

Skinfold Thickness and Mid-upper Arm Circumference in Pediatric Patients with Chronic Kidney Disease

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Abstract

Chronic kidney disease (CKD) can impair the kidneys' capacity to manage nutrition, and any nutritional imbalances in CKD may affect the disease's progression. This study evaluated triceps skinfold (TSF) thickness and mid-upper arm circumference (MUAC) as indicators of nutritional status in children with early- and late-stage CKD at Dr. Hasan Sadikin General Hospital, Bandung, Indonesia. A descriptive cross-sectional design was used with secondary data from the nephrology division registry collected between August 2021 and August 2022. Data analysis was conducted with Microsoft Excel. The study involved 65 participants, with 32 in the early stage and 33 in the late stage. For early-stage patients, the average TSF was 13.75 mm and the MUAC was 12 cm, while, the average TSF and MUAC in the late stage were 11.39 mm and 11.70 cm, respectively. Based on TSF percentiles, most patients fell within the normal range, whereas MUAC measurements indicated that the majority were below normal. In terms of %TSF, most early-stage patients had above-average values, whereas late-stage patients were below average. All MUAC measurements indicated below-average values for both stages. Overall, TSF percentiles suggested that most patients had adequate nutritional status; however, %TSF revealed excess adiposity in early-stage patients and deficits in late-stage patients. MUAC consistently indicated deficits across both groups.

Keywords: Chronic kidney disease, mid-upper arm circumference, nutritional status, pediatric, skinfold thickness

Introduction

Chronic kidney disease (CKD) is a common kidney disorder. According to Kidney Disease: Improving Global Outcomes (KDIGO), CKD is defined as structural or functional kidney abnormalities lasting more than three months, with health implications, such as decreased glomerular filtration rate (GFR) and/or markers of kidney damage. CKD can then be divided into five stages based on the GFR.¹ In children, CKD is more common due to congenital kidney and urinary tract abnormalities. These causes will then lead to damage to the kidneys. How the kidney responds to the damage will affect the course of the disease.² Damage to the kidneys lead to a significantly kidney function deterioration. One of them is the function of the kidneys as a

regulator of nutrition in the body.³ The presence of nutritional disorders in patients with CKD is also a multifactorial matter. This nutritional disorder can occur through several mechanisms: metabolic disorders, chronic inflammation, nutritional and appetite imbalances, disruption of normal microbiota, gastroparesis, dialysis, and oxidative stress.³

Protein-energy wasting (PEW) is the most common nutritional disorder in children with CKD. For children with CKD, this nutritional disorder is, of course, very detrimental. Given that children are very dependent on nutrition for growth and development. In addition, poor nutrition is also associated with a decrease in the quality of life of sufferers.³ Therefore, it is crucial always to pay attention to the nutritional status of children with CKD.

The severity of CKD is also associated with sarcopenia, which increases the risk of cardiovascular complications. Sarcopenia is preceded by anorexia, which mainly occurs in patient undergoing kidney replacement therapy (KRT) for a long time.⁴ Children with

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sarcopenia may appear cachectic, with reduced subcutaneous fat and diminished muscle mass.

Recommended assessments of nutritional status in CKD include weight, height, triceps and subscapular skinfold thickness, and arm and calf circumferences.⁵ This study focused on triceps skinfold (TSF) thickness and mid-upper arm circumference (MUAC) as key indicators of nutritional status.

The objective of this study was to evaluate TSF thickness and MUAC in pediatric patients with early- and late-stage CKD, as these measurements reflect nutritional status. The findings are expected to raise awareness of nutritional deficits in pediatric CKD, contribute to strategies for preventing malnutrition-related cardiovascular complications, and support improvements in the quality of care for children with end-stage kidney disease at Dr. Hasan Sadikin General Hospital, Indonesia.

Methods

This descriptive cross-sectional study used secondary data from the nephrology division patient registry at Dr. Hasan Sadikin General Hospital, Bandung, Indonesia, collected between August 2021 and August 2022. The study included patient data from individuals aged 3 months to 17 years and 364 days. The inclusion criteria were all patients diagnosed with chronic kidney disease (CKD) during the study period. The exclusion criteria were patients with special needs, where accurate measurements could not be taken, and patients with deformities in both arms.

Patients were classified by CKD stage according to glomerular filtration rate (GFR, mL/min/1.73 m²): stage 1 (≥ 90), stage 2 (60–89), stage 3a (45–59), stage 3b (30–44), stage 4 (15–29), and stage 5 (≤ 15). These stages are then grouped into the early stage, which consists of stages 1–3b, and the late stage, which consists of stages 4–5. The GFR was calculated using the formula for pediatric patients based on the KDIGO, $GFR = 41.3 \times (\text{height in meters} / \text{Serum Creatinine in mg/dL})$.

The anthropometric measurements evaluated in this study included triceps skinfold (TSF), percentage of triceps skinfold (% TSF), mid-upper arm circumference (MUAC), percentage of mid-upper arm circumference (% MUAC), mid-upper arm muscle circumference (MAMC), and mid-upper arm muscle area (MMA).

TSF and MUAC were interpreted using WHO

percentiles for children aged 0–5 years and CDC percentiles for children >5 years. Measurements were categorized as below the 5th percentile (reduced), between the 5th and 95th percentiles (normal), or above the 95th percentile (excess). To calculate and interpret the %TSF and the %MUAC, the TSF and the MUAC were first located in the WHO percentile tables for ages 0–5 years old and CDC for children above 5 years old. The percentages of each were calculated with the following formulas: % TSF = $[(\text{TSF actual}) / (\text{TSF 50}^{\text{th}} \text{ percentile})] \times 100$, MUAC = $[(\text{MUAC actual}) / (\text{MUAC 50}^{\text{th}} \text{ percentile})] \times 100$.

%TSF values >110% indicated adipose tissue excess, while values <90% indicated deficit. %MUAC values >110% indicated muscle tissue excess, while values <90% indicated deficit. The MMA was calculated with the formula: $MMA = (\text{MUAC [mm]} - [\pi \times \text{TSF}])^2 / 4\pi$. It is then interpreted according to the Frisancho percentile tables, average muscle tissue if it is above the 15th percentile, mild to moderate depletion of muscle tissue if it is at the 5th to 15th percentile, and severe depletion of muscle tissue if it is below the 5th percentile.

The mid-upper arm muscle circumference (MAMC) was calculated using the formula: $MAMC = [\text{MUAC} - (\pi \times \text{TSF})]$. The result was then interpreted according to the Frisancho percentile tables, with a reduced muscle area indicated if there was more than a 10% reduction relative to the 50th percentile of the reference population.

The study was approved by the Health Research Ethics Committee of the Faculty of Medicine Universitas Padjadjaran (approval number: 1156/UN6.KEP/EC/2022).

Results

A total of 65 pediatric patients with CKD met the inclusion criteria. Patient characteristics are summarized in Table 1. Among the 65 patients, the majority were male (52.3%) and adolescent (60%). The youngest patient was 2 years and 8 months old, while the oldest was 17 years and 8 months old. Regarding disease stage, 32 patients (45.7%) were in the early stage, and 33 patients (50.8%) were in the late stage. The mean TSF for early-stage patients was 13.75 mm, and the mean MUAC was 12 cm, whereas for late-stage patients, the mean TSF was 11.39 mm and the mean MUAC was 11.70 cm.

In the early stage, half (50%) were male, most were in stage 1 (59.4%), and adolescent age (43.8%). The most common complications

Table 1 Characteristics of The Patients in Early and Late Stage

Variable	Early Stage	Late Stage
	n=32	n=33
Sex, n (%)		
Male	16 (50)	18 (54.5)
Female	16 (50)	15 (45.4)
Age, n (%)		
29 days–1 year	-	-
2–5 years	8 (25)	3 (9.1)
6–10 years	10 (31.25)	5 (15.2)
11–18 years	14 (43.75)	25 (75.8)
Triceps skinfold thickness (mm)	13.75 (1.17)	11.39 (2.)
Mid-upper arm circumference (cm)	12 (2.17)	11.70 (2.0)
Blood pressure		
Systolic blood pressure (mmHg), mean (SD)	105.31 (13.23)	123.03 (24.8)
Diastolic blood pressure (mmHg), mean (SD)	69.68 (11.52)	78.79 (14.9)
Laboratorium results, mean (SD)		
Hemoglobin (g/dL)	12.15 (2.46)	8.28 (2.1)
Serum ureum (mg/dL)	39.62 (39.10)	156.36 (88.2)
Serum creatinine (mg/dL)	0.65 (0.42)	7.05 (5.5)
Serum natrium (mEq/L),	136.66 (2.60)	134.83 (4.4)
Serum potassium (mEq/L))	3.94 (0.52)	4.63 (1.4)
Ion calcium (mg/dL)	4.90 (0.37)	4.83 (0.9)
Serum phosphor (mg/dL)	3.52 (0.00)	3.67 (1.7)
Serum albumin (g/dL)	2.96 (1.43)	3.07 (0.9)
Complication, n (%)		
Hypertension	7 (21.88)	17 (51.5)
Anemia	2 (6.25)	14 (42.4)
Urinary tract infection	1 (3.13)	8 (24.2)
Infection	1 (3.13)	2 (6.1)
Hypoalbuminemia	5 (15.63)	3 (9.1)
Hypokalemia	1 (3.13)	3 (9.1)
Hyponatremia	-	5 (15.2)
Hyperkalemia	-	3 (9.1)
Hyperphosphatemia	-	1 (3.0)
Hypomagnesemia	-	1 (3.0)
Malnutrition	2 (6.25)	10 (30.3)
Marasmus	-	2 (6.1)
Heart failure	-	1 (3.0)

encountered in this stage were hypertension (21.9%) and hypoalbuminemia (15.6%). The mean for triceps skinfold thickness was 13.75 mm with most of the patients (81.3%) at the 5th-95th percentile (good), and for mid-upper arm circumference was 12 cm with most of the patients (90.6%) at <5th percentile (reduced).

As for other measurements, most of the patients have excess adipose tissue (62.5%) according to their %TSE, severe muscle tissue deficit (96.9%) according to their %MUAC, and all (100%) had severe depletion of muscle mass according to their MMA and MAMC.

In the late stage, most patients were

Table 2 Measurement Results in the Early and Late Stages

Variable	Early Stage n=32 n (%)	Late Stage n=33 n (%)
Triceps skinfold thickness (mm)		
<5 th percentile	-	5 (15.2)
5 th -95 th percentile	26 (81.2)	27 (81.8)
>95 th percentile	6 (18.8)	1 (3.0)
%TSF		
Severe deficit of adipose tissue (<70%)	2 (6.3)	10 (30.3)
Moderate deficit of adipose tissue (70–80%)	3 (9.4)	0
Mild deficit of adipose tissue (80–90%)	4 (12.5)	10 (30.3)
Average adipose tissue (90–110%)	3 (9.4)	5 (15.2)
Excess of adipose tissue (>110%)	20 (62.5)	8 (24.2)
Mid-upper arm circumference (cm)		
<5 th percentile	29 (90.6)	31 (93.9)
5 th -95 th percentile	3 (9.4)	2 (6.1)
>95 th percentile	-	-
%MUAC		
Severe deficit of muscle tissue (<70%)	31 (96.9)	31 (93.9)
Moderate deficit of muscle tissue (70–80%)	0	0
Mild deficit of muscle tissue (80–90%)	1 (3.1)	1 (3.0)
Average muscle tissue (90–110%)	0	1 (3.0)
Excess of muscle tissue	0	0
MMA (mm ²)		
Severe depletion of muscle mass (<5 th percentile)	32 (100)	33 (100)
Moderate depletion of muscle mass (5 th –15 th percentile)	-	-
Average muscle mass (>15 th percentile)	-	-
MAMC (mm)		
Reduced muscle mass (>10% reduction in relation to 50th percentile of reference population))	32 (100)	33 (100)

male (54.5%), in stage 5 (66.7%), and in the adolescent age group (75.8%). The most common complications encountered in this stage were hypertension (51.5%) and anemia (42.4%). The mean for triceps skinfold thickness was 11.33 mm with most of the patients (81.8%) were at the 5th-95th percentile (good), and for mid-upper arm circumference was 11.70 cm with most of the patients (93.9%) at <5th percentile (reduced). As for other measurements, most of the patients had mild and severe depletion of adipose tissue (30.3%, each) according to their %TSF, severe muscle tissue deficit (93.9%) according to their

%MUAC, and all (100%) had severe depletion of muscle mass according to their MMA and MAMC.

Discussion

Muscle wasting in CKD is a crucial consequence of undernutrition, which is characterized by reduced muscle mass.⁶ It is also one of the signs of protein-energy wasting (PEW).⁷ Saenz-Pardo-Reyes et al. claim that %MUAC can also be used to evaluate MUAC readings.⁸ In addition, MUAC can also be derived into mid-arm muscle area

(MMA), which estimates the area of the arm's muscle portion excluding the bone. It has been discovered that MMA can be a reliable substitute for adult muscle mass and may be investigated as a standalone evaluation tool for muscle wasting or as a risk factor for PEW in children with CKD.⁸ In the present study, decreased muscle mass was observed in both early and late stages. Similar findings were reported by Yilmaz et al. and Oladele et al., who demonstrated lower MUAC values in CKD patients.^{9,10} Muscle loss associated with CKD can be caused by a disturbed balance between the catabolic and anabolic mechanisms that regulate muscle homeostasis. Dysregulated protein metabolism (increased protein breakdown and decreased protein synthesis) and impaired muscle regeneration are the fundamental underlying biochemical mechanisms that limit muscle growth and turnover.¹¹

Increased protein breakdown can be caused by the activation of the ubiquitin (Ub)-proteasome system (UPS), caspase-3, and autophagy by lysosome. While the decrease in protein synthesis can be caused by metabolic acidosis, upregulated pro-inflammatory cytokine expression, and anorexia-mediated malnutrition. These elements are all linked to the regulation of the IGF-1-PI3K-Akt signaling pathway, which inhibits mTOR and protein synthesis and speeds up proteolysis, causing muscle atrophy.^{4,11}

When evaluated using triceps skinfold percentiles, most patients in both early and late stages were within the 5th–95th percentile, consistent with findings from Lotfy et al., who reported normal TSF values in hemodialysis patients.¹² However, based on %TSF, most patients in the late stage had a deficit of adipose tissue. This is linear with the study conducted by Saenz-Pardo-Reyes et al., where most of the patients who underwent hemodialysis had a deficit of adipose tissue.⁸ The differences between the interpretation of the measurements might be due to the wide range of the percentile. There is also a concern about TSF as one of the methods of measurement. According to Canpolat et al.,¹³ there is debate over whether TSF accurately assesses the amount of body fat in children with CKD due to substantial inter-observer variability and differences in the regional distribution of muscle and fat in CKD patients, even though lower TSF values have previously been seen in children with CKD.

Hypertension was the most common complication in both stages. This is consistent with findings by VanDeVoorde et al.,¹⁴ who

reported that hypertension can appear early in CKD, often remaining undetected and contributing to progression. Several mechanisms can cause hypertension in pediatric CKD. A key role is probably played by the renin-angiotensin-aldosterone system being activated. Children with CKD may have altered renin levels, given their degree of hypertension and fluid status, even though plasma renin levels may not be overtly increased. Other than the renin-angiotensin-aldosterone system, the other mechanisms are sodium and water retention, increased sympathetic tone, endothelial factors, secondary hyperparathyroidism, and drug-induced hypertension.

In early-stage patients, hypoalbuminemia was the second most common complication. In contrast, Schmidt et al. In early-stage patients, hypoalbuminemia was the second most common complication. Dahal et al.^{15,16} reported that hypoalbuminemia may occur across all stages of CKD, while Schmidt et al.¹⁷ observed a progressive decline in albumin levels in advanced stages. Hypoalbuminemia in CKD is associated with inflammation and inadequate protein and caloric intake, and is defined as serum albumin <3.5 g/dL (35 g/L).¹

In late-stage patients, anemia was the second most common complication, consistent with findings by Masalskienė et al.¹⁸ Anemia in CKD may result from chronic inflammation, iron deficiency, the effect of uremia on red blood cell membranes, and diminished erythropoietin production.¹⁹ The North American Pediatric Renal Trials and Collaborative Studies (NAPRTCS) cohort further demonstrated that anemia prevalence increases with CKD severity, with rates of 73% at stage 3, 87% at stage 4, and >93% at stage 5.²⁰ Chronic inflammation, iron deficiency, the effect of uremia on red blood cell membranes, and or diminished erythropoietin production may all play a role in anemia in chronic kidney disease.²¹ As for the definition of anemia, KDIGO defines anemia in children with CKD as: When the Hb concentration is less than 13.0 g/dL (130 g/l) in men and 12.0 g/dL (120 g/l) in females above 15 years old, when the Hb concentration is less than 11.0 g/dL (110 g/l) in children aged 0.5 to 5, 11.50 g/dL (115 g/l) in children aged 5 to 12, and 12.0 g/dL (120 g/l) in children aged 12 to 15.¹

In this study, another complication found in the late stage was malnutrition. This finding is linear with a study by Tutupoho et al.,²¹ where malnutrition correlates with declining GFR. Malnutrition has a complicated and multifaceted

pathological etiology. In addition to decreased appetite and nutritional intake, children with chronic kidney disease also experienced hormonal imbalances, metabolic imbalances, inflammation, increased catabolism, decreased anabolism, and dialysis-related abnormalities.

Beside malnutrition, there are various terms that have been used to describe nutritional issues in CKD, including sarcopenia, and cachexia.⁷ It is stated in a study conducted by Oliveira et al., that according to the clinical consensus, reduced muscle mass appears to be the most reliable indicator of PEW in CKD and emphasizes this in the diagnostic criteria for cachexia as well.⁷ According to the Society for Cachexia and Wasting Disorders (SCWD), cachexia is a complex metabolic syndrome linked to an underlying illness and marked by loss of muscle, with or without loss of fat. Cachexia has been described as a severe form of protein-energy waste common in people with chronic illnesses like CKD and has been linked to morbidity and quality of life in this population. The SCWD proposed the definition of cachexia as a weight reduction of 5% or more over a period of 12 months or a body mass index (BMI) <20 kg/m². Additionally, three of the following five requirements must be met: impaired muscle strength, fatigue, anorexia, reduced fat-free muscle mass, and abnormal biochemistry (including elevated C-reactive protein (CRP) or interleukin-6 (IL-6), anemia, and hypoalbuminemia).⁷

The International Society of Renal Nutrition and Metabolism (ISRNM) define PEW as a condition of nutritional and metabolic abnormalities in individuals with chronic kidney disease (CKD) characterized by simultaneous loss of systemic body protein and energy storage, which ultimately results in cachexia. PEW wasting is diagnosed if three characteristics are present (low serum albumin, transthyretin, or cholesterol), reduced body mass, and reduced muscle mass (muscle wasting or sarcopenia, reduced midarm muscle circumference).⁷

In pediatric CKD, the criteria for diagnosing PEW consists of low BMI (below 5th percentile or below 1.64 Z-score for height-age and sex at entry into CKiD), unintentional weight loss (decrease in BMI of 10% or more for height-age and sex percentile between the first and second annual visits from an initial BMI for height-age and sex percentile of below 80th percentile), decreased MUAC (below 5th percentile for height-age and sex at entry into CKiD or a decrease in MUAC for height-age and sex percentile of 10%

or more between the first and second annual visits), serum albumin below 3.8 g/dL, serum cholesterol below 100 mg/dL, serum transferrin below 140 mg/dL, reduced appetite, and poor growth (below 3rd percentile of for height-age and sex or poor growth velocity (a decrease in height for age and sex percentile of 10% or more between the first and second annual visits). As for diagnosing kidney disease-related syndromes, at least three of the four criteria (body mass, muscle mass, biochemistry, and food intake) must be met.⁷

According to the European Working Group on Sarcopenia in Older People (EWGSOP), sarcopenia is a syndrome marked by a generalized loss of skeletal muscle mass and strength that occurs over time and carries a risk of negative consequences like physical disability, diminished quality of life, and even death. Diagnostic criteria for sarcopenia are reduced muscle mass, low muscle strength, or poor physical performance.⁷ Nutritional status is a crucial prognostic factor in pediatric CKD, associated with hospitalization, mortality, and quality of life, as emphasized by Zhang et al.³

Several limitations should be acknowledged. First, incomplete registry data limited the analysis and may affect generalizability. Additionally, the study did not account for factors such as economic status or racial/ethnic differences, which could influence nutritional status and disease outcomes. Second, only one measurement of skinfold thickness was taken, which limits the comprehensiveness of the assessment. Third, this study provides only an overview of the differences in skinfold thickness and mid-upper arm circumference between early- and late-stage CKD patients, without exploring potential correlations between these measures and other clinical outcomes.

In conclusion, most patients in the early and late stages demonstrated adequate nutritional status when assessed solely by triceps skinfold thickness percentile. However, based on the %TSE, most patients in the early stage have excess adipose tissue whereas most patients in the late stage have deficit values. For all measurements of mid-upper arm circumference, both the early and late stages had deficit values. Future research that investigates the correlation between anthropometric measurements and clinical outcomes in pediatric CKD patients could provide more valuable insights into the impact of malnutrition on disease progression.

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