identifying the patients' particulars by giving them a study code. The patients' names will not be mentioned in any research publication or presentation. The necessary permissions will be sought from the Research Ethics Committee, and all parts of the study will be conducted according to internationally accepted Guidelines such as Helsinki 2013.

The research study is self-funded, and therefore, patients will not receive any kind of remuneration to take part in the study.

Please find attached the following documents:

- I. Research Proposal
- II. Report on the evaluation committee from CUT
- III. Confirmation letter from CUT
- IV. CV of the Researcher

Please let me know if you require any additional information regarding the research study.

Your positive consideration in this regard will be appreciated.

N.L. Setjie

Chief Clinical Technologist, Nephrology 1 Military Hospital

APPENDIX H: RESEARCH ASSISTANT CONFIDENTIALITY AGREEMENT

I, Keabetswe Morwa Maseng, hereby agree to:

- Abide by the confidentiality requirements of this study, as approved by the Faculty of Health Science Research Ethics Committee (HSREC) of the Central University of Technology, by assuring that the identities and information of the patients are not revealed during and after the course of the study.
- Keep all research information shared with me confidential by not discussing or sharing the research information in any form or format with anyone other than the principal investigator.
- Keep all research information in any form or format securely stored while it is in my possession.
- Return research information in any form or format to the principal investigator when I have completed the research tasks.
- After consulting with the principal investigator, erase or destroy all research information in any form or format regarding this research project that is not returnable to the principal investigator (e.g. information stored on computer hard drives).

If you have any questions or concerns about this study, please contact:

External supervisor:

Name: Dr S.C. Benjamin

Phone: 073 508 0362

E-mail: sherileneb@dut.ac.za

This study has been reviewed and approved by the South African Medical Association Research Ethics Committee (SAMAREC). For questions regarding your rights and/or the ethical conduct of research, contact the HOD of the Department of Biomedical Sciences, Prof. P.H. Mfegwana, during office hours at Tel 051 507 3576 or e-mail at pntsoeli@cut.ac.za.

Research Assistant:

Keabetswe Morwa Maseng

Print Name



Signature

20/05/2024

Date

Principal Investigator:

Nelly Lerato Setjie

Print Name



Signature

20/05/2024

Date

APPENDIX I: PERMISSION TO ACCESS RECORDS FROM STEVE BIKO ACADEMIC HOSPITAL

STEVE BIKO ACADEMIC HOSPITAL

Enquiries: Dr J.S. Mangwane

Tel No: +2712 3452018

Fax No: +2712 354 2151

E-mail: joseph.mangwane@gauteng.gov.za

For attention: Nelly Lerato Setjie

NHRD Ref Number: GP_202406_015

Re: REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT STEVE BIKO ACADEMIC HOSPITAL

TITLE: The assessment of malnutrition on dialysis adequacy of peritoneal dialysis patients at public nephrology facilities in Gauteng province

Permission is hereby granted for the above-mentioned research to be conducted at Steve Biko Academic Hospital. This is done in accordance to the Promotion of Access to Information Act No 2 of 2000. Please note that, in addition to receiving approval from Hospital Research Committee, the researcher is expected to seek permission from all relevant departments. Furthermore, collection of data and consent for participation remain the responsibility of the researcher. The hospital will not incur extra costs as a result of the research being conducted within the hospital. You are also required to submit your final report or summary of your findings and recommendations to the office of the CEO.

STATUS OF APPLICATION: Approved

Date: 2024-06-24

Dr J.S. Mangwane

Manager: Medical Service

APPENDIX J: PERMISSION TO ACCESS RECORDS FROM HELEN JOSEPH HOSPITAL



GAUTENG PROVINCE
REPUBLIC OF SOUTH AFRICA

Gauteng Department of Health
Helen Joseph Hospital
Enquiries: Dr. A Manning
Acting Chief Executive Officer
Tel : (011) 489-0306/1087
Fax : (011) 726-5425
E mail: Arthur.manning@gauteng.gov.za
Date: 26 August 2024

Dear Mrs. Nelly Setjie

STUDY: The assessment malnutrition on dialysis adequacy of peritoneal dialysis patients at public nephrology facilities in Gauteng province.

GP_202406_015

The above the study was discussed at the Research Committee meeting. We recommend that permission be granted for Helen Joseph Hospital to be used as a site for the above research,

The researcher is expected to the following:

- Upon completion of the study, copy thereof should be submitted to Helen Joseph Hospital.
- It is the researcher's duty to collect the data from the relevant department after the Research Committee approved the study.

Please liaise with the HOD and Unit Manager or Sister in Charge to agree on the dates and time that would suit all parties.

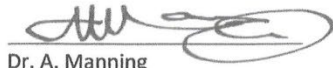
Kindly forward this office with the feedback of your study on completion of the research.

Thank you



Dr. M.D Mukansi
Helen Joseph Hospital
Research Chairperson

Approved



Dr. A. Manning
Helen Joseph Hospital
Acting CHIEF EXECUTIVE OFFICER
DATE: 2024/09/03

APPENDIX K: ETHICS COMMITTEE APPROVAL LETTER

THE SOUTH AFRICAN MEDICAL ASSOCIATION NPC

Block F Castle Walk Corporate Park, Nossob Street, Erasmuskloof Ext3, Pretoria,
0181, South Africa T +27 (0) 12 481 2000 • F +27 (0) 481 2100 • online@samedical.org
www.samedical.org

29A Magnus Rd, Valhalla Centurion 0137

Dear Nelly FINAL APPROVAL Protocol Number: 05 June 2024

Attention: N.L Setjie nellypilane@gmail.com

Protocol Title: The assessment of malnutrition on dialysis adequacy of peritoneal
dialysis patients at a public nephrology facilities in Gauteng province

SAMAREC Approval Number: 280808016/046/2024

Your application dated 15 April 2024 for ethical evaluation of the abovementioned study was considered by the South African Medical Association Research Ethics Committee at the meeting held 08 May 2024. The Committee reviewed the application as detailed below. The Ethics Committee is a registered IRB at the Office of Human Research Protection of the USA. Federal Wide Assurance was also received from the Office of Human Research Protection (Office of Human Research Protection Group). SAMAREC follows the standards adopted by the latest version of the American Food & Drug Administration (FDA) and ICH Harmonized Tripartite Guidelines for Good Clinical Practice; and conforms to the guidelines laid down by the World Medical Association, in particular, the Declaration of Helsinki (October 2013), the Belmont Report, the National Department of Health and the SA Health Products Regulatory Authority. Reports and Monitoring Following approval of a protocol, six-monthly reports on the trial must be submitted to SAMAREC. Failure to forward these reports will result in suspension of approval for the protocol, without any prior notification by SAMAREC. Any decisions taken by SAMAREC after the review of the Progress Reports, will be conveyed to the investigator. Once the study has been completed, the final study report must be submitted in due course. Copies of the SAHPRA reports will suffice. SAMAREC would also appreciate copies of relevant publications arising from reviewed work. All information will be placed on record and kept confidential at the

offices of the SA Medical Association for at least three years after the completion of a trial. Please provide SAMAREC with a last patient and last visit report when closing your study. Protocols are approved for a maximum period of one year only, the approval will lapse 12 months from the date of the approval date mentioned on this approval letter. For protocols, which continue beyond one year, it is the responsibility of the Principal Investigator and the sponsor to submit to SAMAREC an Application for Continuing Review supported by the study progress report. The SAMAREC Application for Annual Renewal must be submitted in time, to allow for review and approval no later than 12 months from the initial review date. Upon receipt of the application for Annual Renewal SAMAREC will review and approve, if appropriate, continuation of the project for the subsequent approval period. Please provide an updated Investigators Brochure with this application.

Dr M. Mzukwa (Chairperson)

Prof. A. Dhai (Vice-Chairperson)

Prof. M. Mabenge (President)

Dr M. Nodikida (CEO) The South African Medical Association NPC Reg. No: 1927/000136/08

The following members evaluated the protocol:

NAME OF MEMBER, FIELD OF INTEREST, DESIGNATIONS FOR REC

Dr N. Naidoo BSc, BMedSc, MBBCh, MPH, MMed (Clin Path), FC Path(SA) Clin Clinical Pathologist Chairperson Medical Professional, Indian, Male

Ms T. Coetzee PG Dip (Health Res Ethics); M Phil (Applied Ethics) Health Research Ethics Project Manager Vice Chairperson Health Research Ethics Expert, White, Female

Prof. J.R. Snyman MBChB, M Pharm Med, MD Pharmacologist Research Ethics Expert, Experience in Quantitative Research Methodologies, Expert in biostatistics, White, Male

Dr M. Groenewald MBChB, DCH (SA), PG Dip Int Res Ethics(UCT) General Practitioner Research Ethics Expert, Medical Professional, White, Female

Prof. M. Kakaza MBChB, MMed(Neuro) Specialist Neurologist SAE Officer Research Ethics Expert, Medical Professional, Black, Female

Mrs B. Fineberg BSc (Hons); H.D.E Educator Layperson, White, Female

Ms N. Madolo BHSc Biomedical Science Quantitative Research Quantitative Research, Black, Female Mr R. Masemola BCom(Law), LLB, Cert. in Corp Govern Legal Advisor Legal Representative, Medico Legal Advisor, Black, Male

Ms M. Raitso Dip. Biomedical Sciences, BSc, Hons Epidemiology & Biostatistics, MSc Epidemiology & Biostatistics Epidemiology & Biostatistics Biostatistician, Black, Female

Ms K. Ledibane BA in Communications, Hons Psychology, MA Forensic Psychology Psychologist Counsellor, Community Representative, Black, Female

Mr M. Shackleton LLB, LLM, PG Course in Corporate Law Legal Advisor Legal Representative, White, Male, Dr S. Nyamathe MBChB, Dip Public Health, MSc Child Health Public Health Clinician SAE Officer Medical Professional, Qualitative Research, Black, Female

RESOLUTION

After noting and considering the input of the evaluators on the above-mentioned Research Proposal, the Committee RESOLVED that the proposal should be Approved.

1. COVERING LETTER

The Covering Letter dated 15 April 2024 and e-mail notifications received 24 May 2024, 29 May 2024 and 05 June 2024 were noted and accepted. The study will be conducted on patients with kidney failure using Peritoneal Dialysis (PD) as the treatment. Peritoneal Dialysis is one of the main treatment options for kidney failure offered to patients with kidney disease. The treatment involves solute and fluid exchange in the stomach (peritoneal membrane), allowing for the elimination of wastes products from the body. The treatment has adverse health effects and consequences such as malnutrition which occurs in 30–50% of the patients that affect the treatment. Patients who suffer from kidney failure have a great chance of worsening by not getting the right amount of nutrients and dialysis treatment or develop malnutrition which can

contribute to the patients' health status. Malnutrition and poor dialysis are risk factors for hospitalization and increased number of deaths of PD patients. Thus, the aim of the study is to determine the significance of dialysis malnutrition on dialysis adequacy of peritoneal dialysis patients on PD treatment and to be able to detect early malnutrition and poor dialysis to prevent complications related to dialysis dose.

2. SAMAREC APPLICATION FORM

The SAMAREC Application form dated 15 April 2024 was noted and accepted.

3. BUDGET

The Budget received 05 June 2024 was noted and accepted.

4. PATIENT INFORMATION AND INFORMED CONSENT DOCUMENT (PID)

The Patient Information and Informed Consent Document date May 2024, Version 3 was noted and approved.

5. RESEARCH PROPOSAL

The Research Proposal dated May 2024 Version 4 was noted and approved.

- SAMAREC notes that updated literature sources and guidelines will be reference in the thesis write-up.

6. DATA COLLECTION INSTRUMENT

Data Collection Sheet dated May 2024, Version 3 was noted and approved.

7. SCIENTIFIC APPROVAL LETTER

The approval letter from the Faculty of Health and Environmental Science's Protocol Evaluation Committee dated 29 September 2024 was noted and accepted.

8. CURRICULUM VITAE OF STUDY STAFF

The Committee noted the CVs, declarations and other relevant documentation and RESOLVED as follows: SITE SITE

STAFF CV AND DOCUMENTATION N/A

N. Setjie Principle Investigator Noted and Accepted. STATUS Approved.

SC Benjamin Main Supervisor Noted and Accepted. Approved.

Dr M. Mzukwa (Chairperson)

Prof. A. Dhai (Vice-Chairperson)

Prof. M. Mabenge (President)

Dr M. Nodikida (CEO)

The South African Medical Association NPC Reg. No: 1927/000136/08

P.H. Mfengwana Co-Supervisor Noted and Accepted. Approved.

- Kindly take note that all health professionals who dispense medicines are required to have a dispensing licence unless a pharmacist is on site to dispense such medicines. In addition, medical practitioners with dispensing licenses are only permitted (legally) to dispense on their own prescriptions.
- Kindly ensure that GCP Training is renewed in due course.
- Take note that Pharmacists dispensing medicines require Malpractice Insurance.
- Kindly ensure that expired registrations with Statutory Councils must be updated/renewed as appropriate.
- Clinical trial information on CV's should have the names-of sponsors, abbreviated titles and protocol numbers of all studies listed.
- Kindly take note that all registered nurses who will be performing duties which fall within the scope of the nursing profession, are required to hold professional indemnity insurance in their personal capacities, unless their professional actions will be indemnified/covered by the insurance held by the sponsor. The onus is on the sponsor to ensure that the necessary and adequate insurance and professional indemnity coverage is in place before commencement of the study.
- Please ensure that all necessary documentation is submitted to SAMAREC as requested.

- Kindly ensure that all staff involved in touching a patient submit malpractice insurance.

Yours sincerely

Lisa Reid

SAMAREC Officer SA Medical Association

(012) 481-2082 samarec@samedical.org

2024/06/04 10:11:46

APPENDIX L: STATISTICAL EQUATION FOR SAMPLE SIZE

POPULATION AND SAMPLE SIZE ¶

¶
An estimated 250 participants will be from the 2 Hospitals, SBAH and CHBAH. The sample will consist of both male and female participants between the ages of 18 to 55 who are receiving PD treatment. Approval from the Hospitals and informed consent from the participants will be obtained before commencing with the study. ¶

¶
Given the sample size equation below, the following parameters were set: confidence level = 0.95; margin of error (ME) = 0.05; population proportion (P) = 0.5. For the estimated population size (N) of 250 patients the total sample size (n) for the study will be 152 patients, that is 76 patients will be randomly selected from each study location. ¶

$$n = \frac{X^2 * N * P * (1-P)}{(ME^2 * (N-1)) + (X^2 * P * (1-P))}$$

Where:

n = sample size

X^2 = Chi - square for the specified confidence level at 1 degree of freedom

N = Population Size

P = population proportion (.50 in this table)

ME = desired Margin of Error (expressed as a proportion) ¶

APPENDIX M: ARM MUSCLE AREA CALCULATION FORMULA

The general formula for Arm Muscle Area (AMA) is:

$$\text{AMA (cm}^2\text{)} = [\text{MUAC (cm)} - (\pi \times \text{TSF (cm)})]^2 / 4\pi$$

Where:

- MUAC is the Mid-Upper Arm Circumference, measured in centimetres (cm).
- TSF is the Triceps Skinfold thickness, measured in centimetres (cm).
- π is the mathematical constant Pi, approximately 3.14159.

Important Considerations

This is an estimation and has limitations. Some researchers have proposed corrected formulas to account for the fact that the arm muscle compartment is not perfectly circular and includes bone.

Steps for Calculation

- **Measure MUAC:** Wrap a non-stretchable measuring tape around the midpoint of the upper arm (halfway between the shoulder and elbow). Record the measurement in centimetres.
- **Measure TSF:** Use a skinfold calliper to measure the thickness of the skinfold on the back of the arm at the same midpoint. Record this measurement in centimetres.
- **Apply the Formula:** Plug the MUAC and TSF values into the chosen formula to calculate the Arm Muscle Area.

APPENDIX N: TWARDOWSKI'S FORMULA FOR KT/V

$KT/V = \frac{\text{Ultrafiltration volume} \times 7 \text{ days}}{\text{Patient weight (Total Body Weight TBW (L))}}$

This formula provided a rough estimate of dialysis adequacy in PD patients, and it was recommended not to be used as the sole measure of dialysis adequacy, because it has limitations.

APPENDIX O: BIOSTATISTICIAN APPROVAL LETTER

Maryn Viljoen
Statistics Consulting Services

082 823 5731
maryn.viljoen1@gmail.com

Protocol & research methodology consultation | Ethical consultation | Database construction & capturing of data
Analysing data using statistical software packages (SAS version 9.2) | Statistics consultation services to analyse and interpret data
Conveys results with statistical tables & figures where needed

15 April 2024

To: Health Science Research Ethics Committee of the Central University of
Technology

Title: "The assessment of malnutrition on dialysis adequacy of peritoneal
dialysis patients at a public nephrology facilities in Gauteng
province."

Researcher: N.L. Setjie (223095750)
Masters in Health Science: Clinical Technology
Department of Clinical Technology in Nephrology
Faculty of Health Sciences
Central University of Technology, Free State

I have seen and read through this protocol. I gave input and recommendations
and will be the biostatistician responsible for the analysis of the data.

Maryn Viljoen
M.Sc. Risk Analysis (UFS)
maryn.viljoen1@gmail.com
082 82 35 731