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# Correlations of Anthropometric Measurements Among Pregnant Women Residing in Arusha City, Tanzania

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## Abstract

Adequate nutrition during pregnancy is a key for early prevention of poor pregnancy outcomes and future diet related non-communicable diseases. The study aimed to determine the correlations between body mass index with body fat percentage and mid-upper arm circumference to simplify nutrition status assessments among pregnant women. A cross-sectional study was conducted in 2018 at Kaloleni and Ngarenaro antenatal clinics among 468 pregnant women. The body fat percentage was measured using bioelectric impedance analyzer™; mid-upper arm circumference by a non-stretchable mid-upper arm circumference tape; weight using a SECA™ scale, and height by a stadiometer. Demographic information was gathered by face-to-face interview using a questionnaire with structured questions and data analyzed by SPSS™ Version 20. The participants were found to have a mean age of 28 years (SD ± 6), gestational age of 28 weeks (SD ± 3.82), mid-upper arm circumference of 27 centimeters (SD ± 3.7), body fat percentage of 33.7 (SD ± 7.2) and body mass index during pregnancy of 27 kg/m2 (SD ± 5.5). About 36% of the pregnant women had mid-upper arm circumference of ≥ 28cm and 37% were overweight and 22.2 % obese based on body mass index. Among 238 pregnant women who recalled their weight before pregnancy, 25.2% were overweight and 22.7% were obese using categories for a normal adult. Partial correlations showed that, body mass index is positively correlated with body fat percentage ($r = 0.701$, $p < 0.001$) and mid-upper arm circumference ($r = 0.661$, $p < 0.001$). In addition, mid-upper arm circumference and body fat percentage have strong positive correlation ($r = 0.774$, $p < 0.001$) even after controlled for maternal and gestational age. There are positive significant correlations among pre-pregnancy body mass index with percentage body fat, and mid-upper arm circumferences, hence, useable during pregnancy to address challenges associated with body mass index.

**Keywords:** C*orrelations; body fat; mid-upper arm circumference; BMI; pregnancy*

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## Introduction

Physiological alterations occurring during pregnancy including maternal fat deposition aim at meeting fetal lipid demands and ensure sufficient supply of the required nutrients for the developing fetus, however, it is accompanied with potential metabolic consequences (Most *et al.*, 2018). Thus, maternal nutrition, as a prenatal diet, modulates the health status of the child through physiological and immunological adaptations with potential life-long disease risk ramifications. Therefore, appropriate nutrition status throughout the pregnancy period is vital for wellbeing of both the mother and her newborn. Generally, prenatal diet has great bearings on the health status of the child as a product of increased physiological adaptations throughout its growth and development (Gluckman *et al*., 2008). For instance, maternal excess weight, due to being obese or overweight, increases the risk of adverse outcomes such as gestational diabetes and preeclampsia in the mothers, and a repertoire of chronic non-communicable diseases in the fetus/infants (Patel *et al*., 2015; Agosti *et al*., 2017). This may increase the chance of developing diet related chronic non-communicable diseases (DR-NCDs) including but not limited to diabetes, different kinds of cancers and cardiovascular diseases in their future life.

Overweight and/or obesity during or before pregnancy goes together with the tendency of increased accumulation of body fats. This situation can transform body composition which may lead into pregnancy-induced diabetes (PID), pregnancy-induced hypertension (PIH) and also predisposing the newborn to overweight and obesity in the future life (Larijani *et al*., 2003; Whitaker, 2004; Jensen *et al.,* 2005; Ay *et al*., 2009).

The condition may also negatively upset the progress of the developing fetus hence, analyzing the changes in body fat composition is vital to comprehend relationships between maternal health status and child health (Reilly *et al*., 2005). In this instance, there is a need to recognize anthropometric methods that can accurately and simplify assessments of nutrition status during pregnancy due to the growing demands for good and appropriate nutrition for the mother and her newborn.

Body mass index (BMI) is a common indicator for evaluating nutritional status during pregnancy, however, it does not delineate the fat mass from lean body mass (Kotnik and Golja, 2012). Also, BMI during pregnancy can best be used before the $16^{th}$ week of pregnancy but in most cases women initiate antenatal clinic (ANC) services very late (Inskip *et al*., 2021; Saldana *et al.,* 2004). In addition, most of the women get pregnant without knowing their pre-pregnancy weight because they have no tendency of measuring body weight regularly unless recommended by healthcare providers. This knowledge deficit complicates the estimations of their BMI for interpreting their nutrition status and interfere the estimation of weight gained during pregnancy which is strongly linked to the changes in body fat mass (Berggren *et al*., 2016). Another limitation of using BMI alone during pregnancy is that, on top of the fat mass and lean body mass, the fetal mass and amniotic fluid comprises of an undefined portion of the total body mass of the pregnant woman. Also, throughout pregnancy, there is a tendency of increasing maternal blood volume and fat deposits to serve the rapidly growing and developing fetus as well as preparing the woman for lactation (Aye *et al*., 2014). All these have great influence on weight of the pregnant women which also affect BMI calculation. Hence, to be more explicit in categorizing nutrition status of the women during pregnancy and spotting out possible related health problems, there is a need to increase attention to other anthropometrics including the less explored measure of body fat percentage (BF%). This will help to design and implement suitable interventions to accurately determine nutrition status and perform regular maternal weight checks for tracking their nutrition status to prevent short and long term negative effects on both the mother and her newborn.

In addition, mid-upper arm circumference (MUAC) is a practically simple measure, that can be used instead of BMI due to its steadiness throughout the pregnancy period. It is also found to have high relationship with pre-pregnancy BMI which is the commonly used indicator (Gale *et al.,* 2007; Fakier *et al.,* 2017). Moreover, MUAC does not need complex calculations and costly devices, such as height charts and scales. It can also readily be conducted on a seriously ill patient who cannot even standup straight as one of the requirements for finding accurate weight and height for computing BMI (Lopez *et al*., 2011). Beyond these two standard methods, bioelectrical impedance analyzer (BIA) that is used to determine body fat percentage is increasingly acknowledged as an inoffensive or safe, accurate, and consistent method for determining nutritional status (overweight and obesity) of pregnant women (Amani, 2007). Therefore, given the challenges in computing

BMI during pre- and intra-pregnancy, there is a need to pinpoint simple but accurate methods for determining nutrition status during pregnancy. In this instance, the current study aimed to establish the correlations for BMI with BF% and MUAC as a proxy for the commonly used BMI in assessing nutrition status during pregnancy.

## Material and methods

### *Study design, area and population*

This study was part of a cross-sectional research that was done on simple methods for identification of women at risk of pregnancy diabetes in urban areas of Arusha district in Arusha region Tanzania. Arusha district, was chosen due to a high prevalence of type two diabetes mellitus (T2DM) especially in urban (22.9%) compared to rural (9.9%) areas, which may, partly be attributed by previously undiagnosed and unmanaged hyperglycemia in pregnancy (Masaki *et al*., 2015) as explained by Msollo *et al*., (2019). The study involved pregnant women at their second and/or third trimesters, who were getting antenatal care services at Ngarenaro and Kaloleni Health Centers in the district. The two centers were purposively selected due to their central location and large numbers of pregnant women accessing Ante-Natal Care (ANC) services across the district reflecting the urban population. The study excluded pregnant women with diabetes before pregnancy and those who were under- diabetes management or treatments. All women who were unwilling to participate or provide consent were also excluded from the study (Msollo *et al*., 2019).

The aim of the research and procedures for data collection were openly described to the pregnant women who were ready to participate in the study and met the predetermined selection criteria. Afterwards, an informed consent was provided and signed by those who willingly agreed to participate. The permission to conduct this study was granted by the Tanzania National Institute for Medical Research (NIMR) with a reference number NIMR/HQ/R.8a/VoLIX/2694. This was done after a critical review of the study protocol and the respective attachments including consent form and data collection tools which were translated form English language to Kiswahili for consistency in administering the tools. The eligible women were randomly chosen to attain a total of 468 pregnant women who met the stated selection criteria as detailed in the study by Msollo *et al.* (2019). This sample size was obtained from the prevalence formula by Daniel (1997).

$$n = [z^2 * p * q]/d^2$$

Where: n = desired sample size, Z = standard normal deviation set at 1.96 corresponding to 95% CI, q = 1.0 – p, d = degree of accuracy desired (0.05) and p= proportion of the target population with hyperglycemia in pregnancy.

In this formula, the prevalence (P) of gestational diabetes was assumed as 50% and non-response rate of more than 20% (Njete *et al*., 2018). This prevalence was used due to lack of large national data for gestational diabetes mellitus (GDM) which was the main focus of the whole study as explained on the previous study by Msollo *et al*., (2019).

### *Data collection*

Data was collected by trained enumerators using structured questionnaires, following a pretesting and survey tool modification session using 20 participants. The collected data included demography such as age, marital status, household size, income, occupation, and education levels. It also collected data on maternal characteristics including pregnancy status, and timing for starting ANC which were obtained from the participants' antenatal care (ANC) records.

Anthropometric assessments were performed by nutrition experts who were among the recruited and trained enumerators. Mid-upper arm circumference (MUAC) was measured halfway between the olecranon of the elbow and the acromion of the shoulder of the arm, using a non-elastic standard and calibrated tape measure. Women were classified and grouped as underweight and/or normal with a MUAC of less than 28 cm and overweight/obese when having a MUAC ≥ 28 cm (Mwanri *et al*., 2014). Weight were measured with the least clothing, without wearing shoes using a digital floor weighing scale (SECA-Germany), placed on a flat surface. The respondent's weight measurements were taken in duplicate and recorded to the nearest 0.1 kg, and the average was recorded, and used for further calculations.

Height was measured using a stadiometer (Shorr Productions, Maryland USA) as previously described by Msollo et al. (2019). BMI values were computed by dividing the measured and recalled pregnancy body weight in kilogram divide by the measured body height in meter square to obtain BMI in kg/m² and categorized as underweight (<18.5kg/m²), normal (18.5-24.9kg/m²), overweight (25-29.9kg/m²), and obese (≥30kg/m²) based on World Health Organization recommendations (WHO, 2005). Body fat percentage, adjusted for age, sex, weight, and height, was determined using a bioelectric impedance analyzer equipment following similar steps for weight measurements (Tanita TBF 105 Fat Analyzer™) (BIA) and the measurement values were performed twice and the average recorded.

***Data analysis***

Data were coded, entered, cleaned, edited, and analyzed using the Statistical Package for Social Science™ (SPSS) Version 20. Descriptive statistics were performed on age, weight, height, BMI, MUAC and body fat percentage variables and summarized appropriately to obtain frequency, mean, standard deviations (SD), and percent of responses. Correlation and partial correlation analyses were used to examine relationships between BMI, MUAC, and BF%. In this analysis, descriptive statistics such as frequency, mean, standard deviations (SD), and percents were obtained for different variables including prevalence of overweight and obesity, mean and standard deviations for etc. During the analysis for descriptive statistics maternal age, gestational age, BMI and MUAC were categorized to obtain the frequencies and percent. Inferential statistics were also performed whereby Partial correlation was run to measure the strength and direction of a linear relationship between two continuous variables that is either BMI and BF% or BMI and MUAC or MUAC with BF% whilst controlling for the effect of other continuous variables including gestational age and maternal age. The values for maternal age, gestational age, BMI, MUAC and BF% were treated as continuous variables during the analysis for correlations and the level of statistical significance was fixed at $p < 0.05$.

**Results**

***Demographic information***

This study examined 468 pregnant women from Kaloleni and Ngarenaro antenatal clinics, with the mean age being 28 years (SD ± 5.8). Over a third of the study participants (65.6%) were over twenty-five years old, with the mean age of first antenatal clinic attendance being 18 weeks (SD ± 5.6). Approximately over half of the respondents (62.2%) were either in their second or third pregnancy (Table 1).

**Table 1**

*Maternal information of the participants*

| Respondent Variables | Frequency | Percent | Mean (±SD) |
|---|---|---|---|
| Age of the women | | | |
| < 25years | 164 | 35.0 | 28 (SD ± 5.84) |
| ≥ 25 years | 304 | 65.0 | |
| First visit gestational age | | | |
| <12 weeks | 57 | 12.2 | |
| 12-24 weeks | 363 | 77.6 | 18 (SD ± 5.62) |
| 25-36 weeks | 48 | 10.2 | |
| Gestational age during the study | | | |
| 24-28 weeks | 291 | 62.2 | 28 (SD ± 3.82) |
| >28 weeks | 177 | 37.8 | |
| Gravidity | | | |

| | | | |
|---|---|---|---|
| Prime | 142 | 30.3 | |
| Second and third | 236 | 50.4 | 3 (SD ± 1.20) |
| Fourth and above | 90 | 19.2 | |

***Nutrition status of pregnant women***

The mean of recalled weight before pregnancy was 67 kg (SD ± 12.5), height 159 cm (SD ± 6.3), percentage body fat (33.7%) (SD ± 7.2) and MUAC was 27 cm (SD ± 3.8). Approximately half of the pregnant women were not able to recall their body weight before pregnancy (Table 2).

**Table 2**

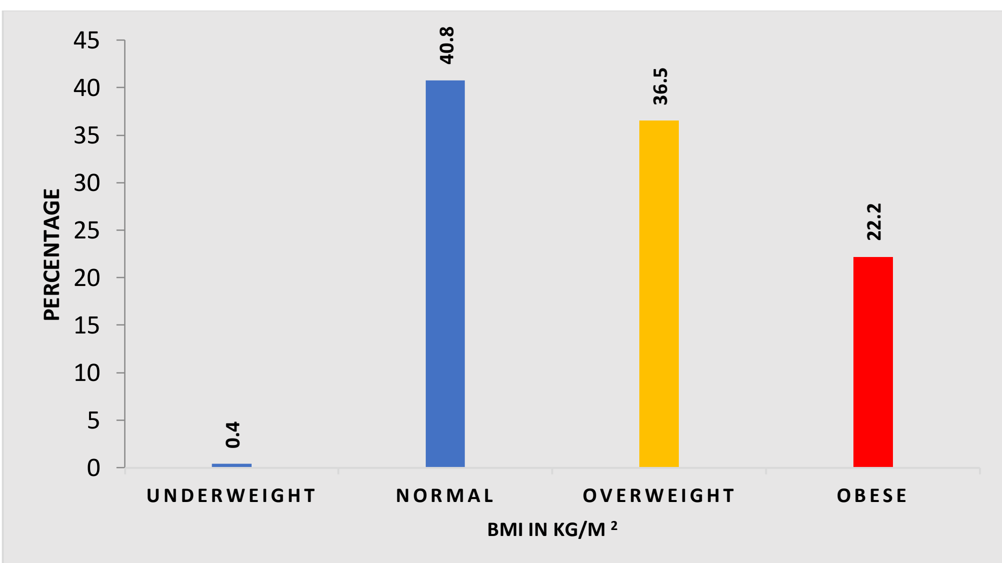
*Anthropometry of the participants (N=468)*

| Variables tested | Frequency | Percent | Mean (SD) |
|---|---|---|---|
| MUAC | 468 | 100.0 | 27 (SD ± 3.8) |
| Percentage body fat | 468 | 100.0 | 33.4 (SD ± 7.8) |
| Weight during pregnancy (kg) | 468 | 100.0 | 68 (SD ± 12.5) |
| Height (cm) | 468 | 100.0 | 159 (SD ± 6.3) |
| Self-reported weight before pregnancy (kg) | | | |
| Remembered weight before pregnancy (kg) | 238 | 50.8 | 67 (SD ± 12.5) |
| Did not remember weight before pregnancy | 230 | 49.2 | |

The measured pregnancy weight was used to calculate BMI of pregnant women of which, 36.5% (n=171) were classified as being overweight and 22.2% (n=104) as obese (Figure 1).

**Figure 1**

*Nutrition status of the pregnant women during pregnancy based on BMI*

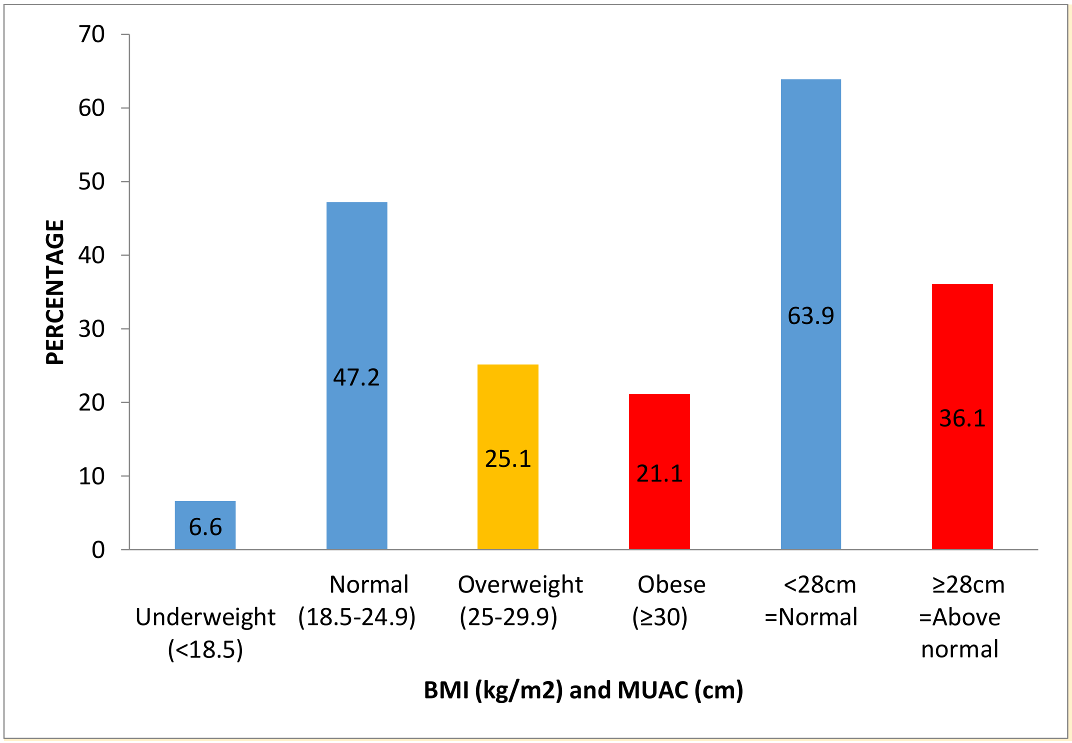



The BMI of the women before pregnancy was determined using the recalled weight and measured height whereby, 25.2% (n=60) were found to be overweight and 22.7% (n=54) obesity. About 36% (n=164) of the women had MUAC ≥

28 cm which is also an indicative of overweight or obesity (Figure 2).

**Figure 2**

*Nutrition status of pregnant women based on MUAC and pre-pregnancy BMI*




***Correlations among MUAC, BF% and BMI***

Partial correlations between anthropometrics indicated that BMI was significantly correlated with percentage body fat (BF%) (r=0.701, p value<0.001) and MUAC (r= 0.661, p value <0.001). In addition, BF% and MUAC shown to have a strong partial correlation (r = 0.774, p value <0.001) even after controlled for maternal age and gestational age (Table 3).

**Table 3**

*Correlation between variables*

| Control variables | Correlated variables | | MUAC | BMI | BF% |
|---|---|---|---|---|---|
| | MUAC | Correlation | 1.000 | 0.661 | 0.774 |
| Maternal age | | P-value | NA | 0.000 | <0.001 |
| Gestational | Pregnancy | Correlation | 0.661 | 1.000 | 0.701 |
| age | BMI | P-value | <0.001 | NA | <0.001 |
| | BF% | Correlation | 0.774 | 0.701 | 1.000 |
| | | P-value | <0.001 | 0.000 | NA |

***Note.*** *NA=not applicable in the entire correlation, BF%=body fat percentage, MUAC=mid-upper arm circumference, BMI=body mass index, Significant at p value of <0.05.*

**Discussion**

This study was conducted to explore the correlations for BMI with MUAC and BF%

among pregnant women residing in urban areas of Arusha district in Arusha region, Tanzania. The study revealed a high prevalence of pregnancy overweight (37%) and obesity (22%). Furthermore, the prevalence of overweight and obesity before pregnancy (pre-pregnancy) was found to be 25.2% and 22.7% respectively. The observed rate of overweight and obesity in the current study is higher than that of Tanzanian National prevalence which was reported to be 20.3% for overweight and 11.2% for obesity among non-pregnant women of reproductive age (Ministry of Health, Community Development, Gender, Elderly and Children [MOHCDGEC] *et al*., 2018). The high prevalence of overweight and obesity may be influenced by urbanization that has changed people's lifestyle including dietary intake and physical activities which need further explorations. Literature shows that urbanization has enormously changed the living condition and human manners together with the health situation and burden of diseases (Kirchengast and Hagmann, 2021).

The current study revealed a significant positive correlation for pregnancy BMI with MUAC and BF% after controlling for maternal age, and gestational age. In addition, MUAC and BF% were found to be strongly correlated which implies that, either MUAC and/or BF% can be used to determine nutrition status of women during pregnancy. Similar studies support the current findings that MUAC may be used instead of BMI because of its virtual constancy throughout pregnancy and highly correlated with BMI before pregnancy (Gale *et al*., 2007; Fakier, *et al*., 2017). Another study done by Kretze *et al*. (2020) in Brazil reported that MUAC is the best measurement that is found to be correlated with visceral adipose and total adipose tissue as compared to pre-pregnancy BMI (BMI before pregnancy). Another study was done in Nigeria and revealed that MUAC has a strong positive correlation with maternal weight and can be used to determine nutrition status during pregnancy regardless of the gestational age (Okereke *et al*., 2013). Furthermore, a strong positive correlation between BMI and BF% has been documented by Ilman *et al*. (2015). Other similar studies in South India and Nigeria support the current findings that there is a strong positive association between BMI and BF% when age was used as a predictor of the relationship (Rao *et al*., 2012; Mukadas *et al*., 2016). Another similar study done among South Asian adults found a significant positive correlation between BMI and BF%, in both male and female participants of all age groups (Ranasinghe *et al*., 2013).

It is reported that BMI cannot determine body composition of fat and muscle exactly because BMI compares weight and height, which are indexes of excess weight, instead of body fatness compositions (Chen et al., 2010). Also, BMI is not capable of differentiating between surplus fat, muscle, or bone mass, nor provide any signs for fat distribution amongst individuals (Chen *et al*., 2010). Although BMI, is broadly used as a proxy for obesity, it does not delineate the contributions of maternal and fetal weight to the gestational weight gain, nor does it consider individual components of body composition including adipose tissues and lean muscle mass (Kannieappan *et al.,* 2013). Therefore, BMI may not be the best measure of maternal body composition during pregnancy that one can depend on, unless used in combination with other anthropometric approaches.

The failure of BMI to sense and estimate body composition accurately creates an imperative for alternative ways of assessing nutrition status which are easy and cost-effective for areas with limited resources as well as epidemiological studies (Mukadas *et al*., 2016). In this case, BF% together with MUAC can be used instead of BMI as determinants of nutrition status due to their strong positive correlations with the more common but less reliable pre-pregnancy or pregnancy BMI. The findings of the current study show that BMI is not a reliable method for assessing nutritional status during pregnancy as nearly half of the women who participated in the study were not able to recall their weight before pregnancy. Also, the recalled information may not be as accurate as the estimated measurements which imply that even if all pregnant women could remember their pre-pregnancy body weights, there is a possibility of reporting incorrect weights as a result of over or under-estimations. A similar study done in Southampton indicates that the BMI calculated from the recalled weight must be treated and interpreted carefully as it provides inaccurate estimates as compared to weights measured in early pregnancy before the first 15 weeks of pregnancy (Inskip *et al*., 2021).

he uses of BMI to assess nutrition status of pregnant women is complicated. This has been reported by Berggren *et al*. (2016) who found that, most of the women become pregnant without knowing their pre-pregnancy body weights making the estimation of their BMI before pregnancy and weight gain during pregnancy to be difficulty or even impossible. All these indicate that BMI is not a reliable and valid method for determining nutrition status during pregnancy hence, more reliable methods are needed. A similar study was done in Tanzania and found that BMI could not be calculated in most of the women because they were not able to remember their body weight before pregnancy (Mwanri *et al.*, 2014). Although weight gained during pregnancy can be determined if the gestational weight within fifteen weeks of pregnancy is available (Saldana *et al*., 2004), women in the current study started their first ANC visit with a mean gestational age of 18 weeks. This implies that, most of the women delay to initiate ANC services which again may make determination of their nutrition status to be challenging. A similar study done by Iqbal *et al*., (2007) reported that the majority of the women started ANC late with a mean gestational age of 20 weeks; therefore, it was difficult to get weight before pregnancy. Hence, information on changes in BF% and MUAC is required due to their strong correlations with BMI. This can eliminate the problems associated with the use of pre-pregnancy or pregnancy BMI in determining nutrition status during pregnancy.

In the current study, gestational age and maternal age were included in the analysis to control for their confounding effects as decrease in physical activity and metabolism are accompanied by aging (Erem *et al*., 2004). On the other hand, weight may be influenced by gestational age. This has been supported by another study which reported that the correlation between BMI and BF% was confounded by individuals age (Ilman *et al.*, 2015), implying that BMI and BF% are increasing with age. Another study done in Kilimanjaro reported that the rate of overweight and obesity increased with age because the individuals with ≥ 35 years of age had higher prevalence compared to the lower age categories after adjusting for other risk factors (Msollo *et al*., 2016). This knowledge shows the necessity of considering age when using BMI to envisage overweight and /or obesity in a given population (Ranasinghe *et al*., 2013).

**Conclusion and recommendations**

Overweight and obesity are found to be high among pregnant women in the urban areas of Arusha. There was a strong positive correlation for BMI, MUAC and BF% which encourages the use of MUAC and BF% for assessing nutritional status during pregnancy to reduce the challenges associated with the use of pre-pregnancy and/or pregnancy BMI. Hence, BF% needs to be more explored to determine proper methods for estimating it, cut-off points to categorize the health and unhealth pregnant women and the appropriate gestational age at which body fat can be determined effectively. Also, there is a need for finding associations among BMI, BF% and MUAC with other anthropometric measurements of skinfold thickness. This will help to be more precise in determining nutrition status during pregnancy to further identify women at risk of poor pregnancy outcomes for appropriate measures to be taken to prevent the associated effects.

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