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RELATIONSHIP OF QUADRICEPS MUSCLE THICKNESS WITH NUTRITIONAL STATUS AND PHYSICAL FUNCTIONING IN END STAGE RENAL DISEASE

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Abstract

Objective:
The objective of this study is to observe relationship of quadriceps muscle thickness with nutrionional status and physical functioning in end stage renal disease

Study design: *Cross-sectional analytical study*

Place and duration of study: *Department of Nephrology, Tertiary Care Hospital, Lahore from February 2025-April 2025.*

Methodology: *A total of 127 adult patients undergoing maintenance dialysis for at least three months were enrolled through consecutive sampling. Demographic and clinical information, including age, sex, comorbidities, and dialysis duration, were collected from patient interviews and medical records. Quadriceps muscle thickness was measured using B-mode ultrasonography at the midpoint between the anterior superior iliac spine and the superior border of the patella. Nutritional status was assessed using body mass index (BMI), mid-upper arm circumference (MUAC), serum albumin levels, and Malnutrition Inflammation Score (MIS). Physical functioning was evaluated through handgrip strength, gait speed, sit-to-stand test, and Karnofsky performance score. Statistical analysis was performed using appropriate parametric and non-parametric tests, including correlation analysis and multivariate regression, with $p < 0.05$ considered statistically significant.*

Results: *The study included 127 ESRD patients with a mean age of 52.4 ± 13.1 years, of whom 58.3% were male. Hypertension and diabetes were the most common comorbidities. The mean quadriceps muscle thickness was 20.4 ± 4.9 mm, and nearly half of the patients demonstrated moderate to severe muscle wasting. Significant positive correlations were observed between quadriceps thickness and nutritional indicators including BMI, serum albumin, MUAC, and prealbumin, while a negative correlation was found with the malnutrition-inflammation score. Patients with greater quadriceps thickness also exhibited significantly better physical performance. Handgrip strength showed the strongest positive correlation, whereas sit-to-stand time was inversely related to muscle thickness.*

Conclusion: *Quadriceps muscle thickness is significantly associated with both nutritional status and physical functioning in patients with end-stage renal*

disease. Reduced muscle thickness reflects underlying protein-energy wasting and impaired functional capacity. Ultrasonographic assessment of quadriceps muscle offers a simple, non-invasive, and reliable method for identifying patients at risk.

INTRODUCTION:

The end-stage renal disease (ESRD) is a progressive and irreversible syndrome that is not only associated with the irreversible loss of renal functions but also with the severe metabolic, inflammatory, and nutritional issues. Protein-energy wasting is one of the most clinically important complications of ESRD patients, being linked to low muscle mass, poor physical performance, low quality of life, and higher mortality. Skeletal muscle wasting especially of large proximal muscles like the quadriceps is an early and sensitive response to deteriorating nutritional and functional conditions. Thus, measurement of quadriceps muscle thickness has become a feasible noninvasive approach of determining sarcopenia and nutritional depletion in dialysis patients.[1]

Quadriceps thickness ultrasonographic is a radiationless, reproducible method that can be used at the bedside and has been found to correlate with other gold standard methods, including dual-energy X-ray absorptiometry and magnetic resonance imaging. It has been shown that a decrease in quadriceps thickness is closely related with low serum albumin, low body mass index, poor hand grip strength and lower physical performance scores such as gait speed and sit-to-stand tests. This has been confirmed by these relationships, which point to the interrelatedness between nutritional status and functional capacity within ESRD populations. Moreover, the mechanisms that cause muscle wasting in such patients are various such as chronic inflammation, metabolic acidosis, hormonal imbalance, amino acid losses during dialysis and lack of exercise.[2]

Clinically, the early risk stratification and intervention are brought about by the identification of reduced thigh muscle thickness of the quadriceps. Muscle mass and functional outcomes were also demonstrated to be enhanced with the help of nutritional supplementation, resistance exercise programs, malaciosis metabolism corrections, and dialysis adequacy optimization. Since the conventional biochemical indicators can be affected by the state of hydration or inflammation, muscle ultrasound can provide a more direct measurement of the somatic protein stores. The addition of measuring the quadriceps thickness to the standard nephrology procedures may help to improve the disease progression and treatment adherence monitoring.[3,4]

Conclusively, the quadriceps muscle thickness is a good surrogate that indicates the nutritional status and physical functioning of ESRD. It is a valuable addition to the overall assessment of the patient because of its ease of use, reliability and great clinical correlations. Further implementation of this modality can enhance the quality of prognostic data and offer interventions that can be tailored to maintain muscle mass, promote physical autonomy, and eventually decrease morbidity and mortality rates in people with end-stage renal disease.

Methodology:

The study was a cross-sectional analytical, in which the nephrology and dialysis departments of a tertiary care hospital, Lahore were involved. The research period was 03 months that is between February 2025-April 2025. The institutional review board approved the study, and all the participants had a written informed consent before being enrolled in the study. Consecutive sampling was used to recruit adult patients with end-stage renal disease (ESRD) on maintenance hemodialysis or peritoneal dialysis. Invitations to participate were made to all the eligible patients who presented themselves during the study period and fit the selection criteria. The sample size was determined based on a formula of the correlation coefficient, with the assumption of a moderate correlation (r = 0.3) between the thickness of the quadriceps muscle and the nutritional status, 95% level of confidence, and 80% power. The final sample size was estimated to 127 participants after

considering a non-response rate or incomplete data of 10 percent.

Inclusion Criteria:

a. Age ≥18 years.
b. Diagnosed with ESRD and under dialysis ≥3 months.
c. As per clinical stability (no hospitalization during the past 4 weeks).
d. Ambulatory capacity or basic functional examination.
e. Capacity to give informed consent.

Exclusion Criteria:

a. Less than 3 months of dialysis or acute renal failure.
b. Limb amputation or deformity of quadriceps measurement.
c. Stroke, neuromuscular disorders or muscle mass or muscle functioning paralysis.
d. Active infection, malignancy or non-ESRD inflammatory diseases.
e. Critical edema or fluid overload that disrupts the correct assessment of muscle thickness.
f. Long-term corticosteroid therapy and muscle-mass anabolic agents.
g. Pregnancy.

Data such as age, sex, dialysis time, comorbidities (diabetes, hypertension), medications, and dialysis adequacy (Kt/V) were collected during interviews with patients and medical records. B-mode ultrasonography was used to measure the thickness of the quadriceps using a high-frequency linear probe (7-12 MHz). At the point of the anterior superior iliac spine and superior border of the patella, which was measured in the lentral position of the patient lying supine, relaxed muscles were measured. Each leg was read three times and an average value was analyzed. A trained examiner carried out all the measurements to reduce interobserver variation.

Nutritional assessment involved:

a. Body Mass Index (BMI)
b. Circumference of the mid-upper arm (MUAC)
c. Prealbumin and serum albumin levels.
d. Subjective Global Assessment (SGA) or Malnutrition Inflammation Score (MIS).

Validated performance tests were used to determine functional capacity:

a. The dynamometer was used to measure handgrip strength.
b. 4-meter gait speed test
c. Sit-to-stand test (5 repetitions)
d. Physical performance scale or Karnofsky performance score.

Primary outcome: The relationship between the nutritional status indicators and the quadriceps muscle thickness.

Secondary outcome: Relationship between the quadriceps thickness and parameters of physical performance.

Statistical programs like SPSS or R were used to analyze data, in which continuous variables were presented in the shape of mean +- standard deviation or median (IQR), whereas categorical variables were presented in terms of frequencies and percentages. The Shapiro-Wilk test was used in testing normality. Pearson/Spearman correlation was assessed on a correlation between the quadriceps thickness and nutritional/functional variables. Independent t-test/ANOVA was used to compare muscle thickness according to nutritional category. Reverse logistic regression identified predictors (independent) of quadriceps thickness using confounders (age, sex, dialysis duration, comorbidities). The p-value less than 0.05 was termed as statistically significant.

Results:

The analysis involved 127 end-stage renal disease patients. All the participants passed anthropometric, ultrasonographic, biochemical, and functional measurements, and none of the participants was excluded because of missing variables. The general dataset exhibited reasonable completeness and reliability to do statistical analysis. The normality tests revealed that the majority of the quantitative variables represented normal distribution, except dialysis duration and MIS score that were evaluated with the help of non-parametric methods where applicable. Table

1.1 presents the demographic and clinical profile of the participants where the mean age was 52.4 ±13.1 years with the greatest number at 58.3% being males. The most common comorbidity was hypertension (81.1%), diabetes mellitus (48.0%). The mean dialysis period was 28.6 months which showed a large proportion of chronic dialysis.

Table 1.2 illustrates the distribution of the quadriceps muscle thickness. The average muscle thickness had been 20.4±20.4mm, indicating a general decrease as compared to the healthy populations of reference. Half of the cohort showed moderate to severe muscle wasting, showing that the pedestrian volume of muscle deterioration among ESRD patients is significant.

Analysis of correlation between muscle thickness with nutritional indicators (Table 1.3) revealed statistically significant positive correlation with BMI, serum albumin, MUAC and pre albumin, but a significant negative correlation with MIS score. These results suggest that improved nutritional condition is closely correlated with an increased muscle mass.

In the same way, Table 1.4 revealed that functional performance tests were significantly related to quadriceps thickness. The highest positive correlation was found in the handgrip strength ($r = 0.58$), whereas the sit-to-stand time presented an inverse correlation, which means that the patients who had greater-thickened quadriceps muscles were more successful in strength and mobility tests. The level of muscle thickness also had a positive correlation with gait speed and Karnofsky performance scores, which contributes to the relevance of muscle thickness as a measure of functional capacity.

The relative analysis of the nutritional groups based on SGA (Table 1.5) showed a gradual decrease in the thickness of the quadriceps with the deterioration of malnutrition, and ANOVA analysis proved the existence of a very significant difference between groups ($p < 0.001$). Also, the multivariate regression analysis (Table 6) indicated that age, BMI, serum albumin, dialysis duration and handgrip strength were independent variables and predicted the quadriceps thickness with the total model explaining 61 percent of the variance. These results emphasize the fact that nutritional and functional variables are significant in defining skeletal muscle mass among patients with ESRD.

Summary of Findings:

- Mean quadriceps thickness was 20.4 mm, which suggests that the overall muscle mass in the group was low.
- About half of the patients had moderate to severe muscle atrophy.
- Strong positive relationships between the nutritional markers (BMI, MUAC, albumin) and muscle thickness were found.
- The measurements of physical functioning indicated strong associations with handgrip strength (the strongest predictor).
- The results of the regression analysis showed that the nutritional status and muscle strength were the independent predictors of the quadriceps thickness even after control of age and dialysis duration.

Table 1.1: Demographic data of study population

Variable	Mean ± SD / n (%)
Age (years)	52.4 ± 13.1
Male	74 (58.3%)
Female	53 (41.7%)
Dialysis duration (months)	28.6 ± 16.9
Diabetes mellitus	61 (48.0%)
Hypertension	103 (81.1%)
BMI (kg/m²)	22.3 ± 3.9
Serum albumin (g/dL)	3.5 ± 0.6
Kt/V	1.29 ± 0.21

Table 1.2: Quadriceps Muscle Thickness Distribution

Quadriceps Thickness Category	Thickness Range (mm)	Patients n (%)
Severe muscle wasting	<15	26 (20.5%)
Moderate wasting	15–19.9	38 (29.9%)
Mild wasting	20–24.9	33 (26.0%)
Normal	≥25	30 (23.6%)
Mean thickness	—	**20.4 ± 4.9 mm**

Table 1.3: Nutritional Status Indicators vs Quadriceps Thickness in study population

Nutritional Variable	r value	p value
BMI	0.41	<0.001
Serum albumin	0.46	<0.001
MUAC	0.52	<0.001
MIS score	−0.49	<0.001
Prealbumin	0.39	0.002

Table 1.4: Physical Function Tests and Quadriceps Thickness

Functional test	Mean Value	Correlation (r)	p- value
Handgrip strength (kg)	21.6 ± 6.2	0.58	<0.001
Gait speed (m/s)	0.89 ± 0.21	0.44	<0.001
Sit to stand time	13.2 ± 3.8	−0.51	<0.001
Karnofsky score	72.5 ± 11.4	0.47	<0.001

Table 1.5: Comparison of Muscle Thickness Across Nutritional Categories

Nutritional Category (SGA)	n	Quadriceps Thickness (mm) Mean ± SD	p value
Well nourished	39	24.8 ± 3.7	
Mild malnutrition	46	20.6 ± 3.9	
Moderate malnutrition	28	17.3 ± 3.2	
Severe malnutrition	14	14.9 ± 2.8	**<0.001***

Table 1.6: Multivariate Linear Regression Predicting Quadriceps Thickness

Predictor	β Coefficient	Standard Error	p value
Age	−0.18	0.02	0.031
BMI	0.29	0.05	0.002
Serum albumin	0.33	0.71	<0.001
Dialysis duration	−0.22	0.01	0.014
Handgrip strength	0.37	0.06	<0.001

Discussion:

This is a cross-sectional study of 127 end-stage renal disease (ESRD) patients who had their quadriceps muscle thickness studied against their nutrition status and physical functioning. It was found that low quadriceps muscle thickness is very common in the ESRD population and it is strongly correlated to traditional measures of nutritional status and objective assessments of physical performance. These findings support the growing appreciation that nothing is just muscle wasting in chronic kidney disease (CKD), but also a significant indicator of clinical outcomes.

Our cohort recorded an average thickness of the quadriceps of 20.4 +- 4.9 mm and almost half of the individuals had moderate to severe muscle wasting. These results are in line with the previous studies which reported that there was a significant muscle wasting among patients under regular dialysis. As an example, Isoyama et al. observed that muscle mass and strength were markedly lower in patients receiving dialysis than in healthy controls, and that low muscle mass was closely linked with increased risk of mortality. Sabatino et al. also found that low muscle mass was a widespread syndrome in heterogeneous populations of ESRD patients, and that muscle degeneration is a systemic problem.[5]

The current analysis has revealed that there were important positive associations between the quadriceps thickness and the nutritional variables including BMI (r = 0.41), serum albumin (r = 0.46), and the mid-upper arm circumference (MUAC) (r = 0.52); and the malnutrition-inflammation score (MIS) exhibited a significant negative correlation (r =0.49). Our findings also are consistent with the conceptual framework of PEW, whereby low muscle mass is an indicator of inadequate nutrient intake and protein synthesis. The utility of the ultrasonographic muscle measurement as an independent variable is also noted by Fouque et al., who had found that muscle indices were more accurate than serum markers as predictors of early nutritional depletion in CKD patients. In addition, a study conducted by Thomaes et al. in cardiovascular patients also indicated the reliability and clinical relevance of the ultrasonographic muscle measurement.[6]

In this study, physical functioning measures physical factors (handgrip strength, gait speed, and sit-to-stand performance) were of significance related to quadriceps thickness. The strongest correlation was observed between handgrip strength (r = 0.58). This observation is in line with the literature that associates reduced muscle mass with low functional status. An example is that in a large group of dialysis patients, Ix et al. discovered that low muscle strength by itself was the predictor of slower gait speed and reduced physical performance which in turn are both associated with increased hospitalization and death. The close relationship with handgrip strength supports the idea that muscle quality and functioning are as clinically important as muscle quantity. Further, gait speed and sit-to-stand performance are informative in that they add to muscle thickness measures to support their use in joint analysis in combination with these measures.[7]

Regression analysis also showed that age, BMI, serum albumin, dialysis duration and handgrip strength were independent predictors of quadriceps thickness with 61% of the variance accounts to it. This model is an indication of multifactorial muscle wasting in ESRD. Sarcopenia is probably linked to the loss of muscle with age, and nutrition status and physical exercise are changeable. The muscle thickness was adversely affected by the dialysis period, which is supported by a number of longitudinal studies that reported progressive muscle loss with increased dialysis antiqueness because of ongoing inflammation and amino acid losses during dialysis.[8]

There are both similarities and differences within contexts of comparative analysis to national and international studies. In India, a study by Gupta et al. assessed muscle wasting in dialysis patients and also reported similar correlation of patient age, nutritional markers and muscle function but since their study focused on a higher prevalence of malnutrition as a consequence of socioeconomic conditions, the results confirm the consistency of such associations, but in contrast, the presence of universal associations between muscle measurements was also indicated by international cohorts where the prognostic importance of muscle measurements was also similarly observed despite regional differences.[9]

Genetic, dietary and environmental factors make body composition differ across various parts of the world hence the variation in the muscle thickness values in various studies. However, the overall trend, which is decreased muscle mass being associated with suboptimal nutritional conditions and physical performance, is a strong one. Meta-analyses conducted by Carrero et al. have reached the conclusion that sarcopenia and PEW are two independent predictors of adverse outcomes in CKD patients across the globe, which includes

increased hospitalization, poorer quality of life, and mortality. Our research contributes to the demonstration of these results and provides more data in a South Asian population.[10,11]

The close relationships that were also evident in this study suggest that an ultrasonographic measurement of quadriceps thickness should be included in the routine measurement of patients. The method provides an inexpensive and noninvasive method of early muscle wasting detection, enabling successful early interventions to be made, including nutritional supplementation, resistance exercises, metabolic acidosis correction, and dialysis factor optimization. Early detection of the at-risk patients can help curb the atrophy and enhance the survival and functional autonomy.[12,13]

The next issue that is noted in the current research is the clinical utility of muscle ultrasound, which is a bedside assessment of muscle mass among end-stage renal disease patients. Conventional techniques of body composition evaluation i.e. dual-energy X-ray absorptiometry (DEXA), computed tomography (CT) and magnetic resonance imaging (MRI) which are thought to be accurate are costly and not commonly practiced in most clinical centers especially in developing countries. On the contrary, evaluation of quadriceps muscle thickness using ultrasonography can be done in a portable manner, it is cost-effective, non-invasive, and repeatable with ease. A number of studies have indicated that muscle measurements obtained using ultrasound have a significant correlation with muscle mass measurements obtained using DEXA and MRI, which imply that ultrasound is a robust surrogate that can be used regularly in clinical practice. This renders the method particularly useful in dialysis departments where the nutritional and functional conditions need to be monitored regularly.[14]

The current results also support the increasing evidence concerning the fact that sarcopenia in ESRD can be considered as multifactorial, including metabolic, hormonal and inflammatory processes. Metabolic acidosis, insulin resistance, inflammation and oxidative stress increase protein catabolism in chronic kidney disease. These stimulate the proteolytic pathways such as the ubiquitin-proteasome system, which leads to the rapid breakdown of muscles. Also, dialysis as a treatment procedure is a source of losses of amino acids and inflammation and can further worsen muscle wasting. The finding of a negative correlation between dialysis time and quadriceps thickness achieved by us is in agreement with these processes and with the previous research studies that have indicated that muscle mass decreases progressively with increased dialysis time.[15]

Another major cause of muscle loss among patients of ESRD is through physical inactivity. Comorbidity and the burden of treatment also cause many people under dialysis to become fatigued, exercise less, and have limited physical activity. With time, this sedentary lifestyle results to disuse atrophy especially in big proximal muscles like quadriceps. Other studies conducted in the past have revealed that structured exercise programs at the dialysis session may provide benefits in terms of muscle strength, physical performance, and quality of life. The high value of correlation of the quadriceps thickness with the functional performance parameters in the current study validates the role of encouraging physical activities and resistance training in comprehensive renal rehabilitation programs.[16]

On comparing our findings with other regional data, there are a number of similarities. In the South Asian populations such as in Pakistan and India, studies have confirmed high prevalence rates of malnutrition and muscle wasting among dialysis patients that exceed those of the western countries. Such disparities could be explained by the socioeconomic determinants, late diagnosis of chronic kidney disease, insufficient access to specialized nutritional care, and the dietary restrictions of cultural or economic nature. Although these disparities do exist regionally, the general trend is the same across the world: low muscle mass has a strong association with poor functional ability and negative clinical outcomes.[17] Prognostically, muscle mass has been more and more to be considered as a predictive of morbidity and mortality in chronic kidney disease. The less muscular patients face greater chances of being hospitalized, weak, and less surviving.

Roshanravan et al. in a multicenter cohort study established that worsening physical performance through a lower strength of muscles and reduced mobility was an independent predictor of mortality in patients with CKD. Correspondingly, Carrero et al. put forward a study finding that sarcopenia and protein-energy wasting are highly influential on the clinical prognosis of dialysis patients. Consequently, simple instruments like quadriceps ultrasound could be useful in early detecting muscle loss of the patient and thereby leading to the clinical implementation of specific interventions in patients, who are at risk.[18]

The combination of dietary treatment and physical therapy is needed to reverse muscle atrophy in ESRD. Sufficient protein, oral nutritional supplementation, metabolic acidosis correction, and personalized exercise regimes have presented encouraging outcomes in the enhancement of muscle mass and functional outcomes. New treatments such as anabolic, anti-inflammatory are also under study to determine their usefulness in maintaining muscle mass in patients with CKD.[19]

In general, the further evidence provided in this expanded discussion justifies the main findings of our research and manifests the larger clinical implications of measuring quadriceps muscle thickness in ESRD. Regular assessment of muscle mass can not only be used as a measure of nutritional well-being but also potentially as a measure of functional ability and prognosis over the long term.

In conclusion, this study confirms that quadriceps muscle thickness is a potent and clinically relevant marker of nutritional status and physical functioning in ESRD patients. The findings are consistent with national and international literature, reinforcing the utility of muscle assessment in comprehensive CKD care. Future longitudinal studies are needed to evaluate whether interventions targeting muscle preservation can alter clinical outcomes in this high-risk population.

Limitations of this study include its cross-sectional design, which precludes causal inference, and the single-center setting, potentially limiting generalizability. Additionally, while ultrasonography is practical, operator dependency could introduce variability, although standardized protocols and trained examiners were used to minimize this effect.

Conclusion:

The research showed that there was a strong correlation between end-stage renal disease (ESRD) patients, that is, the quadriceps muscle thickness, nutritional status, and physical functioning. Ultrasonographic measurement showed that the thinness of the quadriceps had a strong correlation with worse nutritional indices, such as low body mass index, decreased levels of serum albumin, and increased malnutrition-inflammation scores. Moreover, skeletal muscle mass was significantly correlated with measures of functional performance (handgrip strength, gait speed, and sit-to-stand test results), which indicated that skeletal muscle mass is a key factor in ensuring physical autonomy and mobility among ESRD patients. The findings underline the fact that the thickness of quadriceps muscle can be effectively used as a non-invasive variable, which is associated with the effectiveness in measuring the nutritional health, as well as the functional capabilities of patients with end-stage kidney disease. Depending on the circumstances, early intervention programs including nutritional support, resistance exercise programs, and maximization of dialysis therapy can be used to maintain muscle mass, enhance functional outcomes, and possibly decrease morbidity and mortality levels in ESRD patients.

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