Original Article

# Body Fat in Children with Chronic Kidney Disease - A Comparative Study of Bio-impedance Analysis with Dual Energy X-ray Absorptiometry

**Arpana Iyengar, Rebecca Kuriyan[1], Anura V. Kurpad[1], Anil Vasudevan**

*Department of Pediatric Nephrology, St John's Medical College Hospital, [1]Division of Nutrition, St John's Research Institute, St John's National Academy of Health Sciences, Bengaluru, Karnataka, India*

## Abstract

**Introduction**: Nutritional impairment in patients with chronic kidney disease (CKD) is due to decreased body stores of both protein and fat. We need a tool that can be used in clinics to determine and monitor fat composition with a special focus on normalizing fat measurements to height in these children. Bio-impedance analysis (BIA), a portable and simple tool, has been used to estimate body fat in children with CKD but needs validation against the reference tool dual energy X-ray absorptiometry (DXA). The purpose of the cross-sectional study was to estimate the prevalence of low body fat in children with stages 2-5 CKD (non-dialysis) and CKD 5D (dialysis), and to compare fat measures from two different methods namely BIA and DXA. **Method**: Children in stages 2–5 CKD ($n$ = 19) and in CKD 5D ($n$ = 14) were recruited for assessment of fat mass (FM, Kg) by BIA and DXA, from which percent body fat (BF %) and fat mass index (FMI, Kg/M$^2$) were obtained. Low body fat was defined as <5$^{th}$ age and gender centile for BF% or FMI by DXA and BF% by BIA. **Results:** Low body fat was detected equally using BF% and FMI in 18% of children by DXA while only 12% were detected using BF% by BIA. In children with CKD2–5, a good degree of reliability was found with FMI measurements (ICC 0.76 CI [0.48,0.9]) and poor reliability in children with CKD 5D (ICC 0.58 CI [0.1,0.84]). BF% had poor to fair reliability in the children with CKD 2-5 and CKD 5D (ICC 0.64 [0.28,0.84] and 0.53 [0.02,0.82]), respectively. Comparing BF% and FMI obtained by BIA and DEXA, BIA overestimated BF% by 3.5% in comparison to DXA. **Conclusion:** In children with CKD, body fat is preserved in the majority. Among the two measures of fat, BF% estimated by BIA did not compare well with DXA while FMI measure was comparable with a lower bias. However, due to lack of reference values in Indian children for FMI obtained by BIA, BIA cannot be used to measure fat in this population.

**Keywords:** *BIA, body fat, children, chronic kidney disease, dialysis, DXA, fat mass*

## Introduction

Nutritional impairment in CKD is due to a combination of decreased body stores of protein and fat leading to muscle wasting and fat deficits. Indian children with CKD[1] have a higher burden of short stature and underweight compared to western children.[2] However, the profile of fat deficit that could contribute to underweight in them is unknown. There is evidence to suggest that healthy Indian children are characterized by a "muscle thin but adipose" body composition compared to western children.[3] While few studies[4,5] have observed body fat to be preserved in majority of children with CKD, others have shown fat deficits in these children.[6,7]

Dual X-ray absorptiometry (DXA) and bio-impedance analysis (BIA) have been used to measure body fat (BF%) and fat mass (FM Kg) as a part of body composition analysis.[8] DXA is considered a reference tool for BF% detection in health, but is expensive, not portable and exposes subjects to very low radiation.[9,10] However, in CKD, DXA is often used as a reference method for estimating fat content as it is less influenced by hydration status.[11]

BIA, a less expensive and bedside tool provides fat measures that are dependent on the hydration status. Given the simplicity and ease with which BIA can be used to monitor body composition, there has been an interest to validate fat measures obtained by BIA against DXA in CKD. Comparative studies have been conducted mostly in adult population with CKD[12-14] with inconsistent results. Some studies



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***Address for correspondence:***
*Dr. Arpana Iyengar, Department of Pediatric Nephrology, St John's National Academy of Health Sciences, Bengaluru - 560 034, Karnataka, India.*
*E-mail: arpanaiyengar@gmail.com*

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reveal that BIA overestimates FM when compared to DXA.[13-15] Few others have shown a good correlation in adult patients on hemodialysis.[12] In children on hemodialysis,[16] BIA fat measures compared well with air displacement plethysmography except in children with extremes of body weight and puberty. There is no comparative data available between BIA and DXA with respect to fat measures in children with CKD. With regard to fat measures, BF% or FMI have been used in various studies with no clarity on which of these fat measures derived by BIA compare well with that of DXA. Moreover, in view of higher burden of short stature in our population, normalizing fat measurements to height would be important. This cross-sectional study was undertaken to estimate the prevalence of low body fat in children with stages 2–5 CKD (non-dialysis) and CKD 5D (dialysis) and to compare fat measures obtained from BIA with DXA.

## Methods

This study was undertaken in a subset of 33 children out of the 84 children with CKD 2–5 being recruited for a primary study on protein energy wasting. An Institutional Ethical Review Board approval was obtained. Demographic details and anthropometry measures of body weight, height, mid arm circumference, and body mass index were documented. Body weight and height were recorded by a digital weighing scale (Tulaman pvt Ltd, India) to nearest 0.05 kg and a stadiometer (Standard steel, India) to the nearest 0.1 cm, respectively. Mid upper arm circumference (MUAC) was measured using a non-metal measuring tape to the nearest 0.1 cm. MUAC was recorded in centimetres by a measuring tape and expressed as centiles based on age and gender from Indian reference charts.[17] BMI for height age instead of chronological age[18] was expressed as centiles based on CDC charts.[19] Following informed consent, all children underwent a DXA scan and a BIA on the same day. In patients on dialysis, the assessments were done within 2-hr post hemodialysis and after a 24-h cycle for peritoneal dialysis to minimize the influence of hydration on fat assessment.

For DXA, Lunar Prodigy Advanced PA + 301969 (GE Medical Systems, USA) whole body scanner, with software version 12.30 was used. The BIA measurements were obtained using a multifrequency instrument (Bodystat QuadScan 4000, version 5/12, Bodystat Ltd, Douglas, British Isles). Regression equations applicable to children were used to estimate fat measures. Fat measures recorded from DXA and BIA were BF%, FM in kg. FM was indexed to height (FMI). The BF%, FM, and FMI were expressed as centiles based on age and gender from Indian reference charts for DXA and BF% for BIA.[20,21] Reduced fat stores was defined as BF or FMI <5$^{th}$ centile and over fat as >85$^{th}$ centile for age and gender.[20]

Data was analyzed using IBM SPSS statistics for windows, Version 24.0 (Armonk, NY: IBM Corp.). All categorical measures were described as frequency and percentages and continuous measures as mean with standard deviation or median with interquartile range based on the distribution. To compare the two tools, intraclass correlation (ICC) with 95% confidence interval (CI) and Bland–Altman plot were used to find the agreement between measurements. The *P* value was considered significant at 5% level of significance for all comparisons.

## Results

Thirty-three children (21 boys) aged 10.8 ± 3.1yrs in CKD (Stage 2–5:19; Stage 5D: 14) were recruited over a 4-month period. Etiology of CKD was congenital anomalies of the kidney and urinary tract including renal hypo-dysplasia in 66% (22/33) and chronic glomerulonephritis, hemolytic uremic syndrome, steroid resistant nephrotic syndrome in the rest. Anthropometry measures revealed low MUAC in 60% and a low BMI for height age in 24% of children. Fat measures of BF%, FM (kg), and FMI (FM/height) are depicted in Table 1.

### Prevalence of low body fat

Using BF%, DXA and BIA detected low body fat in 18% and 12% children, respectively. Estimation of low body fat by DXA was found to be similar using parameters of BF% and FMI (18%) in the same group of children. Low body fat was identified in 4/19 [21%] with 2-5CKD and 2/14 [14%] with CKD5D ($P$ = 0.49) using DXA and in 4/19 [21%] with 2-5CKD and 0/14 with CKD5D ($P$ = 0.09) using BIA.

### Comparison of fat measures between BIA and DXA

Comparing the two fat measures of BF% and FMI by BIA with DXA, FMI showed good reliability in children with 2-5CKD compared to CKD 5D (ICC 0.76 CI [0.48, 0.9] $P < 0.001$ versus ICC 0.58 CI [0.1, 0.84] $P = 0.01$), respectively. A poor to fair reliability was observed with BF% among children with 2-5CKD and CKD 5D (ICC 0.64 CI [0.28,0.84] $P = 0.001$ vs. ICC 0.53 CI [0.02, 0.82] $P = 0.02$), respectively. In the pooled cohort, BIA overestimated BF% by 3.5% compared to DXA. The agreement analysis between BIA and DXA [Figure 1 (a) and (b)] showed a level of agreement (LoA) of [-4.10 to 4.25] with a lower

**Table 1: Anthropometry and fat measures in children (*n*=33)**

| Anthropometry and fat measures | Median (IQR) |
|---|---|
| MUAC (cm) | 16 [14.2,18.4] |
| BMI | 14.8 [13.4,17.1] |
| BF% | DXA: 14.2% [10.1, 21.5] |
| | BIA: 19.4% [13.7, 25.7] |
| FM (kg) | DXA: 2.8 [1.6, 6], |
| | BIA: 4.1 [2.9, 5.2], |
| FMI | DXA: 2.2 [1.3, 3.4] |
| | BIA: 2.7 [2.2, 3.7] |

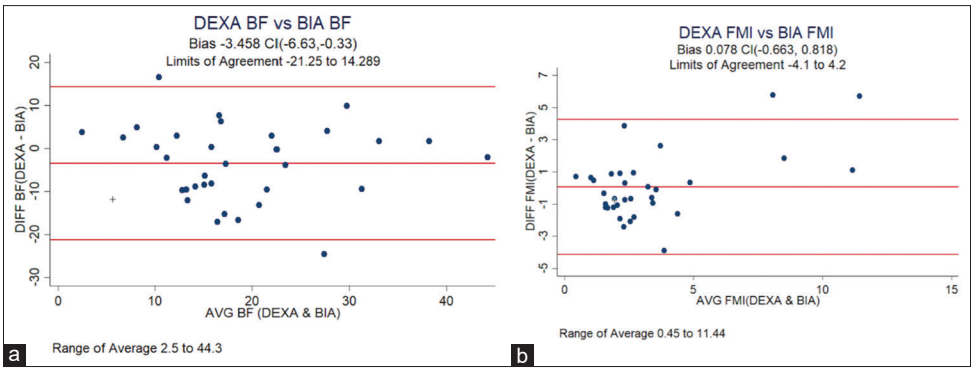


**Figure 1: (a) Bland-Altman comparison LoA analysis between BIA BF% and DXA BF% in the overall cohort with limits of agreement representing 95% CI. Bias represents the mean difference. (b) Bland-Altman comparison LoA analysis between BIA FMI AND DXA FMI in the overall cohort with limits of agreement representing 95% CI. Bias represents the mean difference**

mean difference 0.07 (CI -0.6 to 0.8)] for FMI compared to a LoA of [-21.25 to 14.28] with a high mean difference of -3.48(CI -6.6 to -0.3)] for BF%. However, the wide variance in the level of agreement of FMI is clinically unacceptable.

## Discussion

This study reveals preserved body fat in majority of children with CKD 2–5. Comparing assessment tools for fat measures, BIA did not compare well with DXA for BF% but showed a lower bias with FMI.

The relevance of measuring fat stores in children with CKD stems from the concept of an appetite regulating hormonal dysregulation that potentially influences alteration in body fat profile and nutritional balance.[6] In 33 European children on dialysis,[4] reduced fat stores was observed in 24% using BIA-BF% and similar findings were noted in other studies using BIA and skin fold thickness.[6,7] We observed preserved body fat in majority of children by both DXA and BIA despite a high prevalence of low MUAC. This finding suggests that muscle wasting is profound in these children resulting in low MUAC.

Objective assessment tools like BIA and DXA are used for assessment of BF%. However, unlike in adults, there are no comparative studies of fat measures between BIA and DXA in children with CKD stages 2–5. In a study[22] on 120 adult CKD patients, estimation of FM was 3.1 kg lower using BIA than DXA with a limited agreement between the two tools (-6.8 kg to 13 kg). On the contrary, a small study[12] in adult hemodialysis patients had FM measures by bio-impedance spectrometry correlating well with DXA ($r^2$ = 0.871). In an Indian study[13] in 50 adults with pre-dialysis CKD, comparative data between BIA and DXA showed that BF% had a good correlation between the tools (ICC 0.82) and BIA overestimated BF% compared to DXA by a mean of 1.8%. We found BIA to overestimate BF% by 3.5% which could be attributed to the influence of fluid retention in these children. There has been no consistency in the use of measures of fat as some studies (especially in adults) used BF% while others used FM. Few studies in children on dialysis used FM as a measure of fat[23,24] and reported BIA to underestimate FM in these children in comparison to anthropometrical measures of fat.[24] Considering the presence of short stature in these children, we standardized the measure of FM by indexing it to height of the child. Between the two measures of fat estimated by BIA and DXA, we found FMI to have a better agreement than BF%. A notable limitation of the study is the unavailability of BIA reference nomograms for fat measures of FM and FMI in Indian children.

## Conclusion

In children with CKD, body fat is preserved in the majority. BIA does not compare well with DXA using BF% but shows a lower bias with FMI. However, clinicians need to be aware of the fact that there is a wide variance in the level of agreement of FMI and no available reference values for FMI makes BIA an unreliable tool for estimating body fat in the clinic.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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### Conflicts of interest

There are no conflicts of interest.

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