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RENAL DIMENSIONS IN MALNOURISHED CHILDREN: A COMPARATIVE ULTRASONOGRAPHIC ANALYSIS OF KIDNEY SIZE AND ITS ANTHROPOMETRIC CORRELATES: *A HOSPITAL-BASED CROSS-SECTIONAL STUDY*

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Abstract

Background: Malnutrition remains the most critical public health crisis in low- and middle-income countries, particularly in South Asia. Its systemic effects extend beyond anthropometric deficits to impair organ-level development, including renal growth. Kidney size, measurable non-invasively by ultrasonography, represents a sensitive marker of somatic growth and nephron endowment.

Objectives: To compare kidney dimensions between malnourished and healthy children aged 6–60 months and to assess the correlation between renal parameters and anthropometric variables including age, weight, height, and body surface area (BSA).

Methods: A hospital-based cross-sectional study enrolled 41 malnourished children (cases) and 40 healthy age-matched controls. Bilateral kidney dimensions (length and width) were assessed via B-mode ultrasonography. Anthropometric data were collected, and severity of malnutrition was classified using WHO weight-for-height z-scores (WHZ), mid-upper arm circumference (MUAC), and the presence of bilateral pitting oedema. Statistical analysis included Mann-Whitney U tests for group comparisons and Spearman's rank correlation for anthropometric associations.

Results: Malnourished children demonstrated significantly reduced bilateral kidney lengths compared to healthy controls (left: 6.0 cm vs. 6.55 cm, p<0.001; right: 5.9 cm vs. 6.5 cm, p=0.001), while kidney widths did not differ significantly. Malnourished children weighed 40% less, were 16% shorter, and had 30% reduced BSA compared to controls (all p<0.001). In healthy children, *kidney length correlated significantly with age, weight, height, and BSA. In malnourished children, correlations were reduced and age lost its predictive significance for renal length, with weight and BSA emerging as the dominant anthropometric correlates.*

Conclusion: Malnutrition is associated with significantly smaller kidney lengths, reflecting compromised renal growth and potentially reduced nephron endowment. The decoupling of age from renal length in malnourished children suggests nutritional status, rather than chronological age, governs renal growth trajectories in this population. These findings have important implications for long-term cardiorenal risk in nutritionally vulnerable paediatric populations.

1. INTRODUCTION

Malnutrition in children is one of the most chronic and severe public health challenges faced by LMICs. UNICEF estimates that about 149 million children under-five years old were stunted and 45 million were wasted in the world in 2022 (UNICEF/WHO/World Bank, 2023). Pakistan is severely affected and ranks third in the world for the prevalence of stunted childhood, 38% children under 5 are affected by chronic malnutrition and more than 15% children under 5 are wasted due to malnutrition (Humanium, 2025; Khaliq et al., 2021). These are not just epidemiological numbers; catastrophic individual and societal implications including cognitive function impairment, growth retardation, immune suppression and increased mortality risk. Malnutrition has pathophysiological impacts beyond anthropometric deficits. Growing evidence shows that nutrition during sensitive developmental periods can have a significant impact on organ growth and the maturation of cells (Dogan et al., 2024). The kidney is one of the organs that is especially vulnerable to nutritional insult, and one organ in which the clinical significance of nutritional insult is particularly notable. In humans, nephrogenesis (the development of nephrons) is complete by 36 weeks gestation, but renal growth remains until early childhood, with glomerular and tubular hypertrophy occurring in response to somatic demands (Waters, 2023). The postnatal growth period is one that is particularly susceptible to protein-calorie deficiency, and consequent renal development is severely compromised in this instance with a reduction in kidney size and possibly nephron function.

The significance of kidney size is more than just as a growth marker. In healthy children, smaller renal length is associated with decreased glomerular filtration rate (GFR) (Dogan et al., 2024), suggesting that ultrasonographically-measured renal size is a surrogate marker of functional renal reserve. In addition, epidemiological studies have demonstrated strong associations between impaired intrauterine and early postnatal growth and increased risk for subsequent adult hypertension, proteinuria, and chronic kidney disease (CKD) (Chevalier, 2020). Malnourished children therefore constitute one cohort of children who have a long-term high cardiorenal risk burden of which they are unaware.

However, this clinical importance, there is limited research done to quantify the kidney size in malnourished children, especially in the Pakistani scenario and in South Asia. A basic study performed by Ece et al. 2007 shows that renal length & renal volume are much smaller in Turkish children who suffer from marasmus and in healthy Turkish children, height is the best predictor of renal dimensions in marasmic children. More recently, Dogan et al. (2024) assessed the size of multiple organs using ultrasonography, and found that kidney size is reduced proportionately with malnutrition severity. Kidney length was also significantly shorter in children with severe acute malnutrition (SAM) in the Indian subcontinent, as reported by Kumar et al. (2021). However, no study has been available in the literature that has included all the categories of SAM (mild, moderate and severe) using a clinical population of Pakistan with anthropometrically correlated analysis.

The present study was thus designed to (1) compare the bilateral kidney dimensions of malnourished children with that of age and sex matched healthy controls; (2) describe the clinical severity profile in the malnourished children in relation to WHO recommended diagnostic criteria which includes WHZ z score, MUAC and bilateral pitting oedema; and (3) examine the Spearman rank correlation between renal dimensions and various anthropometric parameters (age, weight, height and BSA) in malnourished and healthy children. The results are to guide clinical management of paediatric renal ultrasound in malnourished populations and to build on the growing body of evidence that early nutritional insults are associated with long term nephrological risk.

2. Materials and Methods

2.1 Study Design and Setting

The study was a cross-sectional comparative study carried out in a tertiary care hospital in the paediatric population. The institutional review board approved the study according to the Declaration of Helsinki. Parents or legal guardians of all participants gave informed written consent before enrolling. The study included 41 malnourished children (cases) and 40 healthy, age matched children (controls) aged 6-60 months.

2.2 Participant Selection

The identification of malnourished children was done through the use of the established criteria for classification of acute malnutrition endorsed by the WHO (WHO, 2013). Cases were defined as those with a weight-for-height *z*-score (WHZ) below −2 standard deviations (SD) of the WHO 2006 Child Growth Standards median, those with a mid-upper arm circumference (MUAC) less than 12.5 cm and those with bilateral pitting oedema. The severity was re-classified as severe acute malnutrition (SAM; WHZ < -3 SD and/or MUAC $<$ 11.5 cm), moderate acute malnutrition (MAM; WHZ −2 to −3 SD; MUAC 11.5–12.5 cm), and mild undernutrition (WHZ −1 to −2 SD). The control children were healthy children who came for routine checkup with weight-for-height and height-for-age *z*-scores within normal range (above −1 SD). All children with a known renal disease, congenital anomaly, urinary tract infection, acute illness, or chronic systemic disease were excluded from both groups.

2.3 Anthropometric Assessment

Standardized protocols were followed to take anthropometric measurements. Children were weighed on a calibrated digital scale in minimal clothing to the nearest 0.1 kg. Standing height (recumbent length for children $<$ 24 months) was measured to the nearest 0.1 cm by a calibrated stadiometer. Body surface area (BSA) was calculated using the Du Bois and Du Bois formula: BSA (cm^2) = 0.007184 × Height (cm)^0.725 × Weight (kg)^0.425. Using a non-stretchable MUAC tape, MUAC was measured as the midpoint of the upper arm, non-dominant, arm at the side.

2.4 Ultrasonographic Renal Assessment

A single experienced radiologist performed b-mode ultrasonography on a high-resolution ultrasound machine with a convex transducer of 3.5–7.5 MHz. The length of the kidney (maximum bipolar length in the longitudinal plane) and the width of the kidney (maximum transverse diameter in the axial plane) were measured for each kidney. For each dimension, three measurements were taken and the mean measured. The participant's group allocation was concealed to the operator when being measured.

2.5 Statistical Analysis

All data were analyzed using SPSS 26.0 (IBM Corp., Armonk, NY). The Shapiro-Wilk test was used to test the normality of continuous data. Median (IQR: interquartile range Q1-Q3) values are used for the presentation of most variables due to their non-normal distribution. Differences between groups were assessed by using Mann-Whitney U test. Categorical data are displayed as frequencies and proportions and compared with the Pearson chi-square test or Fisher's exact test as appropriate. The renal dimensions were compared with the anthropometric parameters by Spearman's rank-order correlation coefficient (ρ). Results were considered statistically significant if P value was <0.05.

3. Results

3.1 Demographic and Anthropometric Characteristics

A total of 81 children were enrolled, with 41 of them having malnourished cases and 40 being healthy controls. There was no significant difference between the two groups with regard to sex (65.0% males in controls vs. 58.5% in cases; p=0.712) and median age (36 months, IQR 20.25–40.75 months vs. 24 months, IQR 16.5–36.0 months; p=0.085), indicating that both groups were adequately matched on these baseline factors. In contrast, children with a low nutritional status had significantly poorer anthropometric status on all three somatic indicators. Median weight was 7.8 kg (IQR 6.55–8.75) in cases versus 13.0 kg (IQR 12.0–14.87) in controls—a 40% reduction (p<0.001). Median height was 77.0 cm (IQR 70.0–83.5) in cases versus 91.5 cm (IQR 76.5–96.0) in controls, representing a 16% deficit (p<0.001). Body surface area was correspondingly reduced by 30% (0.40 cm² vs. 0.57 cm²; p<0.001). The data presented in Table 1 and graphically depicted in Figure 3 validate the severity of somatic growth failure among malnourished children compared to healthy children.

Table 1. Comparative Analysis of Demographic and Anthropometric Findings Between Cases and Controls.

Parameters	Healthy (n=40)	Malnourished (n=41)	p-Value
Gender – Male	26 (65.0%)	24 (58.5%)	0.712
Gender – Female	14 (35.0%)	17 (41.5%)	
Age (months)	36 (20.25–40.75)	24.0 (16.5–36.0)	0.085
Weight (kg)	13 (12.0–14.87)	7.8 (6.55–8.75)	<0.001
Height (cm)	91.5 (76.5–96.0)	77.0 (70.0–83.5)	<0.001
Body Surface Area (cm²)	0.57 (0.44–0.62)	0.40 (0.35–0.45)	<0.001

Values presented as median (IQR Q1–Q3) for continuous data and n (%) for categorical data. Mann-Whitney U test used for continuous comparisons.

3.2 Clinical Profile of Malnourished Children

The distribution of malnutrition severity among the 41 malnourished children showed, 12 children (29.3%) with WHZ of −4 SD (extreme severe malnutrition), 18 (43.9%) with WHZ of −3 SD (severe acute malnutrition), 6 (14.6%) with WHZ of −2 SD (moderate acute malnutrition) and 3 (7.3%) with WHZ of −1 SD. Two children (4.9%) were enrolled in the median with WHZ and fulfilled enrolment criteria for MUAC. Regarding MUAC, 34/41 (82.9%) children were severely wasted (MUAC < 11.5 cm) while 6 (14.6%) were moderately acutely malnourished (MUAC 11.5 - 12.5 cm). Six children (14.6%) had bilateral pitting oedema, mainly the more severely malnourished (WHZ −4 and −3 SD). This was consistent with a mixed marasmic-kwashiorkor phenotype. This clinical distribution is shown in Figure 4.

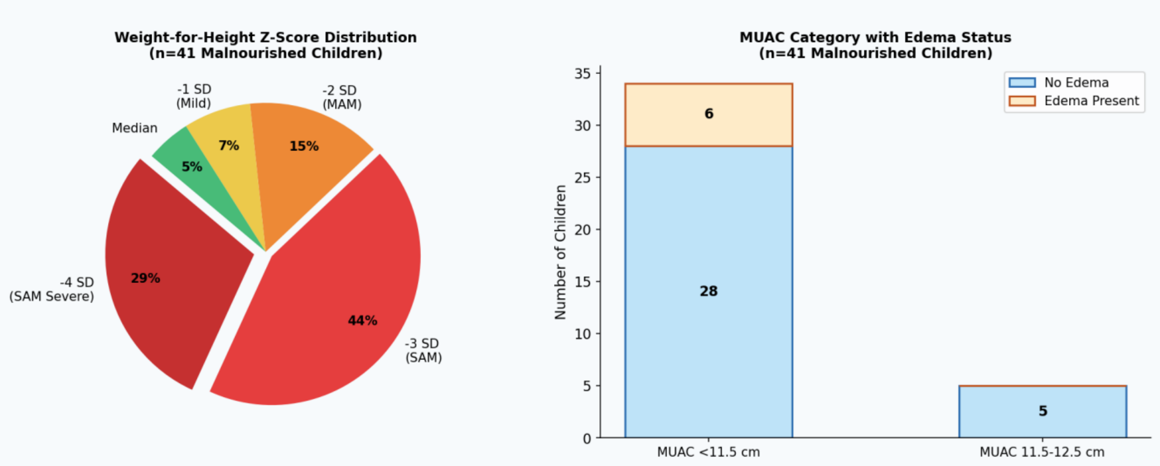

Figure 1. Clinical distribution of malnourished children by weight-for-height *z*-score severity (left) and MUAC category with presence of bilateral pitting oedema (right). The majority of children presented with severe acute malnutrition (WHZ ≤ −3 SD) and MUAC < 11.5 cm.

3.3 Comparison of Kidney Dimensions

The comparative ultrasonographic kidney measurements are shown in tables 2 and figure 1. The length of the left kidney was significantly shorter in malnourished children than in the controls: 6.0 cm (IQR 5.45–6.70) versus 6.55 cm (IQR 6.125–7.17); p<0.001. Right kidney length was similarly significantly smaller: median 5.9 cm (IQR 5.6–6.5) versus 6.5 cm (IQR 6.1–7.17); p=0.001. The statistically significant differences in bilateral kidney lengths between groups, with the effect sizes ranging between 8–9% absolute reduction in renal length, stands as the main finding in this study. However, there were no significant differences in kidney width either left (2.6 cm vs. 2.8 cm; p=0.140) or right (2.5 cm vs. 2.5 cm; p=0.457) sides, indicating that nutritional deprivation preferentially affects the length of the kidneys rather than width, consistent with what was previously reported in a similar study (Ece et al., 2007; Kumar et al., 2021).

Table 2. Comparative Analysis of Kidney Dimensions Between Healthy (n=40) and Malnourished (n=41) Children Using the Mann-Whitney U Test.

Parameters	Healthy Median (IQR)	Malnourished Median (IQR)	p-Value
Left Kidney Length (cm)	6.55 (6.125–7.17)	6.0 (5.45–6.70)	<0.001*
Left Kidney Width (cm)	2.8 (2.5–3.07)	2.6 (2.25–3.0)	0.140
Right Kidney Length (cm)	6.5 (6.1–7.17)	5.9 (5.6–6.5)	0.001*
Right Kidney Width (cm)	2.5 (2.3–2.97)	2.5 (2.2–2.75)	0.457

**p < 0.05 (statistically significant). Values presented as median (IQR Q1–Q3). KL = Kidney Length.*

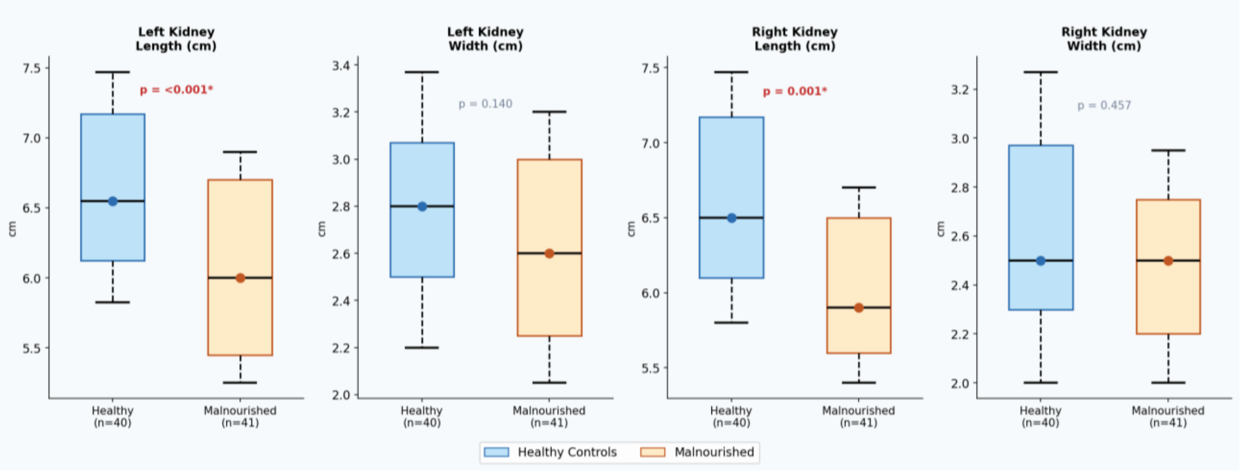

Figure 2. Box plots comparing bilateral kidney dimensions between healthy controls and malnourished children. Kidney lengths (left and right) were significantly smaller in the malnourished group (*p<0.001 and p=0.001, respectively). Kidney widths were not statistically different between groups (p>0.05). Circles represent median values.

3.4 Anthropometric Correlates of Kidney Length

There were clinically relevant differences between the two groups in the anthropometric determinants of kidney length as shown by the Spearman's correlation analyses. In healthy children, kidney length (both right and left) correlated significantly with all four anthropometric variables: age (ρ=0.514, p<0.05 for right; ρ=0.391, p<0.05 for left), weight (ρ=0.441 and 0.345, both p<0.05), height (ρ=0.393 for right, p<0.05), and BSA (ρ=0.379 and 0.321, both p<0.05). The pattern indicates that renal growth is normal in every single anthropometric field in well-nourished children and follows the overall somatic growth.

However, a completely different pattern of correlation emerged in the malnourished group. Perhaps most importantly, after kidney length, age became not significantly correlated with kidney length in both kidneys (right: ρ=0.292, p=ns; left: ρ=0.113, p=ns), even though it was the most significant correlate of right kidney length in healthy children (ρ=0.514). This dissociation of age from renal growth in malnourished children is a novel and important observation: it suggests that chronological age now is no longer the most important factor in determining kidney size in malnourished children; nutrition is now. In the malnourished group, the weight was a significant correlate of kidney length (right: ρ=0.363, p<0.05; left: ρ=0.384, p<0.05), while the height was also significant in the right kidney length (ρ=0.354, p<0.05) and BSA for right kidney length (ρ=0.387, p<0.05). These data are summarised in Table 3 and Figure 2.

Table 3. Spearman's Correlation Coefficients for Kidney Length with Anthropometric Parameters.

Parameters	Right KL – Healthy	Left KL – Healthy	Right KL – Malnourished	Left KL – Malnourished
Age	0.514*	0.391*	0.292	0.113
Weight	0.441*	0.345*	0.363*	0.384*
Height	0.393*	0.218	0.354*	0.301
Body Surface Area	0.379*	0.321*	0.387*	0.293

** p < 0.05 (statistically significant). KL = Kidney Length.*

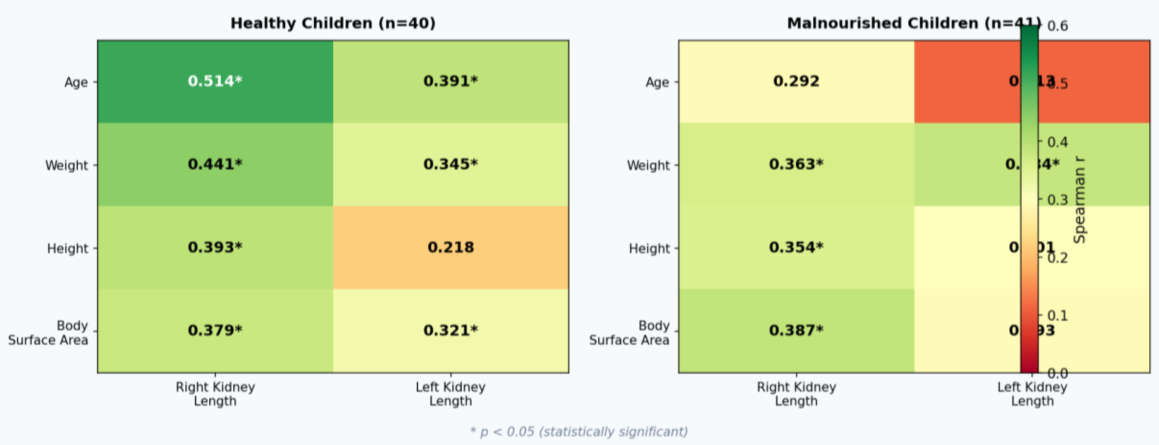

Figure 3. Heatmap of Spearman's correlation coefficients between kidney length and anthropometric parameters in healthy (left) and malnourished children (right). Colour intensity indicates correlation strength (green = stronger, yellow = moderate). Asterisks (*) denote p<0.05. Age loses its significant correlation with kidney length in the malnourished group.

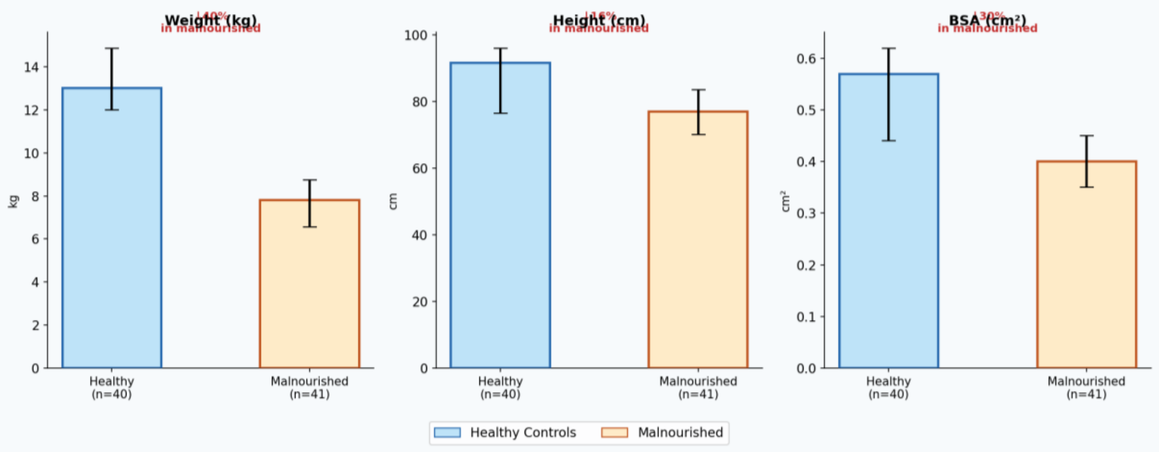

Figure 4. Comparison of anthropometric parameters between healthy and malnourished children. Malnourished children showed a 40% reduction in weight, 16% reduction in height, and 30% reduction in body surface area, all statistically significant (p<0.001). Error bars represent IQR.

4. Discussion

The results of the present study provide support for three interrelated important pediatric and nephrological conclusions. First, malnourished children have much shorter bilateral kidneys than healthy, age-matched children, an 8-9% difference with a very high level of statistical significance and clinical relevance. Second, there is no significant difference in the width of the kidneys between groups, indicating a trend towards nutritional deprivation having a more specific effect on longitudinal growth than on transverse growth. Third, and most importantly, the dissociation of age from renal length in malnourished children demonstrates that nutritional status is the most important factor determining renal growth in malnourished children, not their age.

These results corroborate and support a larger set of previously published results. Ece et al. (2007) compared 74 Turkish children with marasmus and 47 healthy children and found that the malnourished children had significantly shorter kidney length and renal volume than healthy children ($p<0.05$); the body height was the most important parameter in predicting renal dimensions among the malnourished children. In a study of children with SAM from northern India, Kumar et al (2021) also found that renal length was significantly shorter in children with SAM and that BSA was a significant correlate of renal size. In a recent study, Dogan et al. (2024) found that kidney size decreases as malnutrition worsens, from mild to severe undernutrition. The present study extends these findings to the specific Pakistani context where the problem of malnutrition is endemic and data on this matter are directly relevant to policy.

The mechanism of shortness of kidney may have multiple biological factors in malnourished children. Protein and calorie deficiency during the postnatal period affects the growth-hormone/insulin-like growth factor-1 (GH/IGF-1) axis, which is a main regulator of early childhood renal tubular hypertrophy and glomerular enlargement (Dogan et al., 2024). Low circulating IGF-1 levels in malnourished children inhibit tubular cell proliferation and the glomerular filtration surface enlargement that occurs with usual somatic development. Furthermore, chronic protein deficiency causes a decrease in the concentrating ability of the kidneys and may also result in a decrease in tubular mass due to catabolic protein turnover which further reduces the longitudinal dimensions of the kidney. In the present study, kidney width was not significantly different among groups, in agreement with Ece et al. (2007) who showed that the tubular longitudinal axis seems to be more responsive to nutritional deficiency than the vascular-calyceal axis of the kidney.

The clinical significance of the present results are far-reaching. The length of the kidney is also a correlate of GFR in healthy children (Dogan et al., 2024) and smaller kidney may contain less functional renal reserve. Smaller kidneys in the context of malnutrition may simply be a reflection of smaller body size, but also may reflect a reduction in absolute nephron endowment a pathological state that is associated with long-term risk of hypertension, CKD, and proteinuria (Chevalier, 2020). Nephron numbers can only be determined post mortem stereologically but the most convenient clinical surrogate is kidney length on ultrasound. The dissociation of age from renal length in malnourished children has other clinical implications: age-based normative renal size charts are not applicable in malnourished children and appropriate renal ultrasound interpretation in malnourished paediatric patients will require weight or BSA adjusted normative references.

It is also worth an explicit mention the pattern of the correlation difference between groups. The best correlation in children was found with age in healthy children ($\rho=0.514$) and it is well documented that the kidneys continue to grow steadily with increasing age and somatic maturation in the first 5 years of life. This relationship has been well-established in various paediatric cohorts, such as South Asian children (Nadarajah et al., 2019). In malnourished children, age was not a strong predictor anymore ($\rho=0.292$, $p>0.05$ for the right kidney; $\rho=0.113$, $p>0.05$ for the left kidney), and weight was the strongest predictor. The shift suggests that renal growth is 'uncoupled' from chronological age in malnutrition—the kidney has a growth rate, which is independent of chronological age, and depends only on the nutritional status at a given point in time, which is reflected in the weight. This biological finding has direct diagnostic implications: a five-year-old malnourished child may have a kidney size which is similar to a much younger healthy child and this should not be regarded as pathological kidney disease but as a failure of normal growth due to malnourishment.

A few restrictions of the present study should be noted. Due to the cross-sectional design, the study does not allow for causal inference and the possibility of longitudinal tracking of renal growth after nutritional rehabilitation. The sample size is sufficiently large to detect differences in medians with the observed effect size, but does not provide sufficient statistical power for subgroup analysis by level of malnutrition. Volume of the kidneys, which combines length and width measurements, and which may offer a more complete measure of renal mass was not estimated in this study, and could be a topic to explore in future studies. In addition, functional renal parameters (serum creatinine, eGFR (estimated GFR), and urinary albumin to creatinine ratio) were not evaluated, which restricted the direct interpretation of functional renal reserve. Lastly, the study was carried out in one tertiary referral hospital, which could result in selection bias towards more severe cases and reduce generalizability to the community-based malnourished population. Future prospective studies should include multi-centre designs and follow up over time using nutritional rehabilitation, functional renal evaluation, and measure of kidney volume instead of length.

5. Conclusion

Bi-lateral kidney length is associated with significantly lower malnutrition in children 6-60 months of age, with the left kidney being the most statistically significant difference from healthy children. The width of the kidneys is not significantly affected, indicating a directionality of renal growth susceptibility to nutritional deprivation. This was a biologically significant finding of age being independent of renal length in malnourished children with weight and BSA taking precedence as anthropometric markers, with direct implications for radiological interpretation. Together, these observations indicate that children who suffer from malnutrition have an unrecognized nefropathy of nutritional origin with a maybe long lasting effect on cardiorenal health. The systematic renal ultrasonographic assessment and the acceptance of normative references of kidney size based on the child's nutritional status are clinical and policy priorities needed in Pakistan, where millions of children are malnourished.

5. Limitations

The present study has several limitations that need to be taken into account in the interpretation of the results. First, renal volume (which represents the total mass of the kidneys, not just length) was not measured, since depth measurements were not always possible in all participants and future studies should require depth measurements to allow more thorough estimation of renal volume. Secondly, all ultrasonographic measurements were made by a single radiologist, and there was no interobserver reliability undertaken; intraclass correlation coefficients would enhance the repeatability and generalisability of these sonographic findings if they were obtained across multiple observers. Third, there was no formal documentation of hydration status at examination, and subclinical hypovolaemia may have led to some of the observed reductions in renal dimensions, so future studies should standardise hydration assessment before ultrasonography is carried out in malnourished children. Fourth, single centre recruitment at a tertiary referral hospital creates a form of selection bias that may have resulted in over-representation of severe cases, and restricted generalizability to community-level malnutrition. Fifth, no socioeconomic data was gathered or adjusted for in the analysis, although there is well documented effect of socioeconomic status on nutritional status and organ development. Finally, because a dietary intake assessment was not formalized, individual participants could not be quantified for specific macronutrient deficiencies that contribute to renal growth retardation.

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