Maternal Mid-upper Arm Circumference as a Predictor of Low Birth Weight Outcome among Newborn Deliveries of Adolescents in a Tertiary Level Hospital

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ABSTRACT

Background. Maternal malnutrition is a major cause of low birth weight (LBW) newborn outcome especially among adolescent mothers. It is one of the key drivers of child stunting and initiates the vicious cycle of intergenerational malnutrition. The body mass index prior to pregnancy or at the initial trimester is currently being used to establish the desired weight gain throughout pregnancy. However, Filipino adolescents often delay their first antenatal visit at a later stage of pregnancy. Without a baseline weight, the establishment of appropriate weight gain and nutritional status is often challenging. Mid-upper arm circumference (MUAC) was proven to be a good proxy measure of acute malnutrition, however, there was no global consensus on what MUAC cut-off point to use to identify pregnant adolescents at risk for delivering LBW babies. Finding the optimal cut-off could facilitate early identification and intervention of pregnant adolescents who are nutritionally at risk and could eventually break the cycle of intergenerational malnutrition.

Objectives. The study aims to determine the association of maternal MUAC and the birth weight outcomes among newborn deliveries of adolescents in a tertiary hospital for a period of six months and to identify the optimal maternal MUAC cut-off point that can be used to predict low birth weight outcome among newborn deliveries of adolescents in a tertiary hospital.

Methods. A cross-sectional study was conducted among adolescents ages 10 to 19 years who delivered babies in a tertiary hospital in the Philippines for a period of six months. Maternal MUAC and LBW outcome were documented, and their association was determined using a logistic regression analysis. To measure diagnostic accuracy, the sensitivity, specificity, and the area under the curve were taken for each MUAC point. A receiver operating characteristic (ROC) curve was used to aid the MUAC cut-off determination.

Results. Out of 237 newborn deliveries, 35% were noted with low birth weight while 65% had normal birth weight. Most of the mothers were in their late adolescence at 78%. The crude association for the MUAC cut-offs ≤23.00 cm, ≤23.50 cm, and ≤24.00 cm and LBW showed a significant value of 2.19, 2.25, and 2.39 at 95% CI, respectively. However, it is only the cut-off ≤24.00 cm that showed significant results for adjusted association by the logistic regression analysis.

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The MUAC cut-off ≤24.00 cm also showed a better trade-off value between the sensitivity and specificity. Furthermore, the optimal maternal MUAC measurement that predicts LBW newborn outcome points to ≤24.00 cm cut-off based on the ROC curve.

Conclusion. This study shows that the maternal MUAC is predictive of LBW outcome among adolescent deliveries. A MUAC cut-off of ≤24.00 cm was superior to lower cut-offs studied. The pregnant adolescents might need a higher MUAC cut-off than adults to allow timely intervention and prevention of poor neonatal outcomes. By doing this simple screening test, suspected pregnant adolescents can be easily identified and referred for further confirmatory testing

Keywords: mid-upper arm circumference, low birth weight outcome, adolescent pregnancy

INTRODUCTION

Undernutrition remains to be a problem in the Philippines affecting not only small children but also the women of reproductive age group. The prevalence of nutritionally-at-risk pregnant women or women at risk of having poor neonatal outcomes remains high at 20.1%, with pregnant teenage girls having the highest prevalence at 36.6% based on the latest National Nutrition Survey.[1]

Pregnant adolescents are particularly at high risk for dietary inadequacy. The mean one-day intake of an average adolescent girl based on the NNS was only 1735 kcal per day, however, the recommended energy requirement based on the Philippine Dietary Reference Intake (PDRI) was as high as 2225 kcal. This translates to about 490 kcal of energy gap. In fact, only 10.6% of adolescents were able to meet the recommended energy intake based on the latest NNS survey. The energy gap is even higher among pregnant women which is about 607 kcal/day.[2]

According to the National Demographic and Health Survey (NDHS) 2017, about 17.2% of pregnant adolescents delivered low birth weight babies.[3] To address this underlying cause of undernutrition along the life cycle, the National Nutrition Council (NNC) and the Department of Health launched the Philippine Plan of Action for Nutrition (PPAN) 2017-2022 which emphasizes the importance of maternal and child nutrition.[4] The PPAN has included dietary supplementation in one of its Nutrition Specific programs; however, the criteria for admission among pregnant adolescents were not specified in the program and remained unclear.

Some programs use the normal body mass index (BMI) cut-off value of 18.5 kg/m^2 for adult women, assuming it applies to pregnant adolescents. The Philippine Obstetric Gynecologic Society (POGS) recommended to compute for the BMI of pregnant women at the initial visit following the BMI cut-off points for the Asian population then the individualized weight gain should be based on the pre-pregnancy weight as established by the Institute of Medicine Pregnancy Weight Guidelines.[5] However, about 39.2% of Filipino adolescents come for check-ups at a later stage of pregnancy without a baseline weight, hence, making the establishment of appropriate weight gain difficult using the BMI.[1]

Mid-upper arm Circumference (MUAC) is another option mentioned by several studies as an important alternative for BMI.[6] MUAC is a measurement of the circumference of the upper arm at the midpoint from the tip of the shoulder to the tip of the elbow (olecranon and acromion process) using a non-stretchable tape.[7,8] Changes in MUAC can reflect a change either in muscle mass, subcutaneous fat, or both since the arm contains both subcutaneous fat and muscle. However, in marginalized settings, where individuals usually have thinner fat underneath their skin, differences in MUAC are more likely to reflect changes in muscle mass.[7] Previous studies have shown that MUAC is a better choice to measure maternal muscle and fat reserve and may be used to screen women at risk for unfavorable pregnancy outcomes in situations where pre-pregnancy weight is not available or when the pregnant comes in at a later stage of pregnancy for their first prenatal check-up.[9]

A systematic review done among pregnant adolescents and adult women showed steady associations between low MUAC and having a low birth weight baby.[6] Hence, MUAC was the preferred choice of anthropometric measurement for pregnant women because of its strong relationship with LBW; it has a narrow range of cut-off points; the measurement is very simple which can be done even in poor community or humanitarian settings, and it does not require initial data on pre-pregnancy weight.[9]

However, despite its advantages, there is still no global consensus on the appropriate MUAC cut-off measures specific to pregnant adolescents, and neither does our country have existing guidelines on the MUAC cut-off points for this age group. No local studies have explored the relationship between malnutrition using MUAC and pregnancy outcomes among adolescents. Hence, this study would like to determine the MUAC measurement that corresponds to LBW outcome, which could also be the basis for establishing our local MUAC cut-off points that will be needed to identify and prioritize nutritionally- at-risk pregnant adolescents.

MATERIALS AND METHODS

Study Design

This is a cross-sectional study conducted among pregnant adolescents who gave birth at the University of the Philippines - Philippine General Hospital (UP-PGH) from June 1, 2019, to Nov 30, 2019.

Study Procedure

All adolescents aged 10 to 19 admitted to UP-PGH for delivery from June 1 to November 30, 2019, who gave their consent or assent and with parental consent depending on the age of the patient were included in the study. Those with chronic medical conditions like heart disease, HIV, or tuberculosis, those with multiple pregnancies such as twin gestation, mothers who delivered babies with congenital abnormalities, and those with incomplete data were excluded from the study. The participants were then asked to answer a standardized questionnaire form for the demographic profile. Maternal anthropometric measurements were taken within 72 hours postpartum while the participants were still admitted to the ward.

Mid-upper arm circumference (MUAC) was measured using a non-stretchable MUAC tape acquired from the Department of Health. Using the left arm, the distance between the olecranon process and acromion was located. The midpoint between these two points was marked with the arm hanging straight down. MUAC tape was then wrapped around the arm at the midpoint mark then measurement was reported up to the nearest 1 mm. The measurement was obtained twice then the average was recorded. The height and weight were taken using a standardized standing scale available in the ward. The gestational age and neonatal birthweight outcomes were collected from the patient's chart at the NICU and OB wards by the primary investigator. Low birth weight was defined by the WHO as weight less than 2500 grams.

The clinical information of the mothers as well as the outcome of the newborn babies were hidden from the research assistant who performed the MUAC measurements. The primary investigator on the other hand who took the newborn weight outcome does not have access to the result of mothers' MUAC measurements.

Sample Size

To calculate the minimum sample size for this study, G*Power 3.1.9.2 (Heinrich-Heine- Universität Düsseldorf) and the power.roc.test command of the pROC package in R v.3.6.2 (R Foundation for Statistical Computing) was used. Table 1 summarizes the information and assumptions required for the sample size calculation according to the literature. The level of significance (α) and power of the study (1 - β) were set to 0.05 and 0.80, respectively.

Based on the formula, the minimum sample size for this study was the highest sample size obtained from the two objectives, which is 167. However, the total enumeration of all mothers was done during the actual data collection, except during holidays and natural disasters so the sample size was not followed. There was no non-response rate because of this reason. However, should non-response still be accounted for, the final sample size should be 209. In this study, a total of 264 participants were recruited.

Data Analysis

Data was encoded and cleaned using Microsoft Excel 2016 (Microsoft Corporation). Stata v.12 (StataCorp) was used to further clean, recode, and analyze the data. Continuous variables were encoded as is, while categorical variables were coded from 0 to k, k being the number of categories minus 1.

Data on the demographic variables was described in totality, and for each outcome group. Numeric variables like age, height, weight, BMI, and MUAC were described using its mean and standard deviation, while categorical variables like number of pregnancies, household income, educational attainment, occupation, smoking status during pregnancy, number of consultations during pregnancy, pregnancy length, and mode of delivery, were described using their respective frequencies and proportions.

The crude association of MUAC to low birth weight newborns was determined through simple logistic regression. The unadjusted OR standard error, 95% confidence interval, and corresponding p-values of these variables were reported. The association of MUAC to low birth weight newborns was determined through multiple logistic regression to control for other confounding variables. A p-value less than or equal to 0.05 was considered statistically significant.

For each MUAC point to be considered, the sensitivity, specificity, PPV, NPV, and AUC, and their exact 95% confidence intervals were obtained. A receiver operating characteristic (ROC) was utilized to aid the cutoff determination.[10] A p-value of less than or equal to 0.05 was considered significant. These were reported in tables and figures. The data was used as the basis to determine the optimal cut-off point.

Ethical Consideration

The protocol was approved by the University of the Philippines Manila Research Ethics Board (UPMREB)

Table 1. Sample Size Calculations per Objective

Objective	Assumptions			Reference	n
To determine the association of maternal MUAC and the birth weight outcome among newborn deliveries	P(Y=1|X=1)H0	OR	R^2		
	0.25	0.555	0.20	Ververs et al., 2013	167
To determine the optimal cut-off for maternal MUAC needed to predict LBW outcome	AUC	Allocation*			
	0.70	2.5		FANTA	76

**Expected ratio of newborns with normal birth weight to newborns with low birth weight* panel for ethics review and approval under protocol code 2019-198-01. Recruitment of subjects commenced only upon the clearance of the UPMREB. This study was also registered at the Philippine Health Research Registry under registry ID PHRR200330-002579.

Participation in this research was voluntary. All participants were informed in full about the nature of the research, its method, their roles, and the risks and benefits involved in the research. Parental consent was obtained among all participants below 18 years old. Adolescents below 12 years old were asked for their verbal assent, while those aged 12 to 14 were asked to sign a simplified assent form; those participants who were 15 to 17 years old were asked to co-sign the informed consent form with their parents/guardians.

All participants' information was kept confidential, and their identities remained anonymous. Only the research assistant and primary investigator directly involved in the study had access to this information. The data was saved in a computer, and the backed-up data was stored in a secure place. There were no adverse events reported during the conduct of this study.

RESULTS

This cross-sectional study was conducted for six months from June 1, 2019, to Nov 30, 2019, among adolescents who gave birth at the Philippine General Hospital. A total of 264 adolescent mothers were initially included in the study, however, 27 participants were excluded due to incomplete data, maternal illness, and fetal congenital anomaly (Figure 1). The mean MUAC of all the participants was 25.04 cm ± 3.14, with a range of 19 cm to 40 cm. The mean birth weight was 2622 g ± 518.

Table 2 shows the summary of the demographic profile. The mean age of participants was 17.42 ± 1.46, with an age range of 10 to 19 years. The majority (78%) of the mothers were in their late adolescence. About 93% of them belong to low-income brackets; 66% were still in school prior to the delivery while about 24% were already out of school or unemployed. Most of the adolescents were first-time mothers at 86% while about 13.9% already had at least two pregnancies. Most of the mothers had at least four antenatal visits (74%) while about 2% never had any antenatal visit. Though 92% of the mothers did not smoke, about 8% smoked cigarettes anytime during their pregnancy. The majority (77%) of the mothers delivered via spontaneous vaginal delivery, 19% delivered via Cesarean section, and 3% delivered by assisted vaginal delivery. About 80% of the mothers delivered to full-term babies while 20% delivered prematurely.

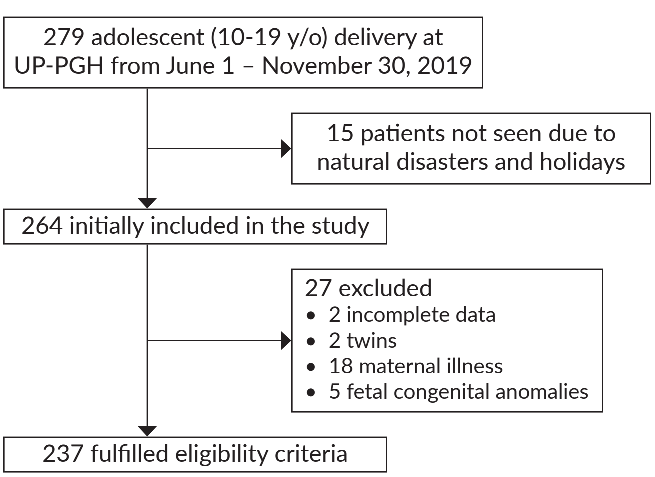


Figure 1. Study participants flow diagram.

Out of 237 newborn deliveries, 83 (35%) were low birth weight (<2.5 kg) while 65% weighed ≥2.5kg. The mean age of the mothers of babies with normal birth weights was higher (17.45+1.47) than that of the mothers of babies with low birth weights (17.37 ± 1.24).

The mean height of the mothers with LBW babies (150.31 ± 5.73) were lower than mother of NBW babies (152.98 ± 5.66). On the other hand, the BMI and weight of the mothers with NBW were higher (22.76 ± 3.93) than the mother with LBW babies. The highest percentage of LBW babies were found among mothers belonging to MUAC range 22.01 to 24cm (33.73%) (Table 3).

Measure of Association Between MUAC and LBW

In the succeeding tables, the logistic regression was presented depending on the prospective MUAC cut-offs to identify which among the cut-offs would present with better association and higher odds of delivering LBW newborns.

The odds of having LBW babies is 2.19 times higher among mothers with MUAC less than or equal to 23.00 cm, compared to those with MUAC greater than 23.00 cm. This association is statistically significant. Controlling for the effects of height, gravida, work, education, income, and smoking during pregnancy, the odds of having LBW babies is 1.89 times higher among mothers with MUAC less than or equal to 23.0 cm, compared to those with MUAC greater than 23.00 cm. This result is consistent with the 23.50 cm cut-off which showed statistically significant findings on crude association but not significant association when multivariate analysis was done. However, at ≤24.00 cm cut-off, the association was proven to be significant both for crude and adjusted association. The odds of having LBW babies is 2.39 times higher among mothers with MUAC less than or equal to 24.00 cm, compared to those with MUAC greater than 24.00 cm. Controlling for the effects of other variables, the odds of having LBW babies is 1.92 times higher among mothers with MUAC less than or equal to 24.00 cm, compared to those with MUAC greater than 24.00 cm (Table 4).

In this study, the preterm outcome was not excluded since the length of gestation may be affected by the lack or absence of specific nutrients. Hence, prematurity per se could be a result of maternal undernutrition.[6,11] However, sub-analysis was done to check if the results would be different had the weight-lowering effect of preterm babies who are naturally small been eliminated. The result of the logistic regression for the entire sample was consistent when the analysis was applied for full-term deliveries only for all the MUAC points. It is only the cut-off ≤24.00 which showed significant results for both crude and adjusted association (Table 5).

Measure of Diagnostic Accuracy

Analysis of maternal MUAC along with sensitivity, specificity, positive predictive value, and negative predictive value associated with LBW is shown in Table 6 to guide in the selection of better cut-off value. Should the MUAC cut-off be set at 23.00 cm, the sensitivity is only 37.35%, meaning 37.35% of those with LBW outcome will be correctly identified, while the specificity is 78.57%, meaning 78.57% of those without LBW will test negative. On the other hand, using 23.50 cm as a cutoff would correctly identify 45.78% of LBW outcomes, but will miss at least 50% of them. Setting it at 24.00 cm would accurately identify more than 54.22% or more of women at risk of having a LBW baby but it will lower its specificity to 66.88%.

The Receiver Operating Characteristics (ROC) provides two results: the diagnostic accuracy using the Area under the

Table 2. Demographic Profile of Pregnant Adolescents who Delivered in UP-PGH from June 1 to November 30, 2019

Variable	Normal Birth Weight, n=154 (64.98%)	Low Birth Weight, n=83 (35.02%)	Total, n=237
Age			
10-13	2 (66.67) [1.30]	1 (33.33) [1.20]	3 [1.27]
14-16	33 (67.35) [21.43]	16 (32.65) [19.28]	49 [20.68]
17-19	119 (64.32) [77.27]	66 (35.68) [79.52]	185 [78.06]
Occupation			
Student	105 (66.88) [68.18]	52 (33.12) [62.65]	157 [66.24]
Unemployed	33 (56.90) [21.43]	25 (43.10) [30.12]	58 [24.47]
Employed	16 (72.73) [10.39]	6 (27.27) [7.23]	22 [9.28]
Household Income			
≤Php 10,000	101 (66.01) [65.58]	52 (33.99) [62.65]	153 [64.56]
Php 10,001-20,000	43 (63.24) [27.92]	25 (36.76) [30.12]	68 [28.69]
Php 20,001-30,000	8 (66.67) [5.19]	4 (33.33) [4.82]	12 [5.06]
Php 30,001-40,000	1 (33.33) [0.65]	2 (66.67) [2.41]	3 [1.27]
>Php 40,000	1 (100.0) [0.65]	0	1 [0.42]
Highest Educational Attainment			
Elementary	8 (38.10) [5.19]	13 (61.90) [15.66]	21 [8.86]
High School	126 (64.62) [81.82]	69 (35.38) [83.13]	195 [82.28]
Vocational	1 (100.0) [0.65]	0	1 [0.42]
College	19 (95.00) [12.34]	1 (5.00) [1.20]	20 [8.44]
Term			
Full term	151 (79.89) [98.05]	38 (20.11) [45.78]	189 [79.75]
Pre-term	3 (6.25) [1.95]	45 (93.75) [54.22]	48 [20.25]
Number of Pregnancies			
1	133 (65.20) [86.36]	71 (34.80) [85.54]	204 [86.08]
2	20 (64.52) [12.99]	11 (35.48) [13.25]	31 [13.08]
3	1 (50.00) [0.65]	1 (50.00) [1.20]	2 [0.84]
Prenatal Visits			
None	4 (66.67) [2.60]	2 (33.33) [2.41]	6 [2.53]
<4	27 (49.09) [17.53]	28 (50.91) [33.73]	55 [23.21]
≥4	123 (69.89) [79.87]	53 (30.11) [63.86]	176 [74.26]
Cigarette smoking during pregnancy			
Yes	10 (55.56) [6.49]	8 (44.44) [9.64]	18 [7.59]
No	144 (65.75) [93.51]	75 (34.25) [90.36]	219 [92.41]
Mode of Delivery			
SVD	112 (60.87) [72.73]	72 (39.13) [86.75]	184 [77.74]
Forceps-assisted	2 (66.67) [1.30]	1 (33.33) [1.20]	3 [1.27]
Vacuum-assisted	5 (100.0) [3.25]	0	5 [2.11]
Cesarean	35 (77.78) [22.73]	10 (22.22) [12.05]	45 [18.99]

Note: values in ( ) show row percentage, [ ] column percentage

Table 3. Anthropometric Measures of Adolescent Mothers in Relation to Birth Weight

Variable	Normal Birthweight, n=154 (64.98%)	Low Birthweight, n=83 (35.02%)	Total, n=237
Height in kg; mean (SD)	152.98 (5.66)*	150.31 (5.73)*	152.04 (5.82)*
Weight in cm; mean (SD)	53.29 (9.86)*	47.24 (7.42)*	51.17 (9.51)*
BMI mean (SD)	22.76 (3.93)*	20.85 (2.55)*	22.09 (3.62)*
MUAC in cm			
19.00-22.00	19 (52.78) [12.34]	17 (47.22) [20.48]	36 [15.19]
22.01-24.00	32 (53.33) [20.78]	28 (46.67) [33.73]	60 [25.32]
24.01-26.00	42 (65.63) [27.27]	22 (34.38) [26.51]	64 [27.00]
26.01-28.00	29 (72.50) [18.83]	11 (27.50) [13.25]	40 [16.88]
>28.00	32 (86.49) [20.78]	5 (13.51) [6.02]	37 [15.61]

Note: values with asterisk denote standard deviation (SD).
MUAC values in ( ) show row percentage, [ ] column percentage

Table 4. Regression Analysis of Entire LBW Samples on Maternal MUAC at Different Cut-off Points

MUAC (in cm)	Crude Association			Adjusted Association		
	OR (SE)	95% CI	*p*	OR (SE)	95% CI	*p*
≤23.00	2.19 (0.66)	1.21, 3.94	0.009*	1.89 (0.63)	0.99, 3.62	0.053
≤23.50	2.25 (0.64)	1.29, 3.94	0.004*	1.82 (0.56)	1.00, 3.33	0.051
≤24.00	2.39 (0.67)	1.38, 4.13	0.002*	1.93 (0.58)	1.07, 3.49	0.029*

OR: Odds Ratio, SE: Standard Error, CI: Confidence Interval, p: P value
Adjusted for potential confounders: height, gravida, occupation, education, monthly income, and smoking status
*Note: *Significant association at P value ≤0.05*

Table 5. Regression Analysis of Full-term LBW Samples on Maternal MUAC at Different Cut-off Points

MUAC (in cm)	Crude Association			Adjusted Association		
	OR (SE)	95% CI	*p*	OR (SE)	95% CI	*p*
≤23.00	2.26 (0.89)	1.05, 4.87	0.038*	1.89 (0.83)	0.80, 4.46	0.148
≤23.50	2.09 (0.79)	1.00, 4.38	0.051	1.76 (0.72)	0.78, 3.94	0.172
≤24.00	2.65 (0.98)	1.28, 5.48	0.008*	2.37 (0.97)	1.06, 5.27	0.035*

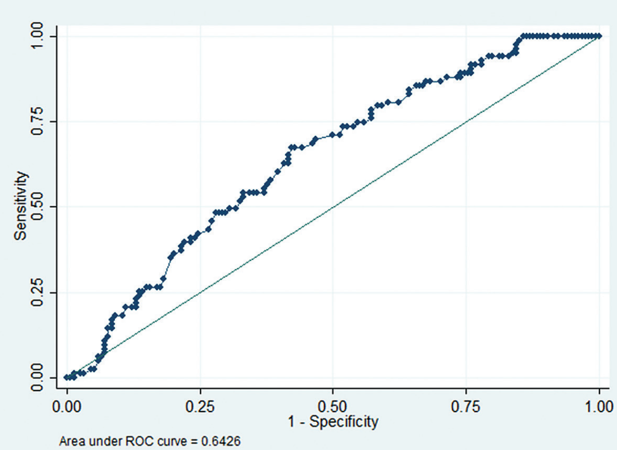
OR: Odds Ratio, SE: Standard Error, CI: Confidence Interval, p: P value
Adjusted for potential confounders: height, gravida, occupation, education, monthly income, and smoking status
*Note: *Significant association at P value ≤0.05*

Curve (AUC), and the optimal cut-off point using Youden's index. The AUC is 0.64 at 95% CI, indicating that if a pair of adolescents were selected at random, there is a 64% chance that the adolescent delivering a LBW infant would have a lower MUAC than the one delivering a NBW (Figure 2).

Youden's index was derived to guide which optimal cut-off can predict LBW outcome. Youden's index will identify which cut-off point gives the best trade off value for both sensitivity and specificity. In this study, the highest value of Youden's index pointed to cut-off ≤24.00 cm (Table 7).

DISCUSSION

Nutritionally-at-risk refers to undernourished pregnant girls with low pre-pregnancy BMI or those who do not gain adequate weight during pregnancy and are therefore at risk of adverse birth outcomes. Compared to pregnant adults, pregnant adolescents are more at risk of undernutrition



95% CI of AUC: 0.57671, 0.70241

Figure 2. Area under the curve for MUAC and LBW.

Table 6. Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value for each MUAC Cut-off

Cut-off (cm)	Sensitivity (95% CI)	Specificity (95% CI)	Positive Predictive Value (95% CI)	Negative Predictive Value (95% CI)
≤20.00	0.00 (0.00, 4.35)	98.70 (95.39, 99.84)	0.00 (0.00, 84.19)	64.68 (58.20, 70.78)
≤20.50	2.41 (0.29, 8.43)	95.45 (90.86, 98.15)	22.22 (2.81, 60.01)	64.47 (57.89, 70.68)
≤21.00	6.02 (1.98, 13.50)	93.51 (88.38, 96.84)	33.33 (11.82, 61.62)	64.86 (58.19, 71.13)
≤21.50	14.46 (7.70, 23.89)	92.21 (86.78, 95.91)	50.00 (29.12, 70.88)	66.67 (59.90, 72.96)
≤22.00	20.48 (12.41, 30.76)	87.66 (81.41, 92.41)	47.22 (30.41, 64.51)	67.16 (60.21, 73.61)
≤22.50	26.51 (17.42, 37.34)	85.06 (78.44, 90.29)	48.89 (33.70, 64.23)	68.23 (61.14, 74.75)
≤23.00	37.35 (26.97, 48.66)	78.57 (71.24, 84.77)	48.44 (35.75, 61.27)	69.94 (62.52, 76.67)
≤23.50	45.78 (34.79, 57.08)	72.73 (64.97, 79.58)	47.50 (36.21, 58.98)	71.34 (63.59, 78.26)
≤24.00	54.22 (42.92, 65.21)	66.88 (58.85, 74.25)	46.88 (36.61, 57.34)	73.05 (64.93, 80.17)
≤24.50	62.65 (51.34, 73.03)	59.09 (50.89, 66.94)	45.22 (35.92, 54.77)	74.59 (65.91, 82.04)
≤25.00	69.88 (58.82, 79.47)	53.25 (45.05, 61.32)	44.62 (35.90, 53.58)	76.64 (67.47, 84.27)
≤25.50	74.70 (63.96, 83.61)	45.45 (37.42, 53.67)	42.47 (34.33, 50.91)	76.92 (66.91, 85.11)
≤26.00	80.72 (70.59, 88.56)	39.61 (31.83, 47.80)	41.88 (34.13, 49.92)	79.22 (68.46, 87.63)
≤26.50	86.75 (77.52, 93.19)	32.47 (25.15, 40.47)	40.91 (33.57, 48.56)	81.97 (70.02, 90.64)
≤27.00	89.16 (80.41, 94.92)	25.97 (19.25, 33.65)	39.36 (32.33, 46.73)	81.63 (67.98, 91.24)

CI: Confidence interval

Table 7. Youden's Index

MUAC cut-off (cm)	Youden's Index
≤23.00 cm	0.1592
≤23.50 cm	0.1851
≤24.00 cm	0.2110

because they are in a period of rapid growth that requires higher nutritional requirements. Consequently, being pregnant also demands increased nutritional requirements as well to support the rapid growth of the developing fetus. The higher nutrient demands put pregnant adolescents at a higher risk for nutrient insufficiency. Hence, mothers need to enter pregnancy at optimal nutrition for better pregnancy outcomes.[12,13] However, adolescent girls often enter pregnancy with insufficient nutrient reserves like in the case of many Filipino adolescents.[1,2]

Undernutrition among pregnant girls can lead to competition for major energy requirements and micro-nutrients between the mother and the fetus; i.e., nutrient partitioning.[14] Research demonstrated that nutrients are partitioned depending on the nutritional status of the mother upon conception. During the marginal state of nutrient deficiencies, the fetal compartment is favored; however, during severe undernutrition, maternal compartment takes precedence.[15] Undernutrition among pregnant also impairs placental development and function, hence hindering fetal growth.[5] A good pregnancy outcome therefore is dependent on the availability of nutrients from maternal stores to the growing fetus.[6] It is therefore well recognized that undernutrition before and during pregnancy is a determining factor for poor pregnancy outcomes like preterm birth, small for gestational age, and LBW leading to increased infant morbidity and mortality.[6]

Over the last decade, the pre-pregnancy BMI has been used as an estimate for appropriate nutrition during pregnancy.[16] However, target weight gain would be a problem in the absence of pre-pregnancy weight like in the case of many adolescents who come in at the later stage of pregnancy for their first prenatal check-up. In this setting, MUAC measurements can be useful as an indicator of acute malnutrition, especially when measurements of weight and height are not available.[6,9]

This current study aimed to identify the relationship of maternal nutrition using MUAC and LBW newborn outcomes and to identify the optimal cut-off that can predict LBW outcomes specific to pregnant adolescents. Included in the study were consecutive eligible pregnant adolescents admitted for delivery in UP-PGH, a tertiary hospital and referral center in the Philippines. The study recruited 237 adolescent mothers for six months. The majority of the participants were late adolescents (78.06%) aged 17 to 19 years, followed by middle adolescents aged 14 to 16 years (20.68%), and early adolescents aged 10 to 13 years (1.27%). The highest percentage of pregnancies was found among the lowest income group, and about 33 % are out-of-school youth, similar to a local nationwide study showing that poor and uneducated teens are the ones mostly getting into teen pregnancy.[3] Similarly, the percentage of low birth weight outcomes was also seen higher among low-income groups which further emphasizes the need to support those belonging to low socioeconomic status. It is also important to note that repeated birth among pregnant adolescents was noted at 13% which is higher with the latest available statistics in the Philippines showing a repeated birth rate of 7.8% in 2013.[17] Hence, there is a need to further review and intensify the government's program for comprehensive sexuality education.

About 35% of the pregnant adolescents gave birth to low birth weight babies. This is higher than the national data which is 17.2%.[3] Another study done in several low- and middle-income countries showed that 27% of the teens who entered pregnancy with poor nutritional status gave birth to infants with LBW. [18] Because of this high percentage, efforts have been made all over the world to prevent this outcome including the First 1000 Days campaign. In our country, Republic Act (RA) 11148, the Kalusugan at Nutrisyon ng Mag-Nanay law was enacted on November 29, 2019, mandating local government units to implement programs for the First 1000 Days.[19] It was recognized that a large contributor of LBW babies are products of unhealthy teen pregnancies. Adolescents and their LBW infants feed the intergenerational cycle of malnutrition. Hence, it is important to properly identify and manage those at risk to be able to intervene and halt this cycle.

Screening pregnant adolescents at risk of delivering low birth weight outcomes is an utmost importance to allow timely intervention and prevent further neonatal morbidity and mortality. Nutrition counseling based on the Philippine Dietary Reference Intakes and Pinggang Pinoy for pregnant women was just one of the few interventions we can do for pregnant adolescents, but it is more effective if given early to those who will be identified. However, the MUAC cut-off which can be used to identify pregnant adolescents at risk for delivering LBW babies is not yet available, hence, the objective of finding the optimal cut-off.

Dietary supplementation has been identified as another effective strategy to address the nutritional needs of the vulnerable groups. It addresses the nutritional gaps in the intake of the target population and helps improve the nutritional status of those receiving the dietary treatment. With the country's limited resources, it is important to have a standardized MUAC cut-off such that those who are most in need are prioritized.

Results of this study showed that the cut-off of ≤24.00 cm demonstrated the highest odds ratio value and degree of association upon adjusting for other variables. Analyzing the cut-offs in terms of association is more straightforward. However, it varies more in terms of diagnostic accuracy since the country's resources and its ability to provide assistance would matter.In choosing a screening test, both sensitivity and specificity are preferred to be high, however, there is no perfect screening test in reality. There is often a trade-off between the value of sensitivity and specificity, meaning increasing the sensitivity will decrease the specificity while increasing the specificity will decrease the sensitivity. In general, a higher sensitivity should be preferred over the specificity if the disease is serious and the consequence of missing the disease is great, on the other hand, a high specificity is preferred when the costs of further diagnostic tests are significant.[20] However, it is suggested that in a resource-limited situation, when setting a cut-off point, the sensitivity should not be set too high because it will restrict other women who could benefit from the nutrition service from accessing the program.[21]

Furthermore, a MUAC cut-off with the highest sensitivity at or above the minimum set of specificity would be preferable for screening. Selecting a highly sensitive test at the expense of specificity will also lead to a high number of false positive cases, and the government should be able to provide supplies for all of those identified nutritionally at-risk pregnant adolescents by the test. On the other hand, if choosing a highly specific test, the program will end up spending more on screening and identifying only a few who are really at risk. In this study, the specificity is best at ≤23.00 cm, however, the sensitivity is poor (37.35%). If we set the minimum specificity at 70%, ≤23.50 cm would have been the better cut-off, however, the sensitivity is still low (45.78%). Therefore, it would fail to correctly identify at least 50% of mothers who had LBW outcomes. The ≤24.00 cm MUAC cut-off showed a better trade-off value for sensitivity and specificity. Looking at the ROC, the maximum value used to identify the optimum cut-off or Youden's index points out to ≤24 cm.

The results of this study are similar to the meta-analysis results done by Tufts University and the FANTA to determine a standard optimal cut-off for MUAC that can identify women at risk for delivering LBW infants. The sensitivity and specificity of each MUAC cut-off varied greatly between studies, however, the combined results showed a sensitivity and specificity of 38.4% and 73.4%, respectively for ≤23.00 cm cut-off; 47.4% and 66.7%, respectively for ≤23.50 cm cut-off; 60.1% and 54.1%, respectively for ≤24.00 cm cut off. The meta-analysis did not mention a specific optimum cut-off to be used internationally; rather, it suggested that each country should do a cost-benefit analysis before adopting a specific cut-off.[6]

The value from this study and the study from FANTA both showed minimal diagnostic ability based on the Area Under the Receiver Operating Characteristic Curve (AUROCC). The AUROCC of this study indicates that if a pair of adolescents were selected at random, there is a 64.26% chance that the adolescent delivering a LBW infant would have a lower MUAC than the one delivering a NBW. However, the utility of MUAC itself as a test to detect LBW among pregnant women has long been established.[6,13] We cannot overemphasize the value of MUAC, especially in a community screening, because of its simplicity, acceptability, low cost, objectivity, quantitativeness, and group precision.[6,22] Results of its diagnostic accuracy could not in anyway minimize its usefulness, especially in the community and humanitarian setting. By doing this simple screening test, suspected pregnant adolescents can be easily identified and referred for further confirmation. LBW outcome can be reduced by nutrition intervention, but timely intervention can only be given if a pregnant at risk of delivering LBW is recognized early.

An incidental finding in the study is the effect of maternal height on newborn weight outcome. The multiple regression analysis showed that upon controlling for the effects of all other variables in the model, the odds of having LBW babies decreased by 6% to 9% for every 1 cm increase in the height of the mother for the three cut-off points. This is consistent with the study in India among adolescent Bengalees showing a greater risk for shorter mothers to deliver LBW babies.[23] To further support this idea, a study in Bangladesh showed that pregnant middle adolescents cease linear growth and deplete fat stores when compared with non-pregnant counterparts.[24] The relationship between the pregnant adolescents' height with newborn outcome needs to be further investigated.

As with most of the research, the design of this current study is subject to limitations. Due to the small number of pregnant adolescents that go on antenatal visits, the MUAC was collected after newborn delivery, though current evidence pointed out that there was no significant difference in the MUAC of adolescents all throughout their pregnancy. Total enumeration was also done because of the small population size and limited time in data collection. In addition, other confounding variables were not considered in the study like the participants' actual dietary intake which could provide additional information on their nutritional status, and other social and structural determinants affecting maternal health. But despite these limitations, this study is the first that examined the relationship between maternal MUAC and LBW outcome of adolescent deliveries, and the first to establish the maternal MUAC cut-off specific for the adolescent age group.

Future research should consider a prospective study that includes multiple center to arrive at a bigger representative sample to come up with the recommendation necessary for the national government program.

CONCLUSION

This study demonstrated that the MUAC of adolescent mothers is predictive of neonatal low birth weight outcome. The logistic regression analysis showed that the odds of having a low birth weight baby is at least twice higher among mothers for cut-offs ≤23.00 cm, ≤23.50 cm, and ≤24.00 cm, however, it is only the ≤24.00 cm cut-off that showed significant results for both crude and adjusted association. Furthermore, Youden's index showed that the cut-off of ≤24.00 cm gave the best trade-off value for both sensitivity and specificity.

The results emphasized the need to reevaluate the MUAC cut-off use to identify nutritionally-at-risk pregnant adolescents. Pregnant adolescents might need a higher MUAC cut-off than adults to allow early intervention and inclusion of more adolescents in the government's dietary supplementation and other related programs to support their own growth as well as fetal development. By doing this simple screening test, suspected pregnant adolescents can be easily identified and referred for further confirmatory tests.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

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