



## The Use of Anthropometrics, BMI and Isotope Dilution Methods in Assessing the Double Burden of Malnutrition in Children (3-5 Years) in the Southern and Northern Regions of Botswana

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### Abstract

**Objective:** To assess the prevalence of under- and over- nutrition using three different assessment methods.

**Design:** Pilot cross sectional study

**Setting:** Malaria prone rural area in the northern (Shakawe) and non-malaria prone rural area in the southern (Moshupa) parts of Botswana.

**Subjects:** A convenience sample (n=197) of children aged three-five years and attending growth monitoring as a standard component of paediatric services.

**Outcome Measures:** Double burden of malnutrition defined according to the three methods as follows: anthropometrics (weight for height z score -2SD vs. weight for height z score + 2SD), BMI calculated according to the Centers for Diseases Control and Prevention gender and age specific growth charts (<5<sup>th</sup> percentile vs. > 85<sup>th</sup> percentile) and deuterium oxide (D<sub>2</sub>O) dilution method calculating body fat mass percentage (< 13% fat mass percentage for boys and < 23% for girls (low fat mass) vs. > 20% fat mass percentage for boys and >30% for girls as under- and overnutrition respectively.

**Results:** Observations indicate that anthropometrics under-estimated the prevalence of the double burden of malnutrition while BMI and D<sub>2</sub>O overestimated it. There was a significant difference on the assessment of under-nutrition using the three methods [H(2) =48.190, P<0.05]. Similarly on over-nutrition, there was a significant difference on the three methods in assessing over-nutrition [H(2) =77.434, P<0.05]. All three methods significantly reduced under - and/or over-nutrition at different magnitudes.

**Conclusion:** A gap still exists between the methods in assessing the double-burden of malnutrition. All three methods, anthropometry, BMI and D<sub>2</sub>O dilution method have significantly different effects towards the assessment of either under- and/or over-nutrition and thus it is recommended that a thorough decision be made prior to choosing which method to use based on the aim of the assessment. This study reflects the need to carefully select an appropriate method to use in assessing the burden of malnutrition.

**Keywords:** Double Burden Malnutrition; Under-Fives; Isotope Dilution Method; Anthropometrics; BMI

### Abbreviations

%FM: Percent Fat Mass; AU: African Union; BMI: Body Mass Index; BNSS: Botswana National Nutrition Surveillance System; CAADP: Comprehensive Africa Agriculture Development Programme; CDC: Centers for Disease Control and Prevention; D<sub>2</sub>O: Deuterium Oxide; DBM: Double Burden of Malnutrition; D: Kolmogorov Smirnov Test Statistic; FFM: Fat Free Mass; FM: Fat Mass; FTIR: Fourier-transform Infrared Spectroscopy; g: Gram; HAZ: Height for Age Z

Scores; H: Kruskal-Wallis Test Statistic; IAEA: International Atomic Energy Agency; IL: Illinois; kg: Kilogram; ml: Millilitre; NEPAD: New Partnership for Africa Development; SD: Standard Deviation; SE: Standard Error; SPSS: Statistical Package for the Social Sciences; TBW: Total Body Water; UNICEF: United Nations Children's Fund; USA: United States of America; U: Mann-Whitney Test Statistic; WAZ: Weight for Age Z Scores; WHO: World Health Organization; Z: Standardized or Corrected Value for the Number of Comparisons Conducted [1].

## Introduction

Due to improved economies and consequent nutrition transition, most countries including those of low and middle income levels, seem to be facing a double burden of malnutrition (DBM) characterized by under and over-nutrition even in the child population [2]. Consequently, a new term has been coined, “new norm” signifying the commonality of this problem in almost all nations worldwide [3]. In 2016, it was estimated that 41 million children under the age of 5 years were overweight and/or obese whereas 155 million were chronically undernourished [4]. Due to the continuous deterioration of the health of many nations, most countries decided to put systems in place to monitor the nutritional status of their people [5]. Botswana was not an exception in this regard [6].

Similar to other countries, Botswana has a National Nutrition Surveillance System (BNSS) through which the growth and/or nutritional status of children under-five years old is monitored. Existing research seem to point to results discrepancies when comparing such data from the clinics to that from national surveys [7]. Although the critical reason for the discrepancy cited in the aforementioned study was possible sampling bias in clinics, the researchers in this study suggest that discrepancies in data could be emanating from the use of different methods with low sensitivity and specificity thus compromising the quality and accuracy of data. For instance, methods such as the use of basic anthropometrics such as weight and height and BMI have been documented to have limited sensitivity and technical errors which may lead to possible misclassification of growth status and/or body composition [8].

With possible misclassification on the prevalence of malnutrition with the use of methods such as anthropometrics and BMI, there is a likelihood of either under-and/or overestimating malnutrition prevalence [9,10]. Under-nutrition and over-nutrition have adverse effects of health and are both associated with negative developments. Therefore, in order for countries to overcome problems emanating from the double burden of malnutrition, it is important that quality data be collected and this can be achieved through the use of reliable methods. Three methods are discussed to this regard.

## Anthropometrics

The anthropometric measurements of weight and height are commonly used to measure malnutrition. These measures are made common by their easiness to use everywhere especially in the field setting. However, just as easy as it is to use this method, it is highly likely to make technical errors that may compromise the quality of results, hence it is highly recommended to have trained and professional people undertaking measurements as well as using calibrated equipment [11,12]. Furthermore, basic anthropometrics of weight and height are disadvantageous in that they tend to be highly influenced by growth, diseases and the limited sensitivity which limits their ability to distinguish true

cases of malnutrition [8,13]. In this study, a weight for height curve signifying wasting is used as a standard for growth evaluation of the children, indicating the percentile rankings for weight according to specific heights but disregarding age. Weight for height Z scores (WHZ) < -2SD are considered under-nutrition and > +2SD as over-nutrition. Despite weight for height (wasting) indicating a measure of recent rapid weight loss or the failure to gain weight due to either poor food intake and/or illness, this was the only parameter that could be used to indicate both under- and over-nutrition. Weight for age (WAZ) (underweight) and height for age (HAZ) (stunting) can only indicate under-nutrition and not over-nutrition. Weight for age reflecting the child’s body weight relative to their age illustrates underweight and/or its severity, however it is not used to categorize overweight and/or obesity in children [14].

## Body mass index (BMI) and BMI for age percentiles

Body mass index is calculated by dividing weight by height squared ( $\text{kg}/\text{m}^2$ ). It is an index derived from the anthropometric measures of weight and height to help predict body fat in children with a BMI < 5<sup>th</sup> percentile and > 85<sup>th</sup> percentile regarded as underweight and/or under-nutrition and overweight and/or over-nutrition respectively [13]. It serves as a better index than height and weight alone in predicting malnutrition [13]. This measure is able to estimate body fat distribution although unable to directly quantify visceral and/or subcutaneous adipose tissues which are risk factors to cardiovascular diseases [15]. Because of the rapid growth of children, BMI may be inappropriate to use in children under five [16]. However, an alternative measure of BMI for age percentiles in the growth curves are availed side by side to ensure BMI is correctly assigned. The latter are gender and age specific and can be thus used to classify the children’s BMI relative to other children of similar gender and age [17].

## Isotope dilution

The dilution method uses stable isotopes and commonly  $\text{D}_2\text{O}$ , to quantify fat through its estimation of total body water (TBW) volume within the fat free mass (FFM) [12,13]. Due to the ability of water to maintain a relatively stable relationship to fat free mass (FFM), it can therefore best predict FFM and fat mass (FM) [13]. Although, the method seems to be better off when compared to anthropometric methods, it is evident that challenges may be presented in some cases where hydration is altered such as in obese individuals and some disease states [18]. Despite presented challenges, the method’s use still remains versatile due to its non-toxicity, -radioactivity and -invasiveness issues and is suitable to be used by everyone including children [18,19].

Available data on the double burden of malnutrition is limited and at best equivocal in Botswana. Therefore, there is a critical need to explore assessment tools and methods that are more reliable. The aim of this study was to assess the prevalence of under- and over-nutrition using the three methods of anthropometrics, BMI and isotope dilution .

## Materials and Methods

### Study design and participants

This was a pilot cross sectional study conducted on 197 children under five years of age who were attending growth monitoring as a standard component of paediatric services. Convenience sampling was used to enrol children who met the inclusion criteria of the study. Enrolment followed recruitment at the time of clinic visit. Children were included if they had access to Tsabana food supplement for at least 6-12 months prior to the commencement of the study. The children had to be aged between 36 and 59 months, be free from infection shown by lack of raised temperatures above normal 36°C and to have signed consent from parents.

### Sampling

Since the study was a pilot in preparation for a bigger study, the target sample was set at 200 with 100 children per study site. Recruitment of children was done during routine growth monitoring at local clinics in the study areas. In Moshupa (South) there were three clinics and the target sample was distributed amongst all of them hence, 33 children were recruited from each. In Shakawe (North) since there was one clinic all 100 children were recruited from there. The study was conducted during the dry season at the beginning of the month of October in the year 2017.

### Study areas

Data was collected from two sites classified as high and low risk for malaria infection. Shakawe village in the north was selected representing high risk malaria zone whereas Moshupa in the south signified low risk malaria zone. This selection of the two study sites was based on the malaria stratification and mapping which stratified the country different zones according to risk posed by malaria. According to this map transmission is more intense in the Northern Region where Shakawe village is. Moshupa falls within the non-endemic area [20].



Figure 1: Map of Botswana showing study sites [21].

### Data collection

#### Anthropometric measurements

##### Weight and height

Height and weight measurements were taken on all enrolled children. Heights of children were measured using a Leicester height measure stadiometer (Leicester, United Kingdom), and measurements were recorded in centimeters to the nearest 0.1 decimal place. Weight was measured using a digital Seca weighing scale (Seca Vogel and Halke Hamburg, model 882) and recorded in kg to the nearest 0.1 decimal place. Instruments were calibrated prior to use. The date of birth of children was extracted from the clinic card.

##### Body mass index percentiles

Body mass index (BMI) was calculated by dividing weight in kg by height squared. Thereafter, the CDC gender and age specific growth charts were used to classify the children which assisted in expressing the children's BMI relative to other children of similar gender and age. Below 5<sup>th</sup> percentile was considered as under-nutrition and >85<sup>th</sup> percentile as over-nutrition [22].

##### Deuterium dilution method

Body composition was determined using deuterium dilution method which utilized a double compartment model focusing on FM and FFM. A pre-dose saliva sample was collected. Thereafter the child received an accurately weighed dose of deuterium oxide (0.5g/kg/body weight) orally. The rinsing of the dose bottle was done with 50 ml of water which the child drank to ensure the entire dose was ingested. The D<sub>2</sub>O was allowed to mix with body water until it reached plateau or equilibrium. Parents were advised to keep track of their children that they don't eat nor exercise until the completion of the exercise. Thereafter, two post-dose saliva samples were collected first at 2.5 hours and the next at 3.0 hours. All samples were properly labelled with the code of the child, time and date of collection, dose amount, dose bottle number, and who administered the dose. These samples were kept in a cooler box with ice packs while waiting to be transported to the main storage where they were kept in a -20°C freezer awaiting analysis. Baseline saliva samples were kept separate from the post-saliva samples. The enrichment of deuterium in body water was measured using the Fourier Transform Infrared Spectrometer (FTIR). The enrichment was used to determine total body water which was used to calculate fat free mass (FFM). Fat mass was calculated as the difference between body weight and FFM [23]. DBM was defined as fat mass percentage < 13% for boys and < 23% for girls (low fat mass) and > 20% for boys and >30% for girls (high body fat) as under- and overnutrition respectively. These cutoffs were guided by the references using BOD POD references since there are no internationally established references as yet. With known TBW, FFM can be calculated by dividing it with a relevant hydration factor dependent upon the age of the children and their gender [24]. Children in this study had hydration factors ranging from 77.8-78.3

with females tending to have higher hydration factors. To minimize errors, a spreadsheet was used to calculate fat mass which was expressed as Fat mass percentage (%FM).

### Statistical analysis

The children's weight and height were entered into World Health Organization Anthro-plus version 1.0.2 software for the calculation of weight-for-height z scores (WHZ) and body mass index (BMI). Under-nutrition was defined as  $-2SD$  for weight for height and overweight as  $>+2SD$  of the same parameter. BMI was defined using the CDC gender and age specific growth charts definitions (under-nutrition: below 5<sup>th</sup> percentile, over-nutrition: greater than 85<sup>th</sup> percentile). For body composition the following cut-off points were used. Low fat mass (fat mass percentage  $< 13\%$  for boys and  $< 23\%$  for girls (low fat mass) – under-nutrition: High body fat ( $> 20\%$  for boys and  $>30\%$  for girls (high body fat) – over-nutrition. All data was exported into Statistical Package for Social Sciences (SPSS, Chicago, IL, USA) version 21 for further analysis.

Normality tests were run to check the distribution of the numeric data, first starting with normality plots that showed data was not normally distributed. This was followed by the use of a non-parametric Kolmogorov-Smirnov Test. The aforementioned test confirmed that data was not normally distributed, hence the analysis used non-parametric tests of Kruskal-Wallis and its post hoc Mann-Whitney to find comparison between assessment methods in measuring either under- and/or over-nutrition. Kruskal-Wallis was used because it is the equivalent to the non-related ANOVA and can be used on data that does not assume normality. Furthermore, it can allow independence of observations implying that it's not necessary that a relationship between observations in each group and/or between groups themselves exist [25]. To further focus on the comparison between assessment methods, a Bonferroni correction was done to limit Type 1 errors from building up to more than 0.05. The Bonferroni Correction was conducted by adjusting the normal significance of 0.05 by dividing it with the number of test, in this case being three (Anthropometrics vs BMI; BMI vs D<sub>2</sub>O and D<sub>2</sub>O vs Anthropometrics). Thus the main analysis with the Mann-Whitney between pairs could only be considered significant if they are below the adjusted Benferroni corrected value ( $0.05/\text{number of test pairs} = 0.05/3 = 0.0167$ ) [1]. Finally, effect size for the different methods towards the assessment of double burden of malnutrition was conducted. The formula used for effect size can be illustrated as follows:

Effect size for pair1 ( $r_1$ ) =  $\text{Mann-Whitney } Z_1 / \sqrt{\text{Total Observations}_1}$

Results are presented as mean  $\pm$  standard error (Mean  $\pm$  SE) for continuous data and percentages for categorical data. For non-parametric tests, test statistics according to test (H for Kruskal-Wallis and U for Mann-Whitney followed by degree of freedom and the corresponding significance will be reported. For effect size, corresponding Z and significance will be reported. Results were significant at  $p < 0.05$ .

### Ethical Considerations

Ethical clearance was obtained from the Health Research and Development Committee of the Ministry of Health and Wellness and the study was approved by the District Health Management Teams in the two districts. The study was performed in accordance with the principles of the Declaration of Helsinki (2008), Good Clinical Practices. An oral and written explanation of the study, including possible risks, was provided to the parents and guardians. Parents and guardians gave written signed consent for their children to participate in the study.

### Results and Discussion

#### Normality test results

All numerical data (WHZ, BMI and % Fat mass) were checked for distribution and were found to be non-conforming to a bell shape. To confirm whether the data was not normally distributed, a Kolmogorov-Smirnov test was conducted. This test indicated that WHZ (D (197) = 0.07,  $p = 0.23$ ), BMI (D (197) = 0.09,  $p = 0.00$ ) and %FM (D (197) = 0.06,  $p = 0.05$ ) did not follow a normal distribution leading to use of non-parametric tests.

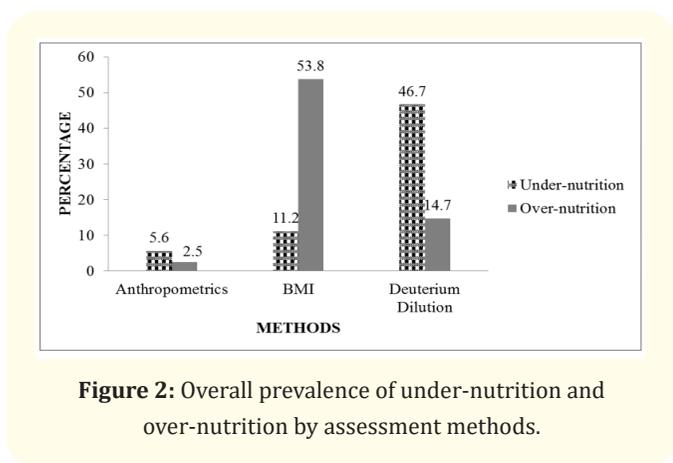
A total of 207 children were enrolled but only 197 children had data for all indicators of interest for this publication, hence this study focused on these only. The results presented are for 98 children in Moshupa (south) and 99 in Shakawe (north). The age distribution ranged from 3-5 years of age with 106 (54.1%) and 90 (45.9%) children in the 3-3.9 years and 4-5 years categories respectively. There were 109 (55.3%) girls and 88 (44.7%) boys participating in the study.

Table 1 indicates the study children's descriptives. Ninety-eight (98) and 99 children were from the Moshupa (south) and Shakawe (north) study sites respectively. There were no statistically significant differences observed in the descriptive parameters of age, weight, height, weight for height z scores, BMI AND %FM when comparing study sites, implying similarities amongst study children in the two study areas. Irrespective of the assessment method used, results showed that children from both study sites seemed to have similar under- and over-nutrition prevalence rates (Figure 3 and 4). Despite living in different geographical regions, the similarities of children in this age group does not come as a surprise. This is because the Botswana Government has from the 1970s invested in health promotion program that would prioritize the welfare of under-five children [6,26]. Children are provided with monthly growth monitoring and are given supplementary food to promote good nutritional status [27]. This means that if ever there were any compromised growth in children of this age in their respective homes, the care and provisions the government gives would fill in the gap. Furthermore, the world being a global village, has promoted availability of goods everywhere even in villages which may boost the variety of foods consumed in the homes and by children [28]. Other areas especially in the North have abundant natural re-

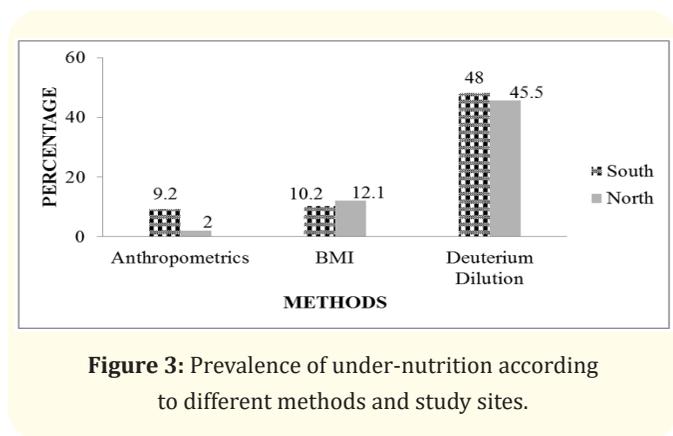
| Parameter    | Moshupa (South)<br>N = 98 | Shakawe (North)<br>N = 99 | Sig.<br>(2-tailed) |
|--------------|---------------------------|---------------------------|--------------------|
|              | <b>Mean ± SE</b>          |                           |                    |
| Age (months) | 47.23 ± 0.7               | 47.4 ± 0.7                | P>0.05             |
| Weight (kg)  | 14.4 ± 0.2                | 14.8 ± 0.2                | P>0.05             |
| Height (cm)  | 98.6 ± 0.6                | 99.5 ± 0.6                | P>0.05             |
| WHZ          | -0.6 ± 0.1                | -0.45 ± 0.1               | P>0.05             |
| BMI          | 14.8 ± 0.1                | 14.9 ± 0.1                | P>0.05             |

**Table 1:** Study children’s descriptives.

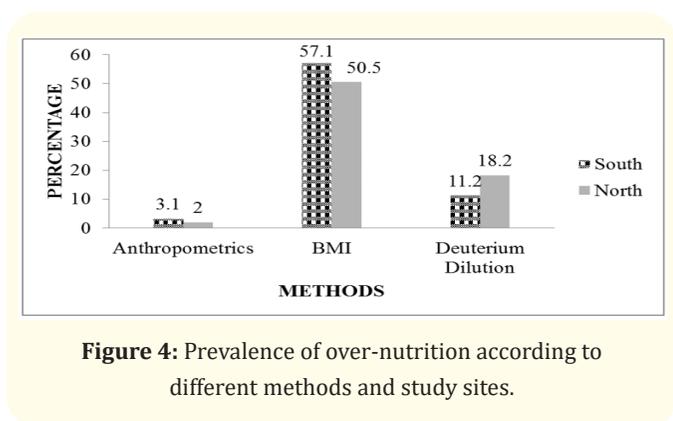
sources such as wild fruits, vegetables, plants and fish that can either supplement diets and/or be harvested and sold to boost purchasing power that can improve household dietary intake [29,30].



**Figure 2:** Overall prevalence of under-nutrition and over-nutrition by assessment methods.



**Figure 3:** Prevalence of under-nutrition according to different methods and study sites.



**Figure 4:** Prevalence of over-nutrition according to different methods and study sites.

Figures 2-4 illustrates the prevalence of under- and over-nutrition as assessed by the different methods and according to study sites. An overall observation was the likelihood of anthropometrics to under-estimate prevalence of the double burden of malnutrition and BMI and D<sub>2</sub>O to overestimate it when comparison is made against wasting (under-nutrition) (national at 7.2% and global at 7.3%) and overweight (over-nutrition) (national at 11.2% and global at 5.9%) prevalences [31,32]. However, part of the data suggests the use of anthropometrics at village level seemed to be unpredictable, at times over-estimating under-nutrition and/or under-estimating over-nutrition when comparing with national and/or global prevalences. The D<sub>2</sub>O dilution method mostly seemed to over-estimate either under- and/or over-nutrition but it seemed to be in agreement with the national over-nutrition prevalence whereas over-estimating the global prevalence.

The unpredictability of these methods in the assessment of the double-burden of malnutrition are confirmed by the statistical analysis conducted. In assessing undernutrition, it was evident that there was a significant difference on the assessment of under-nutrition using the three methods [H(2) =48.190, P< 0.05]. A more focused comparison between pairs of methods showed that the three methods affected the assessment of under-nutrition differently. For instance, anthropometrics compared to BMI, had a significantly high effect in reducing the prevalence of under-nutrition (U=0, z=-4.622, r=-0.80). The D<sub>2</sub>O dilution method in comparison to anthropometrics had a medium effect in reducing under-nutrition (U=0, z=-5.404, r=-0.53). Body Mass Index on the other hand when compared to D<sub>2</sub>O, had a medium effect in reducing undernutrition though lower than other pairs (U=358.500, z=-4.693, r=-0.44). All methods seemed to have a reducing effect on under-nutrition though at different magnitudes.

Similarly for over-nutrition, there was a significant difference using the three methods to assess over-nutrition [H(2) =77.434, P< 0.05]. All methods seemed to have a significantly reducing effect on over-nutrition but at different magnitudes. For instance, when comparing BMI vs. D<sub>2</sub>O, and D<sub>2</sub>O vs anthropometrics, these seemed to have a significantly high reducing effect on the assessment of over-nutrition as illustrated by U=0, z= -8.235, r=-0.71 and U=0, z=-3.526, r=-0.60 respectively. Anthropometrics compared to BMI had a significantly low effect in reducing under-nutrition (U=0, z=-3.768, r=-0.36).

The inconsistencies in the observed results mirrors the existing work where these methods seem to produce contradictory results [33-35]. The principles behind the different methods may be responsible for the varying results. For instance, anthropometrics despite its popularity and easiness to use, may easily have technical errors during measuring especially when working with children who are undergoing a growth spurt and could be easy to under and/or over-estimate prevalence [36]. On BMI, it is an indirect measure of body obesity and disregards differences in FM and FFM

and changes occurring with age which can end in misclassification of under- and/or over-nutrition [36-38]. The D<sub>2</sub>O dilution method seems to have an advantage by factoring in water in the body that maintains a relatively stable relationship to fat free mass and constant densities of the fat mass and fat free mass [13,39]. However, in young children who are rapidly growing and have extracellular water and organ mass in the bulk of their body mass, it may thus increase hydration of FFM and consequently bias estimates of body composition [33].

It is important to point to the limitations of this study and caution readers to use the information with care. The sample size of the study was small. A confirmatory study with a bigger sample size would be necessary to establish the accuracy of the results observed in this study. Furthermore, the lack of established reference standards for the isotope dilution method in the under-fives may have caused a bias in the results. Even with such limitations, there are strengths that are evident in the study. This is the first study of its kind in the country to attempt to bring together two commonly used methods of anthropometrics and BMI with a more advanced and new method of D<sub>2</sub>O dilution method to assess the double burden of malnutrition. Knowledge about the performance of the different methods is critical in helping researchers choose which methods to use so as to produce quality results that can be used to develop effective interventions.

## Conclusion

A gap still exists between the methods of assessment that can be used to assess the double-burden of malnutrition. All three methods, anthropometry, BMI and D<sub>2</sub>O dilution method have significantly different effects towards the assessment of either under- and/or over-nutrition. It is thus recommended that a thorough decision be made prior to choosing which method to use. Additionally, it is important to use more than one method to validate data received and to improve the accuracy and quality of data produced. A confirmatory study is urgently needed to confirm the findings to allow for timely intervention.

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## Conflict of Interest

We declare that there are no financial interest involved and/or any conflict of interest that exists with this study.

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