Sexual & Reproductive Healthcare 20 (2019) 60–65

Contents lists available at ScienceDirect

Sexual & Reproductive Healthcare

journal homepage: www.elsevier.com/locate/srhc

Associations of pre-pregnancy body mass index, middle-upper arm circumference, and gestational weight gain

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ARTICLE INFO

Keywords:
Pre-pregnancy body mass index
Middle-upper arm circumference
Gestational weight gain
Nutritional status
Pregnant women
Malaysia

ABSTRACT

Objectives: An optimal gestational weight gain is essential for maternal health and to reduce adverse birth outcomes. Current guidelines to monitor gestational weight gain are based on pre-pregnancy body mass index (BMI). However, middle-upper arm circumference (MUAC) is increasingly used as an alternative nutritional status measure for pregnant women. Hence, this study aimed to determine associations of MUAC and pre-pregnancy BMI with gestational weight gain rate among Malaysian pregnant women.
Study design: A cross-sectional study was conducted among 444 pregnant women (≥20 weeks gestation).
Main outcomes measures: Women completed questionnaires on sociodemographic data, maternal characteristics and pre-pregnancy weight. Height, current weight and MUAC were measured at study visit (from 1st February 2016 to 31st January 2017).
Results: About a third (34.24%) of pregnant women were overweight or obese prior to pregnancy. MUAC was inversely associated with an inadequate rate of gestational weight gain (OR = 0.77; 95% CI: 0.68, 0.87) as compared to normal gestational weight gain. In contrast, a higher MUAC was associated with a higher odds ratio (OR = 1.28; 95% CI: 1.11, 1.49) of having excessive rate of gestational weight. No associations were found for pre-pregnancy BMI categories for gestational weight gain rate.
Conclusion: Our findings revealed that women with low MUAC were more likely to have an inadequate gestational weight gain rate during pregnancy whereas higher MUAC was associated with an excessive gestational weight gain rate. MUAC may be a useful indicator of nutritional status associated with GWG. Routine measurement of MUAC in pregnant women may help health professionals, particularly in middle-income countries, to counsel women about gestational weight gain.

Introduction

Gestational weight gain (GWG) serves as one predictor for fetal growth, development and maternal health [1]. Optimal GWG is imperative to reduce risk of adverse maternal and infant outcomes. GWG outside the recommended level has numerous negative implications. Inadequate GWG is associated with small for gestational age infants, intrauterine fetal growth restriction, low birth weight and preterm delivery [2]. Excessive GWG during pregnancy is associated with large for gestational age infants, macrosomia, and caesarean delivery. Furthermore, women with excessive GWG have a higher risk for gestational diabetes, maternal hypertension, postpartum weight retention and subsequent maternal obesity later in life [3].

The Institute of Medicine (IOM) guidelines are most widely used to recommend optimal GWG based on pre-pregnancy BMI. BMI is a measure of body composition and body fatness [4]. Due to substantial evidence that Asians have increased risk for cardiovascular diseases at a lower BMI than Caucasians, World Health Organization (WHO) proposed a cutoff of BMI over 23 kg/m^2 as overweight for Asians [5], compared to 25 kg/m^2 cutoff used in Caucasians [6]. However, since the IOM GWG guidelines are based on pre-pregnancy BMI categories for Caucasians; its generalizability to Asians is questionable [7]. Despite BMI being the most commonly indicator at population level to identify under- and overnutrition, it relies heavily on reliable equipment and mathematical formulas [8] which may not be available in all settings.

Apart from BMI, middle-upper arm circumference (MUAC) is

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https://doi.org/10.1016/j.srhc.2019.03.002
Received 2 January 2019; Received in revised form 1 March 2019; Accepted 18 March 2019

increasingly used to assess nutritional status of pregnant women; both measures were shown to correlate strongly with one another [4]. As compared to BMI, MUAC is inexpensive and simple; it only requires a lightweight tape and no calculations are involved [9]. MUAC reflects maternal fat and protein reserves of the body whereby a low MUAC indicates wasted lean mass and malnutrition [10]. The usefulness of MUAC in assessing the nutritional status of pregnant women is well documented [11]. Low MUAC is a reflection of presently existing malnutrition and has been associated with adverse pregnancy outcomes such as low birth weight [11]. MUAC can also be used to identify obesity during pregnancy regardless of gestational age [4] and to predict faltering fetal growth [12].

Most studies evaluating associations of pre-pregnancy BMI and GWG are in high-income countries [13]. Studies on association of MUAC and GWG are generally lacking, especially in developing nations. Since GWG can affect pregnancy outcomes, exploring the influence of nutritional measures such as pre-pregnancy BMI and MUAC on GWG is vital particularly for middle-income countries like Malaysia. Therefore, this study aimed to determine associations of MUAC and pre-pregnancy BMI with GWG in Malaysian pregnant women. We hypothesized that greater pre-pregnancy BMI (nutritional status before pregnancy) and MUAC (nutritional status during pregnancy) were associated with increased risk of excessive GWG whereas lower pre-pregnancy BMI and MUAC were associated with increased risk of inadequate GWG among pregnant women.

Methods

This cross-sectional study was conducted between 1st February 2016 and 31st January 2017 in Selangor, Central Malaysia. A list of districts and its sub-districts in urban and rural areas of Selangor was obtained from the Department of Selangor Town and Country Planning [14]. In total, 45 urban and rural government antenatal clinics (Klinik Kesihatan Ibu dan Anak) were selected through stratified random sampling. The clinics offer free-of-charge services for pregnant women which include short interview with the nurse, urine test, blood pressure test, body weight measurement and consultation with in-house doctor. After first antenatal checkups, subsequent appointments were made monthly until the 28th week, where appointments were arranged fortnightly from 29th to 36th month and finally, weekly from 37th week of pregnancy until delivery.

Our target sample size was 434 women, based on 95% confidence level, 5% precision to detect the prevalence of 62.0% of women not achieving an optimal GWG [15], after taking into account of 20% of non-response rate [16]. Participants aged 19 to 40 years old, ≥20 weeks of gestation were recruited. Women with multiple pregnancies, disabilities, who were unable to understand English or Malay were excluded.

At study visit, participants completed questionnaires on their maternal age, ethnicity, marital status, education level, residential area, monthly household income, parity, gestational age and pre-pregnancy weight. MUAC measurement was taken midway between the olecranon of the elbow and acromion process of the shoulder of the non-dominant arm using non-stretchable measurement tape. MUAC was classified as undernourished (< 23 cm), normal (23 to 31 cm) and obese (> 31 cm) [4,9]. Current weight and height were measured using the Tanita SC330 scale and a stadiometer, respectively. Pre-pregnancy BMI was categorized based on standard international classification of weight status [6], and further categorized to underweight, normal weight and overweight/obese for the purpose of analysis. Rate of GWG was derived by subtracting pre-pregnancy weight from current weight at assessment point, before dividing it by current gestational week. Rate of GWG was further categorized as inadequate, normal or excessive [1].

Data analyses were conducted using IBM SPSS Statistics (Version 22.0, SPSS, Chicago, IL). Results were presented as mean (standard deviation) for continuous variables and frequency (percentage) for categorical variables. All descriptive statistics were presented as overall and according to GWG categories. Pearson chi-square identified the associations of pre-pregnancy BMI and MUAC category with GWG rate. Multinomial logistic regression was used to determine odds ratios and 95% confidence intervals for inadequate and excessive GWG associated with MUAC and pre-pregnancy BMI categories. Normal GWG rate was set as the reference category and this model was adjusted for maternal age, residential area, monthly household income and parity. Statistical significance was set at $p < 0.05$.

Research was conducted in accord with prevailing ethical principles. National Medical Research Registrar (NMRR)-15-1532-26422 and Medical Research Ethics Committee (KKM/NIHSEC/P15-1362) granted approval for the study. Consent for data collection from directors of health district offices and informed consent from participants were obtained prior to the study visit.

Results

In total, 498 eligible pregnant women was recruited. However, analysis was conducted for only 444 pregnant women due to incomplete data (54 participants) of pre-pregnancy BMI. According to sociodemographic data, most pregnant women were in third trimester, married, had low or middle household income and with at least secondary school education (Table 1). There was no significant association between sociodemographic characteristics of pregnant women with their GWG rate categories. About a third (34.24%) of pregnant women were overweight or obese before pregnancy (Fig. 1). However, there were still a portion of pregnant women that were underweight (14.41%). Unexpectedly, our study found that overweight/obese pregnant women categorized by pre-pregnancy BMI, had inadequate GWG rate (36.7%) as compared to excessive GWG rate (34.7%) (Fig. 2). On the other hand, almost half (47.8%) of obese pregnant women as categorized by MUAC had excessive GWG rate (Fig. 3)

When comparing between underweight women as categorized by pre-pregnancy BMI and undernourished women as categorized by MUAC, more undernourished women (88.5%) had inadequate GWG rate as compared to underweight women (74.6%) (Figs. 2 and 3). Furthermore, more women with normal MUAC had optimal GWG rate (25.3%) in comparison with women with normal weight as per pre-pregnancy BMI (20.9%).

After adjusting for confounders, our multinomial logistic regression model demonstrated that MUAC was inversely associated with the risk of inadequate GWG rate (OR = 0.77; 95% CI: 0.68, 0.87) as compared to normal GWG rate (Table 2). In contrast, a higher MUAC was associated with increased risk of having excessive GWG rate (OR = 1.28; 95% CI: 1.11, 1.49). No associations of pre-pregnancy BMI categories with inadequate or excessive GWG rate were found.

Discussion

In the current study, we used nutritional status measures before pregnancy (pre-pregnancy BMI, a self-reported data) and during pregnancy (MUAC, a measured data) to investigate their associations with rate of GWG. Approximately half of the women in the current study embarked on pregnancy with a suboptimal weight status (underweight or overweight/obese), which reflects the double burden malnutrition often present in middle-income countries [17].

We demonstrated that increased MUAC is associated with excessive GWG rate and low MUAC is associated with inadequate GWG rate, independent of pre-pregnancy BMI category. Currently, there is no standardized MUAC cut-off value to indicate women with malnourishment and obesity, however a range of < 23 cm and > 31 cm is often used [4,9]. It was shown in India that MUAC correlates well with GWG [18]. Additional energy intake and nutrients are needed during pregnancy to support adequate GWG for fetal and maternal tissues [19]. Particularly, protein is needed for building blocks of both structural and

Table 1
Maternal and socio-demographic characteristics overall and by GWG rate categories, n = 444.

Variables	Frequency (%)			
	Overall (n-444)	Inadequate GWG (n = 249)	Normal GWG (n = 100)	Excessive GWG (n = 95)
Age, (years)*	29.40 (4.99)	29.40 (5.16)	29.65 (4.54)	29.12 (5.05)
Gestational age at study visit, (weeks)*	30.59 (5.51)	30.04 (5.72)	31.96 (5.09)	30.57 (5.17)
Residential Area				
Urban	204 (45.95)	115 (25.90)	45 (10.14)	44 (9.91)
Rural	240 (54.05)	134 (30.18)	55 (12.39)	51 (11.49)
Parity				
0	172 (38.74)	98 (22.07)	34 (7.66)	40 (9.0)
1–2	129 (29.05)	70 (15.77)	35 (7.88)	24 (2.4)
≥3	143 (32.21)	81 (18.24)	31 (6.98)	31 (6.98)
Marital Status				
Married	439 (98.87)	246 (55.41)	99 (22.29)	94 (21.17)
Single/Widowed	5 (1.17)	3 (0.68)	1 (0.23)	1 (0.23)
Education level				
Primary School	19 (4.28)	15 (3.38)	0 (0.00)	4 (0.90)
Secondary School	201 (45.27)	111 (25.00)	44 (9.91)	46 (10.36)
Tertiary School	224 (50.45)	123 (27.70)	56 (12.61)	45 (10.14)
Monthly Household Income†				
Low (< USD612.45)	199 (44.82)	112 (25.23)	41 (9.23)	46 (10.36)
Middle (USD612.45–1,371.64)	187 (42.12)	106 (23.87)	43 (9.68)	38 (8.56)
High (≥USD1,371.65)	58 (13.06)	31 (6.98)	16 (3.60)	11 (2.48)

* Reported in Mean (SD).
† Based on the cut-off of 11th Malaysia Plan; RM = Ringgit Malaysia (1 USD = RM4.08).

functional components of cells; protein requirements are highest at second and third trimesters [20]. MUAC is useful during pregnancy to assess protein calorie malnutrition [21], whereas pre-pregnancy BMI may be limited as it is only a measure of overall adiposity [22]. Our findings suggest that sufficient protein intake, as reflected in MUAC, is needed for adequate energy to support healthy GWG, which may explain the observed association of lower MUAC with inadequate rate of GWG.

On the other hand, earlier study demonstrated that women who exceeded GWG recommendation had increased fatness reflected in their significantly larger MUAC than women who did not exceed GWG recommendation [23], in line with our findings. Despite increased caloric needs during pregnancy, the additional provision of energy should be balanced against percent of body fat to fat free mass [20]. Since the arm contains both subcutaneous fat and muscle, high MUAC mirrors increased in muscle mass, subcutaneous fat or both [10], explaining the association of high MUAC with increased risk of excessive rate of GWG in current study. We demonstrated that MUAC, a measure of nutritional status during pregnancy, is more strongly associated with GWG rate than pre-pregnancy BMI category, a measure of nutritional status before pregnancy. Currently, WHO Recommendations on Antenatal Care for a Positive Pregnancy Experience suggest the use of pre-pregnancy BMI for recommending optimal GWG, which is a common practice among health professionals [24]. Considering the increasing evidence of the associations of MUAC with GWG rate, MUAC may be useful for assessing the nutritional status of pregnant women to inform optimal GWG especially in low and middle-income nations, where malnutrition is highly prevalent.

Pre-pregnancy BMI was not associated with GWG rate in our study. Maternal weight gain consists of the growth of body fat mass, fat free mass, total body water, red blood cells mass, the fetus, placenta, amniotic fluid, and other products of conception [25]. BMI, however, is only a surrogate indicator of obesity and fat mass [22]. A well-nourished, undernourished or obese women can have high or low weight gain during pregnancy [26]. Previous study in a middle-income country, Argentina, demonstrated that no differences were observed in

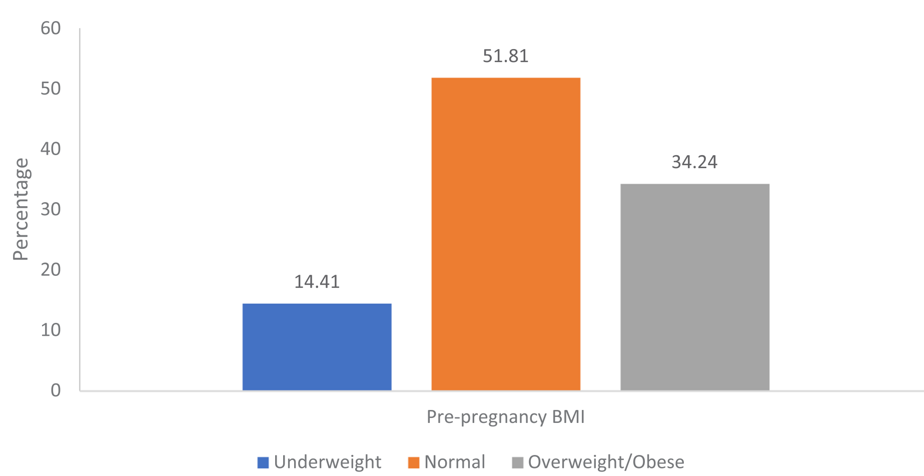

Fig. 1. Pre-pregnancy BMI of pregnant women (n = 444).

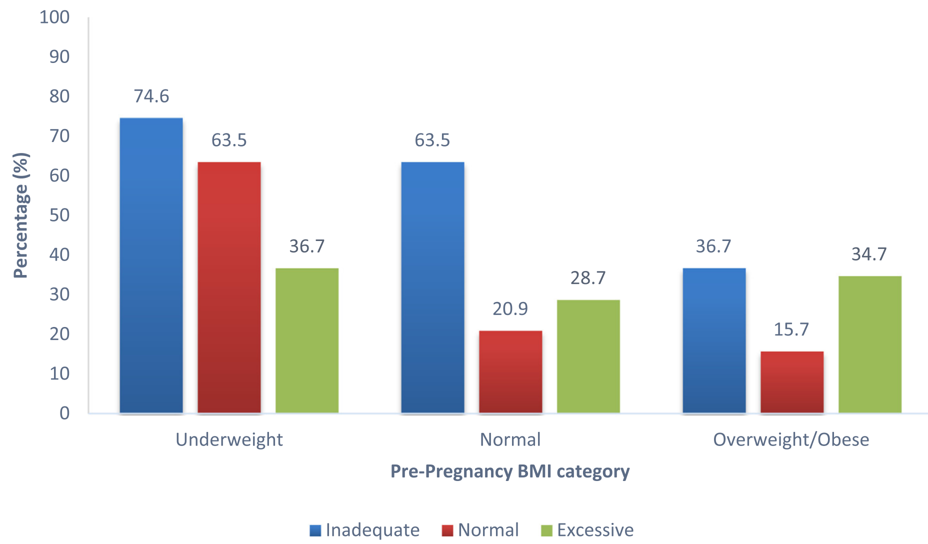

Fig. 2. GWG rate categories by pre-pregnancy BMI women (n = 444). Pearson Chi-square suggests that pre-pregnancy BMI and GWG are associated. Chi-square statistic = 39.9, df = 4, $p < 0.001$.

weight gain between underweight, normal or overweight women at start of pregnancy [27].

Another potential reason for the lack of association between pre-pregnancy BMI category and GWG rate in our study is the use of standard pre-pregnancy BMI categories. The use of IOM guidelines based on pre-pregnancy BMI among Asians is debatable. Studies in Korea [7] and Japan [28] demonstrated lower risks of adverse perinatal outcomes using Asians-specific pre-pregnancy BMI instead of Caucasians. Asians have different body composition and fat deposition than Caucasians [5,7]. IOM guidelines were not developed for Asians [1] however, they are being used widely since national guidelines based on evidence-based research are lacking. Furthermore, pre-pregnancy BMI in our study relied on memory, which may induce inaccuracy. Previously, it was shown that body weight is often under-reported [29]. Our findings add to the body of knowledge that the use of standard pre-pregnancy BMI categories to recommend rate of GWG may not be suitable for Asian populations.

This was a cross sectional study whereby all data and measurements were collected at one point in time. Future studies should assess GWG prospectively. GWG rate is only calculated at study visit and may not reflect GWG rate across the entire pregnancy including later pregnancy. Although pre-pregnancy weight is self-reported, this is a common practice in clinics whereby pre-pregnancy weight are often self-reported during first antenatal visit [30]. Another important limitation is the potential for reverse causation- it is possible that MUAC is the

Table 2
Associations of maternal characteristics with inadequate and excessive GWG rate.

	Inadequate GWG rate		Excessive GWG rate	
Variables	OR	95% CI	OR	95% CI
MUAC	0.77	0.68–0.87	1.28	1.11–1.49
Pre-pregnancy BMI				
Underweight	1.02	0.43–2.44	1.31	0.39–4.43
Overweight/Obese	1.79	0.88–3.65	0.63	0.25–1.57
Normal*	–	–	–	–

Multinomial regression adjusted for maternal age, residential area, household income and parity.
* Normal weight as reference category.

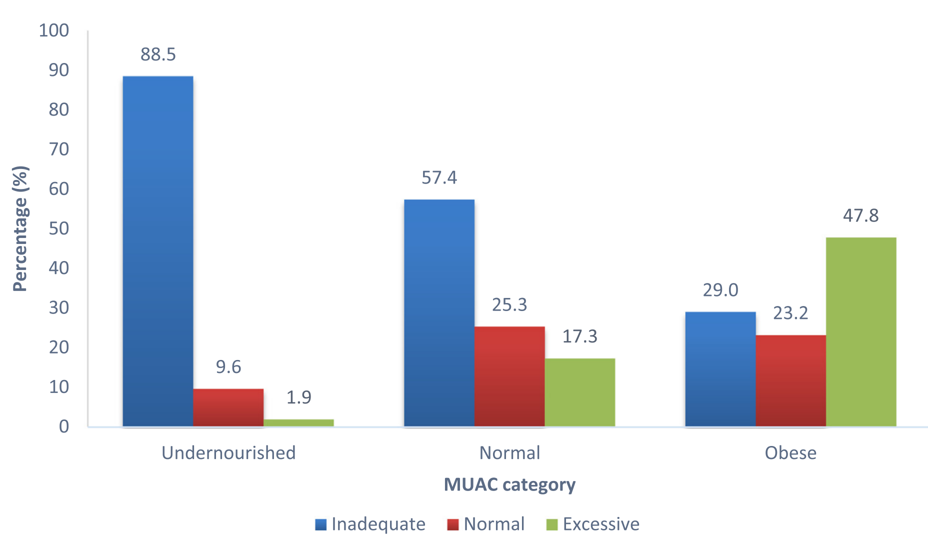

Fig. 3. GWG rate categories by MUAC category, (n = 444). Pearson Chi-square suggests that MUAC and GWG are associated. Chi-square statistic = 58.72, df = 4, p = < 0.001.

consequence of GWG, hence, pregnant women that gain excessively during pregnancy would have a bigger arm. However, MUAC is a measure of fat mass and fat-free mass such as the skeletal muscle, non-skeletal muscle, soft lean tissues, and skeleton, consisting of water, minerals, and protein [31] whereas GWG consists of maternal components (blood, extracellular liquid, tissues), placenta, and fetal tissues aside from just fat reserves [19]. It is possible that protein and energy reflected in MUAC allows for the growth needed for maternal and fetal tissues during pregnancy. Furthermore, this study was conducted in one state in Malaysia, as such, generalisation to the country may be limited. However, Selangor is a state in Malaysia with rapid urbanization and development, yet Selangor still comprises of rural areas as well and this potentially mimics Malaysia's urban-rural demographic [32]. Moreover, our study provides a basis to further explore MUAC, nutritional status, and GWG as it is the first known study to compare associations of nutritional status measures taken before and during pregnancy with rate of GWG among women in middle-income countries like Malaysia. Our sample was also representative of pregnant women with different sociodemographic backgrounds from both urban and rural areas. As a recommendation, future studies should explore both pre-pregnancy BMI and MUAC as nutritional status measures to monitor GWG rate in different populations across countries.

Conclusions

Our findings revealed that women in our study population with low MUAC was more likely to gain inadequate GWG rate during pregnancy. Higher MUAC was associated with excessive GWG rate. No associations of pre-pregnancy BMI with GWG rate were found. MUAC may be a useful measure to recommend GWG, compared to pre-pregnancy BMI. Strategies to promote optimal nutritional status and GWG during pregnancy are crucial. This study is in line with the National Plan of Action for Nutrition of Malaysia to promote maternal and infant nutrition with at least 50% of pregnant women achieving the recommended GWG [15] and the Sustainable Development Goals to enhance maternal nutrition and infant health among pregnant women in middle-income countries [33]. Evidence from our study suggests that MUAC may be an additional nutritional status indicator that should be considered when counselling pregnant women about their recommended rate of GWG. We suggest health professionals in antenatal clinics to conduct periodic assessment of MUAC from first to third trimester to monitor GWG rate closely. The later may be ideal to measure pregnant women nutritional status especially in low- and middle-income countries.

Declaration of interest

All authors declare that they have no conflicts of interest.

Source of funding

This work was supported by Centre of Excellence for Research, Value Innovation and Entrepreneurship (CERVIE) UCSI University (Proj-In-FAS-036). Funding body was not involved in the research study.

Acknowledgement

We would like to extend gratitude to Centre of Excellence for Research, Value Innovation and Entrepreneurship (CERVIE) UCSI University (Proj-In-FAS-036) for providing funding. Our heartfelt thanks to staffs of Ministry of Health for supporting this research and providing adequate assistance during study period. We are also grateful to all pregnant women who participated in the study.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.srhc.2019.03.002.

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