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Review on studies of mid-upper arm circumference among pregnant women

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ABSTRACT

Maternal nutritional status and health disorders are important matters of concern in both developing and underdeveloped countries. Various methods of nutritional assessment have been conducted to derive information regarding such issues. Mid-upper arm circumference (MUAC) is one of them. This review has attempted to provide an insight of how successful this method has been able to predict maternal nutritional status, their pregnancy outcomes and other health disorders. The present review has attempted to document and analyze the publications on the study and validation of mid-upper arm circumference (MUAC) for predicting and/or screening the nutritional status of pregnant women and its associated pregnancy outcomes. This review has also approximated number of studies conducted in various continents and on various areas of research field. An attempt has also been made to focus on the importance of MUAC in these issues and further discussion on other pertinent issues like problems faced due to non-availability of universally accepted cut-off points, the advantages and disadvantages of using MUAC in such studies and diagnostic test of accuracy of maternal MUAC in this regard.

Keywords: *mid-upper arm circumference, MUAC, pregnant women, maternal*

INTRODUCTION

Maternal under-nutrition is one of the most important causes of maternal morbidity and mortality, particularly in the developing countries as it has a direct association with foetal nutrition (Ali et al., 2014). Maternal under-nutrition is highly prevalent in resource-poor settings, ranging from 10% to 19% in these settings, but is particularly high (>20%) in sub-Saharan Africa, south-central and south-eastern Asia, and Yemen (Black et al., 2008). Under-nutrition in women before, during and after pregnancy is recognized as a key determinant of poor pregnancy outcomes including poor foetal development, preterm births, and small for gestational age and low birth weight (LBW) babies, often leading to increased infant morbidity and mortality and also occurrence of various maternal health disorders.

Poor maternal nutritional status continues to be a major health burden in developing countries and also in developed countries to a lesser extent. It is globally the most important risk factor for illness and death, with hundreds of millions of pregnant women being affected. Innumerable studies have been conducted on the risk factors of poor nutritional status of pregnant women though the situation could not be kept under control completely till date. Various methods of assessing the nutritional status of both pregnant women and the forthcoming individuals have been used till date, with anthropometry being the most commonly used method. However, fewer of them have focused on the question as to which is the best indicator for the prediction of risk of malnutrition among pregnant women and its associated pregnancy outcomes with greater sensitivity, specificity and accuracy.

Mid-upper arm circumference (MUAC) is an easy, non-invasive and inexpensive technique in anthropometry used to detect nutritional status and is used in developing countries for rapid and extensive nutrition surveillance and screening programs (Velzeboer et al., 1983; Roy, 2000). As stated by the term itself, MUAC refers to the measurement of circumference of the mid-upper arm. It is the circumference of the right upper arm (conventionally, left upper arm) measured at the midpoint between the tip of the shoulder and the tip of the elbow (between the olecranon process and the acromium).

Reasons as to why maternal MUAC is preferred

MUAC is preferred to other anthropometric measurements in determining the nutritional status of pregnant women and its associated pregnancy outcomes. One advantage of using MUAC to assess women at nutritional risk of resulting into poor pregnancy outcome

is that arm circumference measurements can be taken whenever a woman visits a health worker or health centre. The measurement of MUAC not only yields useful data, but also raises awareness about nutritional status among the pregnant and/or non-pregnant women participating in the study.

In pregnant women, weight alone may not be the best indicator of maternal muscle and fat stores, since it is a measure of both the mother and the foetus. Therefore, simple and inexpensive anthropometric measurements, such as MUAC and skinfold thickness measurement, are used in large-scaled epidemiological studies to derive estimates of lean muscle mass and adiposity (Friss et al., 2002, 2004; Villamor et al., 2004).

Moreover, MUAC is rather insensitive to changes over the total period of pregnancy for adult women (Katz et al., 2010; Lechtig, 1988; Mohanty et al., 2006; Ricalde et al., 1998). It can be used as a proxy for body weight, since it is largely independent of gestational age (Krasovec and Anderson, 1991). Therefore, MUAC could be considered as a potential indicator of maternal nutritional status, and may be used instead of pre-pregnancy weight, as an alternative indicator to assess women at risk of poor pregnancy outcome in communities where weighing is not feasible for pregnant women and/or when presentation for prenatal care is late (Ricalde et al., 1998). Furthermore, recently published paper based on review of evidences revealed that MUAC is a preferred anthropometric measurement during pregnancy (Ververs et al., 2013).

On the contrary, one disadvantage of MUAC is that weight increase (accumulation of fat) is not directly reflected in an increased MUAC. MUAC is therefore not suitable for monitoring the nutritional status of the individual pregnant women during the intervention or for evaluating the impact of the nutritional intervention.

MUAC studies on pregnant women

Our literature search has yielded that the pioneering study on the assessment of nutritional status of pregnant women first appeared in 1988 when Lechtig (1988) published a study comparing the association of several traditionally high-risk anthropometric indicators during pregnancy with risk of having a low birth weight (LBW) baby in Guatemala. The results showed that low MUAC (≤23.5 cm) performed just as well as the other measures (weight gain during pregnancy, uterine height, and weight gain as a percentage of weight-for-height). Besides this, this cut-off level of 23.5 cm has shown high sensitivity (77%) and

specificity (71%) for the prediction of low birth weight. Since the publication of that study, the necessity to identify pregnant women at risk of poor birth outcomes in resource-limited settings has continued to enhance and it could be evidenced by the unceasing publication of papers with this focus, comprising of a 0.5 decades earlier published review article that suggested simple and standardized anthropometric indicators (such as low MUAC) to predict acute malnutrition and poor birth outcomes among pregnant women in humanitarian contexts (Ververs et al. 2013). Prior to the studies of Lechtig (1988), there were few studies like that of Jansen et al (1984), Mbofung and Atinmo (1985), etc needs to be mentioned here.

As we all know, maternal health encompasses gestational period, delivery and also post-partum period. Maternal MUAC has served to be one of the best anthropometric techniques in predicting various issues during these periods which we will be discussing in the following paragraphs.

Maternal nutritional status using MUAC

MUAC is a good indicator of the protein reserves of a body, and a thinner arm reflects wasted lean mass, i.e. malnutrition (FANTA, 2003). Innumerable studies (Carrillo et al., 2010; Kalanda et al., 2006a; Olukoya and Giwa-Osagie, 1991; Pérez et al., 2010) have tried to assess nutritional status of pregnant women using MUAC. Nevertheless, there is no consensus about the cut-off point that can be associated with such issues as the recommended figures vary according to socioeconomic and demographic characteristics of the population studied. Data from Africa and Asia (Kruger, 2005; Ojha and Malla, 2007) suggest that during pregnancy, MUAC below 25cm can be used as a warning of malnutrition, below 23cm as a strong indicator of malnutrition, and figures lower than 22cm are highly associated with an increased risk of adverse pregnancy outcomes, especially LBW.

A MUAC value less than 22 cm has been recommended to classify acute malnutrition or wasting among women in third world countries (James et al., 1994). Research evidences have also shown that it is not affected by non-nutritional changes (López et al., 2011). Furthermore, wasting in pregnant women can be defined as MUAC< 22cm (Villamor et al., 2002). They are considered to be at risk of adverse pregnancy outcomes (Kruger, 2005).

In addition, increases of MUAC during pregnancy are generally less than .05 cm and it can be considered a proxy indicator for women's pre-pregnancy or early pregnancy weight (Krasovec and Anderson, 1991; WHO, 1995). The same cut-off value can be used to define

under-nutrition in both pregnant and non-pregnant women because of the slight change of values change during pregnancy.

Maternal MUAC and pregnancy outcomes

Pregnancy outcomes related to maternal nutritional status have been measured by anthropometry. Numerous research projects of Naeye (1979), Tripathi et al. (1987), Winikoff and Debrovner (1981), etc. have studied several maternal anthropometric indicators as predictors of birth outcomes. However, fewer of them have focused on the question as to which is the best indicator for the prediction of pregnancy outcomes with greater sensitivity, specificity and accuracy. The usefulness of MUAC for screening women at risk of poor pregnancy outcome is promising both on theoretical grounds (reflecting maternal fat and/or lean tissue stores), because (i) of the relationship between MUAC and weight (Anderson, 1989; Krasovec, 1989; Shah, 1982) and (ii) it is independent of gestational age (Lechtig, 1988).

There are differences between developed and developing countries in determining the most appropriate cut-off points for anthropometric measurements (Kramer, 1987; Shah, 1991). Screening with measurements that require only one contact with a woman are useful due to limitations in available prenatal care in developing countries. To answer these questions some researchers like Anderson (1989) and Shah (1982) have studied the relationship between maternal MUAC and pregnancy outcome. They have shown that MUAC is a good indicator of pregnancy outcome. Several studies (Begum et al., 2003; Dhar and Bhadra, 2008; Elshibly and Schmalisch, 2008; Janjua et al., 2009; Ogbonna et al., 2007; Ojha and Malla, 2007; Osman et al., 1995; Sen et al., 2010b) on pregnant women examined the association between low MUAC and birth outcome.

- *Low birth weight (LBW)*: Low birth weight (LBW) has been defined by World Health Organization (WHO, 1992) as weight at birth of less than 2.5 kg. By international agreement, LBW has been defined as a birth weight of less than 2500 grams, with the measurement being taken preferably within the first hour of life, before significant postnatal weight loss has occurred (Park, 2009). According to Villar et al. (1984) and World Health Stat Q (1980), maternal nutritional status influences infant's birth weight. A vast majority of studies (Assefa et al., 2012; Karim and Mascie-Taylor, 1997; Lechtig, 1988; Mohanty et al., 2006; Ricalde et al., 1998) have unveiled a strong association between

maternal MUAC and birth of LBW babies whereas some studies like Dhar and Bhadra (2008), Elshibly and Schmalisch (2008), etc. did not find any significant association between low MUAC and infant LBW (both based their choice of cut-offs <24 cm and <27 cm, respectively) on what was determined to be optimal (highest sensitivity and specificity) in their study samples.

Maternal MUAC is commonly used as a screening tool for LBW babies in developing countries (WHO, 1991, 1995). Women who had low Mid Upper Arm Circumference (MUAC) measure are more likely to give birth to LBW babies than their counterparts (Janjua et al., 2009; Mohanty et al., 2006). An increment of 45 g in birth weight can be expected for each additional cm in maternal arm circumference measurement (Ricalde et al., 1998). The study of Ramlal et al. (2012) supports the use of MUAC as an efficient, cost effective screening tool for LBW in HIV-infected women, as in HIV-uninfected women.

- *Intrauterine growth retardation (IUGR):* IUGR also known as foetal growth retardation refers to poor growth of a foetus while in the mother's womb during pregnancy. In other words, it refers to a condition in which an unborn baby is smaller than it should be because it is not growing at a normal rate inside the womb. The three categories are normal intrauterine growth (AGA, or appropriate for gestational age), subnormal growth (SGA, or small for gestational age) or supranormal growth (LGA, or large for gestational age) (Lubchenco et al., 1966).

  Since MUAC is correlated with pre-pregnancy weight, it may be useful for identifying pregnant women at risk of IUGR, especially where scales are not available (WHO, 1995). Studies of Kalanda et al. (2006b), Sebayang et al. (2012) and Verhoeff et al. (2001) have shown a strong association of maternal MUAC and the risk of occurrence of IUGR in babies.

- *Preterm labour/delivery:* It refers to the birth of a baby at fewer than 37 weeks gestational age. Maternal MUAC is also seen to a good screening tool for preterm labour/delivery as depicted by the studies of Kalanda et al. (2006b), Sebayang et al. (2012) and Verhoeff et al. (2001). Study of Feresu et al. (2004) revealed that mother's increasing mid-arm circumference reduced the risk of preterm delivery.

- *Birth asphyxia*: It refers to a medical condition resulting from decreased or discontinued supply of oxygen to a newborn infant before, during or just after the birth. Study of Lee et al. (2009) revealed that mothers with mid-upper arm circumference smaller than 21.5 cm carried a higher risk of delivering an infant with birth asphyxia compared with those with arm circumference greater than 23 cm (adjusted RR: 1.5; 95% CI: 1.1- 2.0).

Maternal and infant mortality

A question might arise as to whether low values of maternal MUAC indicate maternal and infant mortality? The answer might seem to be yes as in a large prospective study in Nepal amongst almost 26,000 pregnancies, it was demonstrated that a MUAC of approximately 21-22 cm increased risk of maternal mortality (Christian et al., 2008). Additionally, studies by SUMMIT (2008) has revealed that there could be infant death whose mother had a MUAC of <23.5 cm.

Post-partum MUAC

Studies on changes in maternal MUAC after childbirth i.e. post-partum MUAC are conducted by various studies (Katz et al., 2010; Mbofung and Atinmo, 1985; Rah et al., 2010). It was unveiled that women lose MUAC from pregnancy through postpartum. Besides this, the risk of low MUAC increased with decreased maternal age (Katz et al., 2010). Studies by Mbofung and Atinmo (1985) revealed that arm circumference tend to decrease with increase in period of lactation. The findings of Rah et al. (2008) indicate it is more likely that the loss of MUAC in adolescents occurred during lactation.

Problems regarding the unavailability of appropriate maternal MUAC cut-offs

No universally accepted cut-offs of maternal MUAC in assessing nutritional status of pregnant women and their associated pregnancy outcomes have been developed till date. Various MUAC cut-offs are being used in assessing maternal nutritional status in different countries, e.g., <23.0 cm (Altena and Voorhoeve, 1996 : Indonesia), ≤23 cm (Jayatissa et al., 2006 : Sri Lanka); in predicting the risk of delivering LBW babies e.g., ≤23.5 cm (Lechtig, 1988: Guatemala), <27.6 cm (Rollins et al., 2007: South Africa), <22 cm (Ojha and Malla, 2007: Nepal and Sen et al., 2010b: India), <23 cm (Assefa et al., 2012: Ethiopia and Sebayang et al., 2012: Indonesia); in predicting the risk of IUGR e.g., <23 cm (Kalanda et al., 2006b: Malawi and Verhoeff et al., 2001: Malawi); <23.5 cm (Sebayang et al., 2012: Indonesia); in

predicting the risk of preterm delivery/ labour e.g., <23 cm (Kalanda et al., 2006b: Malawi; Sebayang et al., 2012: Indonesia; Verhoeff et al., 2001: Malawi). Hence, there is an urgent need to determine appropriate and universally accepted reference values and cut-off points of maternal MUAC. Studies are yet to be conducted to address the issues of lower pregnancy outcomes and reproductive performance and also increased morbidity among pregnant individuals who are below the specific cut-off points (Sen et al., 2010a). Moreover, genetic and ethnic differences in MUAC have not been sufficiently studied to determine whether a single cut-off point for MUAC could be used for all groups of individuals (Sen et al., 2010a), especially pregnant women.

Maternal MUAC and other health disorders

Apart from being an indicator of nutritional status of pregnant women and a screening tool for associated pregnancy outcomes, maternal MUAC also serves to prove as a better indicator of other health disorders.

- *Maternal obesity and related complications*: This refers to obesity (often including being overweight) of a woman during pregnancy. Maternal obesity increases the risk of a number of pregnancy complications, including pre-eclampsia, gestational diabetes mellitus, and others. Studies of Cooley et al. (2011), Stone et al. (1995) and White et al. (2016) has been conducted to establish an association of maternal MUAC and obesity and its associated pregnancy complications. Studies of Mwanri et al. (2014), Ramirez et al. (2014) and White et al. (2016) had revealed the association of high maternal MUAC and gestational diabetes mellitus. Studies of James et al. (2017), Mwanri et al. (2015), Oliveira et al. (2002), de Oliveira SM (1996) revealed a close association of maternal MUAC and the risk of high blood pressure among pregnant women as they usually experience changes in blood pressure as a side effect of the increase in blood volume that occurs to support the developing foetus.
- *Maternal anaemia*: Maternal anaemia is a ubiquitous pregnancy complication in developing countries (Zhang et al., 2009) which refers to a reduction in the number of circulating red blood cells or haemoglobin per unit of blood which can eventually be regarded as a major risk factor for unfavourable pregnancy outcomes (Xing et al., 2009). Studies of Charles et al. (2010), Verhoeff et al.

(1999), etc have shown that pregnant women with MUAC less than 25 cm and <23 cm (in secundigravidae) respectively are more likely to be anaemic.

- *HIV-infected pregnant women*: Increasingly, MUAC is also being used to assess nutritional status and determine eligibility for nutrition support among HIV-infected pregnant women who are eligible for antiretroviral therapy. In sub-Saharan Africa, studies have established a link between HIV-infection and maternal wasting (mid-upper arm circumference <22 cm) in pregnant women (Villamor et al., 2005) as it was depicted among HIV-infected women in Tanzania who lost an average 1 cm (95% CI: 0.8, 1.1) MUAC between 12 and 38 weeks of gestation (Villamor et al., 2003). A notable significant declination in MUAC in HIV-infected, pregnant Malawians were observed during the exposure to famine season (Ramlal et al., 2013). However, patterns and predictors of maternal body composition throughout pregnancy among HIV-infected women remain poorly understood till date. In one study (Ramlal et al., 2013), CD4 count was found to be directly associated with MUAC in HIV-infected pregnant women as each 100 cells/μL increase in CD4 count was associated with an increase of 0.08 (95% CI: 0.01, 0.15) cm in MUAC.
- *T.B. and Malaria pregnant patients* : Study by Venkatesh et al. (2005) revealed that women (during pregnancy) with MUAC <22 cm were 2.4 times more likely to have an incident T.B. infection than women with MUAC ≥22 cm. In a malarious region of Malawi, Kalanda et al. (2006b) studied that maternal malnutrition having low MUAC <23 cm [AOR 1.9, 95% CI 1.0-3.7] is associated with disproportionate foetal growth.
- *Others*: Unlike above-stated areas of research which had wide-ranging studies till date, there are few other areas of research where studies using MUAC among pregnant women were conducted. Though those studies are very meagre in quantity, but it could be anticipated these studies would yield a great revelation in the forthcoming days. These included studies showing correlation of maternal MUAC with other variables. Study of Cooley et al. (2011) disclosed that maternal BMI is directly correlated with mid arm circumference (MAC) ($r = 0.836$) and estimates of BMI may be calculated from the simple equation BMI = MAC ± 2. Besides this, study by Fakier et al. (2017) revealed that MUAC correlates strongly with BMI ($r=0.92$) in pregnancy up to a gestation of 30

weeks. Furthermore, study of Zapata-López and Restrepo-Mesa (2013) revealed that maternal MUAC greater than 24cm is associated with a 94% reduction in low gestational weight (OR: 0.1; 95%CI: 0.0-0.2). A study by Chao et al. (2007) stated that total TEQ (Toxicity Equivalency Quantity) level in placentas was significantly correlated with mothers' arm circumference (r=0.22, p=0.043). Another study on obstetric complications in rural northwest Bangladesh by Sikdar et al. (2014) exhibited that MUAC <21.5 cm increased the risk of haemorrhage and sepsis. Low maternal MUAC was also found to be significantly associated with postpartum endometritis myometritis (Libombo et al. 1994). Study of Kumar et al. (2017) stated that maternal MUAC was significant predictors for bilirubin among pregnant women suffering from acute viral hepatitis. A hookworm infection was associated with a lower maternal MUAC was proved in a study of van Eijk et al. (2009).

Diagnostic test of accuracy of maternal MUAC

Apart from studies that assessed the strength of association between low MUAC and various measures of poor nutritional status and health outcomes, there were numerous studies (Elshibly and Schmalisch, 2008; Karim and Mascie-Taylor, 1997; Mohanty et al., 2006; Olukoya and Giwa-Osagie, 1991; Sen et al., 2010b) that had yielded information on the diagnostic test accuracy of specific MUAC cut-offs among pregnant women against various outcomes. Out of these studies, few have yielded AUC (Area Under Curve) statistics but no data on specificity and sensitivity for any maternal MUAC data e.g. study of Elshibly and Schmalisch (2008) determined optimal MUAC cut-off value of 27cm for prediction of birth of LBW babies [AUC with 95%CI: 0.542 (0.497 to 0.586); p-value: 0.351] while few studies have mentioned both information e.g., Sen et al. (2010b) determined 21.5cm MUAC cut-off value [AUC with 95% CI: 0.776 (0.721–0.831)] with 81.29% sensitivity and 72.09% specificity for the prediction of incidence of LBW babies.

Moreover, there were many studies (Karim and Mascie-Taylor, 1997; Mohanty et al., 2006) that had not mentioned AUC statistics but have presented the information on specificity and sensitivity. Hence, it could be suggested that there is a need to enhance studies on diagnostic test of accuracy of maternal MUAC with detailed information on AUC statistics, percentage of specificity and sensitivity with positive and negative predictive value.

MATERIAL AND METHODS

The review was conducted during the period from March 2018 to May 2018. Detailed information on studies of MUAC among pregnant women was obtained from various peer reviewed indexed journals abstracted in the "Pubmed" database (*http://www.ncbi.nlm.nih.gov/Pubmed/*). PubMed Central® (PMC) is a free full-text archive of biomedical and life sciences journal literature at the U.S. National Institutes of Health's National Library of Medicine (NIH/NLM). The following key words have been used for the literature search both independently and in combination:

1. Arm circumference in pregnant women
2. birth weight mid upper arm circumference
3. mid upper arm circumference and pregnancy outcomes
4. mid upper arm circumference and pregnancy
5. mid upper arm circumference and maternal infant mortality
6. mid upper arm circumference and anaemia pregnant population
7. mid upper arm circumference obesity pregnant
8. mid upper arm circumference pregnant HIV

Original articles, reviews, surveys, clinical trials and investigations pertinent to this theme were considered for this review. A thorough search in "Pubmed" database using the above keywords and an in-depth scrutiny over the references lists of those publications retrieved 2367 publications till May 2018 (**Figure 1**).

Out of 2367 publications retrieved, 1530 publications (both abstracts and full papers) were discarded as they included duplicate references or studies published in languages other than English. As a result, a total of 837 publications (abstracts and full papers) persisted for further analysis. Out of 837 publications, 651 publications (abstracts and full papers) were discarded as those publications lacked studies of MUAC among pregnant women. This stage of selection left out 186 publications for further analysis. It should be worth mentioning that 22 abstracts from the remaining 186 publications have mentioned neither their place of field study nor the country at which the study was conducted. As a result, we had to omit those studies while counting the number of studies done in various continents. Ultimately, 164 publications (both abstracts and full papers) were selected for our study.

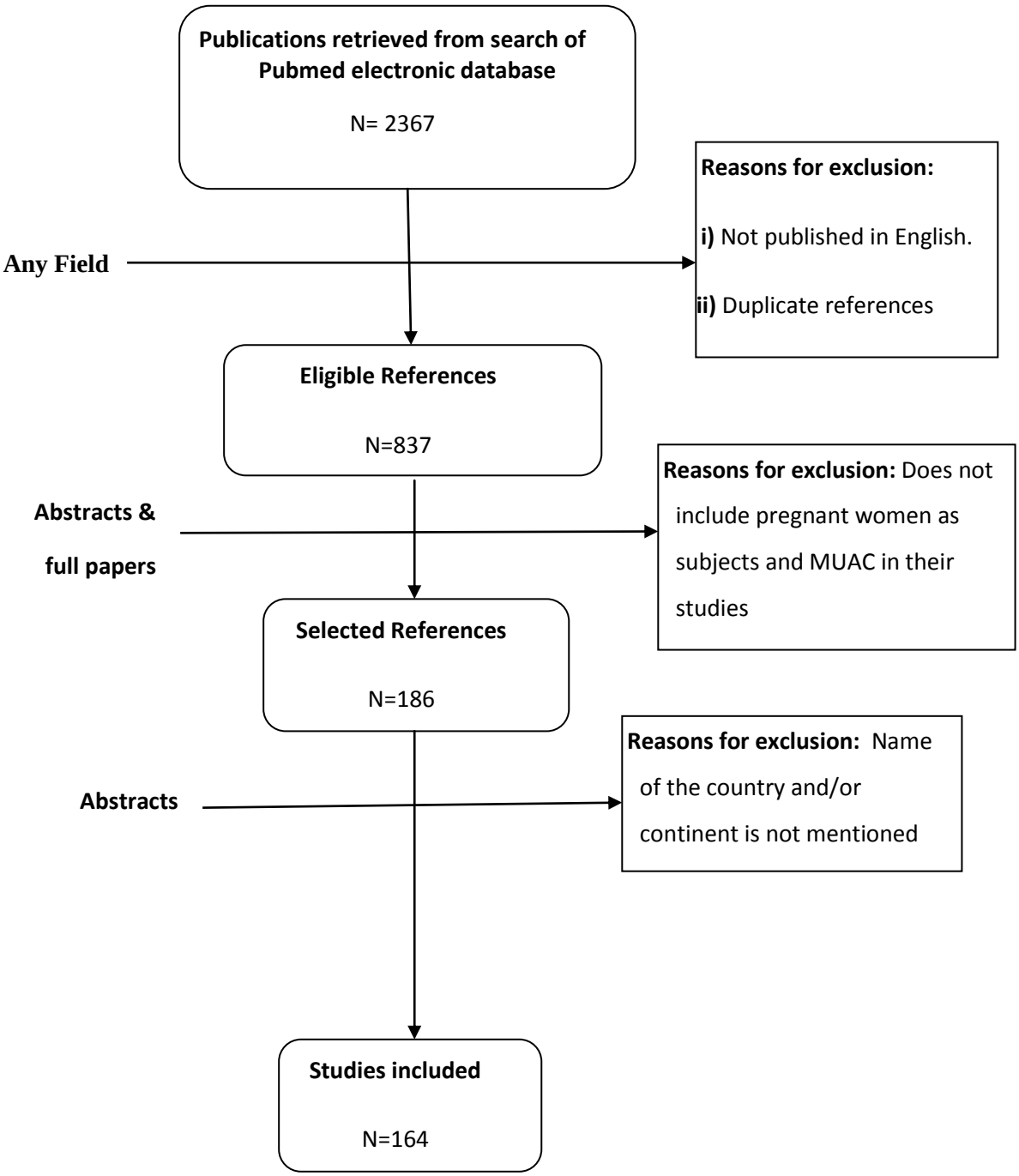
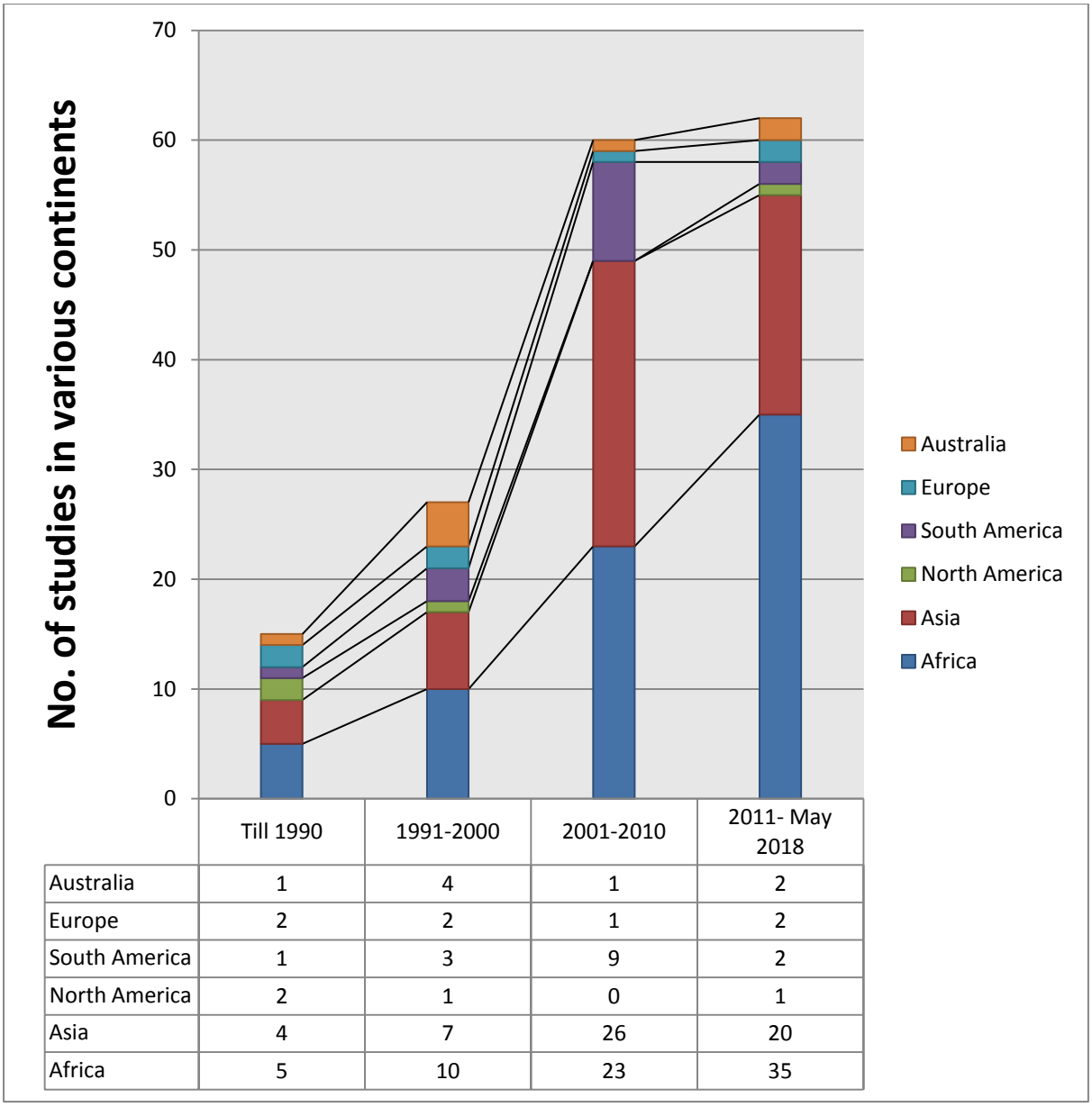


Figure 1: Flow chart displaying the summary of our literature search and study selection process

RESULTS AND DISCUSSION

The breakup in the number of publications done using MUAC among pregnant women in various continents from late 1980s to May 2018 is presented in **Figure 2**. It is quite obvious that there has been a quantum leap in the number of publications from late 1980s to May 2018.



	Till 1990	1991-2000	2001-2010	2011- May 2018
Australia	1	4	1	2
Europe	2	2	1	2
South America	1	3	9	2
North America	2	1	0	1
Asia	4	7	26	20
Africa	5	10	23	35

Figure 2: Stacked column chart showing number of publications using MUAC among pregnant women of various continents from late 1980s to May 2018

A steady elevation in the number of publications has been observed through this time period. The period till 1990 has witnessed very meagre number of publications, i.e. 15 (9.15%), the period 1991-2000 has witnessed comparatively more number of publications, i.e. 27 (16.46%), which is equivalent to double the number of publications done till 1990. The period 2001-2010 has gained more than double publications done in the period 1990-2000, i.e. 60 (36.59%). Finally, the uncompleted decade i.e. the short phase of time from 2011-May 2018 has witnessed 62 publications (37.80%) which is more or less equal to number of publications done in the previous decade (2001-2010).

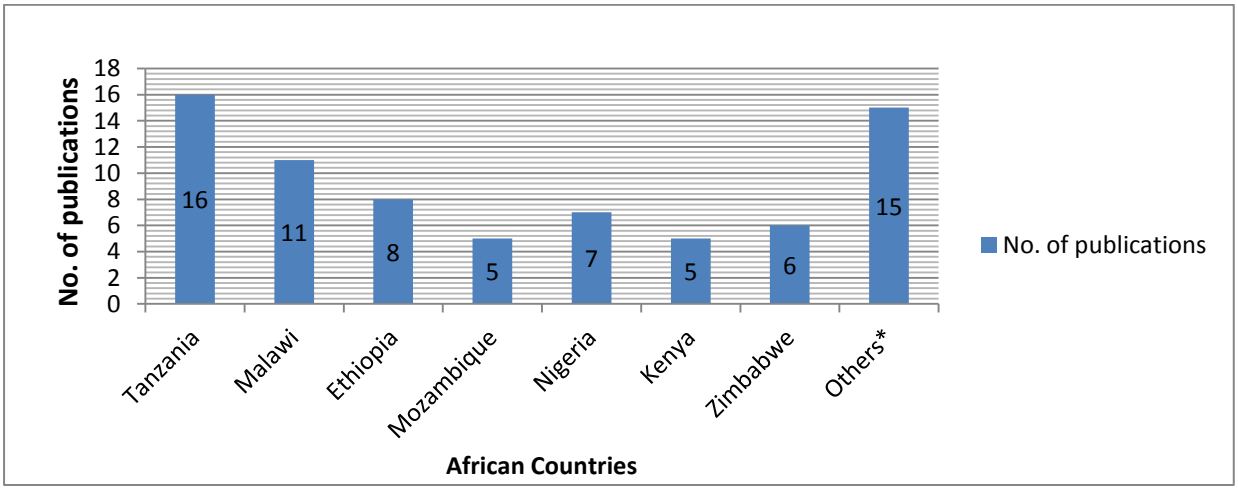
Thus, it could be inferred that there has been giant strides in the number of publications from late 1980s to May 2018. The short period 2011-May 2018 gained utmost number of publications followed by the period of 2001-2010, followed by the period of 1991-2000 and finally the period before 1990. The sole reason behind this situation is the fact that being an easy, non-invasive and inexpensive technique, MUAC serves to be one of the best methods in assessing the nutritional status of pregnant women and its associated pregnancy outcomes. Hence, it may be conjectured that the forthcoming years will witness a huge elevation in the number of publications conducted using MUAC among pregnant women.

From the stacked column chart displayed in **figure 2**, it can be observed that Africa has the highest number of studies (total 73 studies) which comprises of 44.51% of the total publications. Asia has the second highest number of publications (total 57 studies) comprising of 34.76% of the total publications. Other continents like South America (15 studies, 9.15%), Australia (8 studies, 4.88%), Europe (7 studies, 4.26%) and North America (4 studies, 2.44%) contributed scanty number of publications. A close observation through the stacked column chart (**Figure 2**) unveiled that African continent has unceasing elevation in the number of studies of MUAC among pregnant women through the four time periods with 5 studies till 1990, 10 studies during 1990-2000, 23 studies during 2001-2010 and 35 studies during 2011- May 2018. Scanning through the column depicting Asia reveals that this continent also follows the same trail i.e., the number of studies keeps on proliferating with each decade with 4 studies till 1990, 7 studies during 1991-2000, 26 studies during 2001-2010 and 20 studies during 2011-May 2018. Thus, both of these continents prefer maternal MUAC in assessing nutritional and anthropometric status, in determining other health disorders and pregnancy outcomes. One of the reasons behind this situation could be the necessity to reduce the maternal and infant mortality rate as well as morbidity rate in these two continents. According to UNICEF data, these two continents i.e. Africa (especially sub-Saharan Africa) and Asia (especially South Asia) account for 88 per cent of maternal deaths worldwide. Additionally, being an easy and inexpensive technique, study using maternal MUAC serves to be the best technique in these developing and underdeveloped countries.

It can also be viewed that continents like South America, Australia, North America and Europe have scarce publications on the study of MUAC among pregnant women compared to Africa and Asia (**Figure 2**). Our literature search in "Pubmed" database has revealed that these continents preferred other methods to assess nutritional status of pregnant women. For example, Europe has maximum number of studies on dietary intake method to assess

nutritional status of pregnant women and its associated pregnancy outcome. Similarly, Australia, South America and North America assess nutritional status and other health disorders of pregnant women and its associated pregnancy outcomes by studying dietary intake, effects of probiotics and other dietary supplements. They also preferred other anthropometric techniques like skinfold thickness, pre-pregnancy weight, height, etc. for their study. Moreover, biochemical and clinical techniques were also observed in most of their studies.

Figures 3 and **4** display the number of studies conducted in different countries of African and Asian continents respectively. In the African continent (out of total 73 studies), maximum number of studies using MUAC on pregnant women were done in Tanzania (16 studies) followed by Malawi (11 studies), Ethiopia (8 studies), Nigeria (7 studies), Zimbabwe

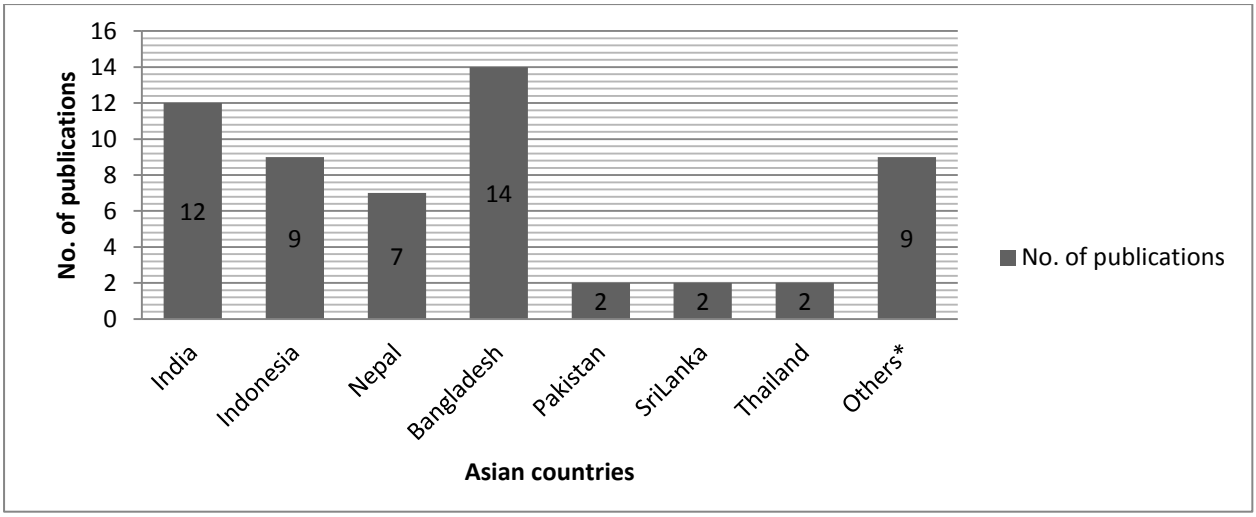


*others included those countries that had scarce publications on this issue

Figure 3: Column chart displaying the number of studies conducted in African continent

(6 studies), Mozambique (5 studies), Kenya (5 studies) and other countries like Gambia, Ghana, Guinea-Bissau, Niger, Sudan, Zambia, Uganda contributed 15 studies *in toto* (**Figure 3**). The known cause for the highest number of studies in these countries is that women from these regions are disproportionally at risk of maternal death and health disorders. Moreover, these sub-Saharan African regions also suffer from high "under 5 mortality" incidence.

On concentrating our focus on studies in Asian continent (total 57 studies), it could be clearly affirmed that maximum number of studies of MUAC among pregnant women has



*others included those countries that had scarce publication on this issue

Figure 4: Column chart displaying the number of studies conducted in Asian continent

been bestowed by Bangladesh (14 studies), India (12 studies), Indonesia (9 studies) and Nepal (7 studies) (**Figure 4)**. The achievement of higher number of studies in these countries is due to its high infant and maternal mortality rates (WHO, UNICEF, UNFPA, World Bank, 2015a; 2015b). Countries like Pakistan (2 studies), Sri Lanka (2 studies), Thailand (2 studies) and others like Afghanistan, Taiwan, Burma, Vietnam, Iran, Iraq, Cambodia (contributing 9 studies *in toto*) had also conducted their study on this issue (**Figure 4**).

The number of studies done using MUAC in different areas of research among pregnant women is summarized in Table 1 where it can be clearly observed that a wide range of

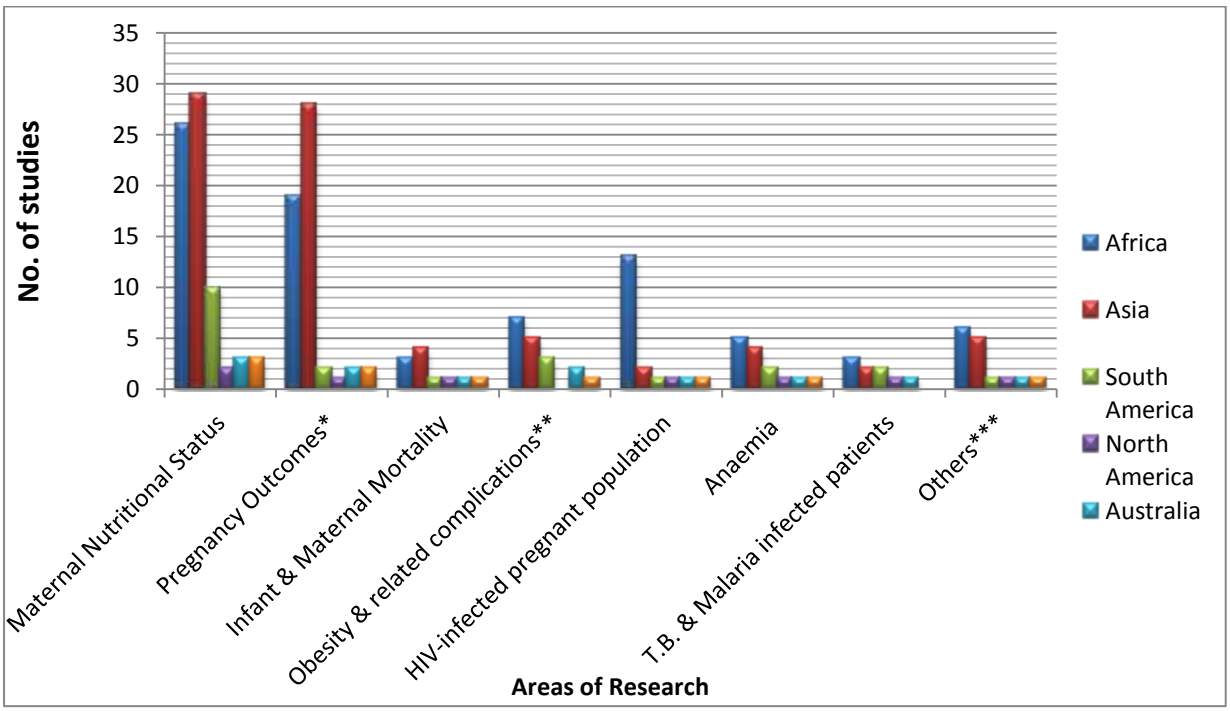
Table 1: Number of publications done using MUAC among pregnant women in different areas of research

Area of research	***No. of publications***
Maternal nutritional status	73
Pregnancy outcomes	54
Infant and maternal mortality	11
Obesity and related complications	18
HIV-infected pregnant population	19
Anaemia	14
T.B. and malaria infected patients	9
Others	15

*Many papers have been published in more than one research area

studies were conducted on the assessment of (maternal) nutritional status of pregnant women using maternal MUAC (73 studies). This is followed by studies based on pregnancy outcomes like LBW babies, IUGR, birth asphyxia and preterm delivery using maternal MUAC (54 studies), maternal obesity and related complications (18 studies), infant and maternal mortality (11 studies). Studies conducted solely in some specified group of population like HIV-infected pregnant population (19 studies), T.B. and malaria infected patients (9 studies) and pregnant women suffering from anaemia (14 studies). All these studies were conducted with a sole motive to reduce maternal and infant mortality and morbidity rate worldwide. According to WHO (2018), maternal mortality worldwide dropped by about 44% between 1990 and 2015. Also, the infant mortality rate has decreased globally from an estimated rate of 64.8 deaths per 1000 live births in 1990 to 30.5 deaths per 1000 live births in 2016, as stated by WHO Global Health Observatory (GHO) data.

Figure 5 displays the number of studies done using maternal MUAC conducted in various continents. Studies on maternal nutritional status are highest in both Asia and Africa



*includes LBW, IUGR, preterm delivery, etc.

**includes high blood pressure, hypertension, preeclampsia, etc

***includes less than 3 studies in each research area

Figure 5: Clustered column chart displaying areas of research using maternal MUAC among various continents

followed by South America and others. This is equally important for both maternal and infant health as both are closely linked. Studies on pregnancy outcomes like LBW, IUGR, preterm delivery and birth asphyxia based on its association with maternal MUAC is seen to be highest in Asia where incidence of LBW babies and SGA babies is relatively higher than Africa (Lee et al., 2013) which occupies the second position in our analysis. Asia and Africa occupies the first and second positions respectively in conducting studies on association of maternal MUAC with maternal and infant mortality. On the other hand, other continents have insufficient number of studies on this issue. This occurred as maternal mortality rates are very high in Asia and Africa (Prakash et al., 1991) compared to other continents. Similar is the case of maternal obesity and related complications.

Number of studies on HIV-infected pregnant population is seen highest in Africa as Sub-Saharan Africa remains the most heavily affected region of the world, accounting for approximately two thirds of all incident and prevalent HIV infections and three quarters of all AIDS deaths (Vitoria et al., 2009). Number of studies on pregnant women suffering from anaemia is also seen to be higher in African and Asian countries than other continents owing to the fact of being its high prevalence in these two continents. Africa and Asia occupy more or less similar position in conducting studies on T.B. and malaria infected pregnant women as because T.B. and malaria are common infectious causes of death worldwide, especially in Asia and sub-Saharan Africa (Vitoria et al., 2009). Studies using maternal MUAC on other areas of research were also conducted more in Africa and Asia continent compared to other continents.

LIMITATION OF THE STUDY

This study had few limitations: (1) The review has attempted to present the approximate number of publications in the “Pubmed” database done using MUAC among pregnant women and not exact number of publications. (2) Though this literature review examined articles published as studies of not only adult pregnant women but also pregnant adolescents who may have differences in physiology and anthropometry compared with their adult peers. Additionally, the pregnant women in some of the studies have received tertiary care while those of other studies might not. (3) Studies included both longitudinal as well as cross-sectional types. (4) There is likely more data in the grey literature, but as these are not peer-reviewed, they were not included while abstracts of some of them like that of Lechtig (1988) have been studied from databases other than “Pubmed”. (5) This review includes

many significant publications, some of which are discussed, have not been included in the "Pubmed" database but these publications had been provided to understand the application of MUAC among pregnant women in a better way.

CONCLUSION

Presently, there is no data available regarding universally accepted MUAC cut-off points that would aid us in concluding whether the pregnant woman falls under the category of being malnourished or not. Neither we have categories for maternal MUAC that indicate high or relatively even higher risks for adverse outcomes and/or occurrence of any other sorts of health disorders. Studies using MUAC among pregnant women should be encouraged in highly-populated developing and underdeveloped regions like Asia and Africa.

Pregnant women are a very important section of our society as they are not only valuable citizens of this generation but are a source of our next generation. Several factors such as socio-economic status, environment, attitude towards female children and adolescent girls, poor prenatal care, ignorance with regard to nutritional requirement, hygiene and illness are responsible for present sub-optimal nutritional status of pregnant women. Poor nutrition before birth is carried into adult life and this event can span into generations. Investing in nutrition throughout the life-cycle will have both short-term as well as long-term benefits of economic and social significance. It is imperative to know the baseline nutritional status of pregnant women in a community for planning appropriate interventions. Studying the nutritional status of pregnant women will help to plan strategies for combating macro- and micro- deficiencies of future citizens as only a healthy pregnancy will help to yield to a healthy birth.

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