Mid upper arm and calf circumferences as indicators of nutritional status in women of reproductive age

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استخدام محيط الذراع ومحيط الرَّبلة كمؤشرين للحالة التغذوية للمرأة في سن الإنجاب

خديوزاده طلعت

الخلاصة: يُعتبر محيط الذراع وسيلة فعّالة لتحرّي سوء الحالة التغذوية بين البالغين. غير أن صلاحية محيط الرَّبلة calf كأداة للتحري لم تثبت بشكل كامل. وقد تم في هذا البحث دراسة 2000 امرأة يتمتّعن بصحة جيدة (من عمر 15 إلى 49 عاماً) من مدينة مشهد، في جمهورية إيران الإسلامية، وذلك لتقدير القياسات البشرية لمن في سن الإنجاب ومدى فائدة محيط الرَّبلة ومحيط الذراع في تقدير مَنْسَب كتلة الجسم، وفي تحرّي النساء المتعرِّضات لمخاطر تغذوية عالية. وتبين نتائج الدراسة ارتباطاً وثيقاً بين محيط الذراع ومحيط الرَّبلة من جهة وبين الوزن ومَنْسَب كتلة الجسم من جهة أخرى. وتشير الدراسة إلى إمكانية استخدام محيط الذراع ومحيط الرَّبلة في تقدير مَنْسَب كتلة الجسم واكتشاف الاضطرابات التغذوية.

ABSTRACT Mid upper arm circumference (MUAC) is recognized as an effective means of screening for poor nutritional status in adults. The efficacy of calf circumference (CC) as a screening tool, however, is not well reported. We studied 2000 healthy women (age range: 15–49 years) in Mashed, Islamic Republic of Iran, to assess anthropometric measurements at reproductive age and the usefulness of MUAC and CC for estimating body mass index (BMI) and screening of women at nutritional risk. We found a strong correlation between MUAC and CC with weight and BMI, suggesting that MUAC and CC can be used to estimate BMI and detect nutritional disorders.

Le périmètre brachial à mi-hauteur et le périmètre du mollet comme indicateurs de l'état nutritionnel des femmes en âge de procréer

RESUME Le périmètre brachial à mi-hauteur est reconnu comme moyen de dépistage efficace d'un mauvais état nutritionnel chez l'adulte. Toutefois, l'efficacité du périmètre du mollet comme outil de dépistage n'est pas bien documentée. Nous avons étudié 2000 femmes en bonne santé (fourchette d'âge : 15-49 ans) à Mashed (République islamique d'Iran) afin d'évaluer les mesures anthropométriques pendant la période reproductive et l'utilité du périmètre du mollet et du périmètre brachial à mi-hauteur pour estimer l'indice de Quételet et dépister les femmes qui présentent un risque nutritionnel. Nous avons trouvé une forte corrélation entre le périmètre brachial à mi-hauteur et le périmètre du mollet avec le poids et l'indice de Quételet, ce qui semble indiquer que ces deux mesures peuvent être utilisées pour estimer l'indice de Quételet et dépister les troubles nutritionnels.

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Received: 19/04/01; accepted: 06/12/01

Introduction

Women are particularly vulnerable to developing nutritional problems. The many daily pressures they experience can lead to nutritional stress and poor maternal nutritional status. Anthropometric indicators are useful tools for screening women at nutritional risk, monitoring nutritional status and predicting unfavorable infant outcomes related to pregnancy [*1*]. In adults, body mass index (BMI), or weight (kg)/height squared (m^2), is used to define underweight or overweight [2].

Mid upper arm circumference (MUAC) has recently emerged in the literature as a potential screening tool for poor nutritional status in adults. MUAC has been analysed in adults and cut-off points for chronic energy deficiency have been established using a range of datasets from developing countries [2].

The typical distribution of weight gain during pregnancy is to the conceptus and maternal organs such as the breasts and uterus [*3*]. Thus, in societies in which weight gain and MUAC changes in pregnancy are low, MUAC may be an accurate indicator of pre-pregnancy weight, especially in the early months of pregnancy. Measuring MUAC has several advantages. The measurement can be taken quickly and at little cost. It requires neither sophisticated equipment nor anything but the most basic literacy level to carry out [*1*].

Although the usefulness of the MUAC measurement is being increasingly acknowledged, the same cannot be said of calf circumference (CC). Therefore, to assess the relationship of anthropometric measures of MUAC and CC to BMI and the usefulness of the two indices in estimating BMI in woman of reproductive age, we examined both among women in the city of Mashed in 1997–1998.

Methods

Mashed is the capital of the Islamic Republic of Iran's largest province, Khorasan, in the north-east of the country. It is also the country's second largest city, with a population of approximately 1.9 million people (1996 census), one-quarter of whom are women of reproductive age (i.e. aged 15–49 years) with a literacy rate of 92.5%.

Using clustered, multi-stage random sampling, 2000 women from this age group were selected for a cross-sectional study. All were in good health. None were pregnant, lactating or users of hormonal contraceptives or other drugs. Sportswomen were excluded. All had experienced menarche and none had reached menopause. The women were interviewed and assessed in their homes, at their workplaces or at their educational institutions between the hours of 09.00 and 11.00.

Using non-stretchable tapes, MUAC and CC were measured to the nearest millimetre. Left MUAC was measured at the mid-point between the acromion process of the scapula and the olecranon process of the ulna, with the arm and forearm hanging loosely by the side [*4*]. Triceps skin fold (TSF) was measured with skin fold caliper at the mid-point of the arm [*4*]. Left leg CC was measured by passing the tape around the point of maximum circumference. Two measurements of CC were taken: the subject standing (CC standing); and the subject seated, with thigh flexed at 90° to the trunk and calf flexed at 90° to the thigh (CC sitting). The mean of three consecutive measurements was recorded to the nearest millimetre. All subjects were weighed wearing minimal clothing. Body weight was measured to within 100 g using scales, which were checked with standard weights each day. Height was measured with the subject standing at ground level without footwear against a wall. BMI was calculated as weight (kg) divided by height squared (m^2). The cut-off points for overweight and underweight were 19.8 and 26, respectively [5]. A trained midwife took all measurements.

Data were analysed using the Pearson correlation coefficient. Data to assess the utility of MUAC and CC as an instrument for estimating BMI were analysed using multiple regression analysis. Sensitivity, specificity and positive and negative predictive values of MUAC and CC in screening underweight and overweight were calculated.

Results

Of the 2000 women enrolled in the study, 22% were < 20 years of age; 37.8% were 20–29 years of age; 29.3% were 30–39 years of age; and 10.9% were > 40 years of age. The most common occupation of subjects was non-paid domestic duties in the family home (65.1%), followed by full-time study (23.7%) and paid employment outside the family home (11.2%). Educational levels attained were: primary school (24.4%), middle school (17.3%), high school (39.3%), tertiary (14.5%) and illiterate (4.5%).

Parity of the women was: nullipara (41.4%), 1 viable birth (11.6%), 2–4 (33.2%) and ≥ 5 (13.8%). The mean and standard deviation of anthropometric measurements were: body weight 58.2 ± 23.9 kg; height 156.5 ± 6.1 cm; BMI 23.6 ± 4.4 kg/m^2; percent of ideal body weight 103.5 ± 15.9%; MUAC 26.6 ± 3.9 cm; and CC 33.77 ± 3.42 cm (Table 1).

BMI values had a mean value of 6.2 BMI units and tended to be within normal ranges. Of all women in the study, 21.1% were underweight (i.e. BMI < 19.8 kg/m^2). All indices were lower in younger women, with 41.1% of those aged 15–19 years and 26.2% of those aged 20–24 years being underweight. Conversely, the prevalence of obesity (36.2%) and overweight (24.5%) were greatest in women aged 40–44 years. The mean and SD of anthropometric indices are given in Table 1. BMI correlated

Table 1 **Mean and SD of anthropometric measurements of 2000 women of reproductive age**

Age (years)	Weight	Height	BMI[a]	MUAC[b]	CC[c]
15–19	52.3 ± 8.2	158.0 ± 5.6	20.9 ± 3.1	23.9 ± 2.8	33.5 ± 2.8
20–24	55.0 ± 9.6	157.3 ± 6.0	22.2 ± 3.6	25.3 ± 3.2	33.0 ± 3.2
25–29	61.9 ± 5.1	155.8 ± 5.7	24.3 ± 4.1	27.2 ± 3.6	34.1 ± 3.3
30–34	59.3 ± 10.7	155.7 ± 5.7	24.5 ± 4.3	27.4 ± 3.7	34.2 ± 3.6
35–39	62.6 ± 10.7	155.9 ± 7.5	25.8 ± 4.2	28.9 ± 3.5	34.2 ± 3.4
40–44	65.1 ± 11.6	154.7 ± 5.2	27.1 ± 4.5	29.7 ± 3.6	34.9 ± 3.7
45–49	62.9 ± 11.2	155.6 ± 5.4	25.9 ± 4.3	29.1 ± 3.5	35.6 ± 3.5
Total	58.2 ± 23.9	156.5 ± 6.1	23.6 ± 4.4	26.6 ± 3.9	33.8 ± 3.4

[a]Body mass index; [b]Mid upper arm circumference; [c]Calf circumference.

strongly with MUAC and CC, with CC standing correlating more strongly to BMI than CC sitting.

Anthropometric measurements were significantly correlated with each other and with age, raising the possibility that some measurements could replace others in a regression model (Table 2). Entering age, MUAC and BMI as dependent, stepwise regression analysis revealed that MUAC, but not age, independently correlated with BMI (Table 3).

The relationship between BMI and MUAC was formulated:

$$BMI = 0.1036\ MUAC\ (mm) - 3.9$$

There was no significant difference between real BMI and BMI estimated by the above formula (23.626 ± 4.39 compared to 23.607 ± 4.03, $t = 0.04$, $P = 0.97$). The mean and SD of difference between real BMI and BMI estimated by the above formula were 0.182 ± 1.805 and was significantly correlated ($r = 0.912$, $P = 0.000$). Entering CC and MUAC and BMI as dependent, stepwise regression analysis revealed an association between MUAC and CC and BMI (Table 4).

The relationship of BMI to MUAC and CC was formulated:

$$BMI = 0.07745\ MUAC\ (mm) + 0.03795\ CC\ (mm) - 9.7578$$

Table 2 **Correlations between anthropometric measurements and age**

Measurement	Correlation	TSF[a]	IBW[b]	BMI[c]	CC Sit[d]	CC Stand[e]	MUAC[f]	Height	Weight	Age
Age	*r*	0.393	0.279	0.393	0.279	0.275	0.497	0.183	0.378	1.000
	P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weight	*r*	0.75	0.920	0.920	0.845	0.893	0.870	0.210	1.000	
	P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Height	*r*	−0.07	−0.006	−0.170	0.109	0.116	0.080	1.000		
	P	0.001	0.380	0.081	0.000	0.000	0.000	0.000		
MUAC	*r*	0.83	0.850	0.910	0.766	0.781	1.000			
	P	0.000	0.000	0.000	0.000	0.000	0.000			
CC Stand	*r*	0.712	0.815	0.837	0.999	1.000				
	P	0.000	0.000	0.000	0.000	0.000				
CC Sit	*r*	0.711	0.816	0.829	1.000					
	P	0.000	0.000	0.000	0.000					
BMI	*r*	0.790	0.940	1.000						
	P	0.000	0.000	0.000						
% of IBW	*r*	0.760	1.000							
	P	0.000	0.000							
TSF	*r*	1.000								
	P	0.000								

[a]Triceps skin fold; [b]Ideal body weight; [c]Body mass index; [d]Calf circumference measured with subject sitting; [e]Calf circumference measured with subject standing; [f]Mid upper arm circumference.

Table 3 **Stepwise regression analysis for assessing the relationship between BMI[a], MUAC[b] and age**

Variable	R^2	Change in R^2	SEB	b	*t*	Significance
MUAC	0.83	0.83	1.045	0.1036	99.2	0.000
Constant	–	–	0.28	–3.9	–13.9	0.000

[a]Body mass index; [b]Mid upper arm circumference.

There was no significant difference between real BMI and BMI estimated by the above formula (23.6259 ± 4.394 compared to 23.6246 ± 4.088, $t = 0.04$, $P = 0.97$). The mean and SD of differences between observed BMI and BMI estimated by the above formula were 0.00141 ± 1.26. Its correlation ($r = 0.92$, $P = 0.00$) was significant. BMI estimation by this means was similar to real BMI.

The relationship between BMI and CC was:

$$BMI = 0.09784 \text{ CC (mm)} + 0.12326 \text{ age (years)} - 12.29$$

The difference between real BMI and BMI estimated in this way was 0.4999 ± 2.249. The correlation between them was significant ($r = 0.859$, $P < 0.000$), but was less so than other previously mentioned correlations.

To assess the validity of MUAC and CC as screening instruments in detecting underweight and overweight, sensitivity, specificity and positive and negative predictive values (PPV and NPV) were calculated at various cut-off points for MUAC and CC. Using an MUAC cut-off point of 24 cm for detecting underweight, the sensitivity, specificity, PPV and NPV were 93.6%, 83.9%, 60.6% and 98.1% respectively (Table 5). Using a CC cut-off point of 31.5 cm, sensitivity, specificity, PPV and NPV became 74.8%, 86.6%, 67.9% and 92.1% respectively. This meant that 93.6% of women with a BMI < 19.8 kg/m^2 had a MUAC < 24 cm and that only 6.4% of these women were not identified by this means. Conversely, 60.6% of the mothers with MUAC < 24 cm were underweight and 98.1% of women with MUAC > 24 cm were not underweight (Table 5).

In our study, 88.8% of women with BMI > 29 kg/m^2 had a MUAC > 30.5 cm,

Table 4 **Stepwise regression analysis for assessing the relationship between BMI[a], MUAC[b] and CC[c]**

Variable	R^2	Change in R^2	SEB	b	*t*	Significance
MUAC	0.831	0.831	1.4965	0.007745	51.75	0.000
CC	0.865	0.034	1.6915	0.037951	23.43	0.000
Constant	–	–	0.3618	–9.757880	–26.97	0.000

[a]Body mass index; [b]Mid upper arm circumference; [c]Calf circumference.

Table 5 **Validity of various cut-off points of MUAC in detecting BMI < 19.8 in women of reproductive age**

MUAC[a]	23.5 cm	23.8 cm	24.0 cm	24.5 cm
Sensitivity	80.5	85.7	93.6	96.6
Specificity	92.5	89.7	83.9	80.2
PPV[b]	69.5	68.9	60.6	56.5
NPV[c]	95.9	95.9	98.1	98.9

[a]Mid upper arm circumference; [b]Positive predictive value; [c]Negative predictive value.

with only 10.2% of these women not identified by this means. On the other hand, 70.9% of the mothers with MUAC > 30.5 cm were overweight and 98.3% of women with MUAC > 30.5 cm were not overweight (Table 6). The sensitivity, specificity, PPV and NPV for detecting overweight for women with a CC of 36 cm was 83.1%, 87.2%, 49.3% and 97.2%, respectively.

Discussion

The use of BMI for assessing undernutrition in adults is now being applied worldwide [*6*]. There is also a need to assess whether other, simpler measures that could be used in situations such as emergencies, when only semi-skilled monitors are available, or even in the home when a person wants to be certain her weight is within or near the normal range.

Mean weight and height in our sample were lower than the United States of America's National Center for Health Statistics average [*4*], and greater than those reported in 1994 by James et al. for adults in eight African and Asian countries [*6*].

Our study demonstrated lower anthropometric lean BMIs in younger women, especially those < 25 years of age and higher indices in women aged > 40 years, indicating the need for nutritional education for women as they approach the end stages of their reproductive period. Similar findings for women 40–50 years of age were reported in a Brazilian study [2].

In the present study, MUAC and CC were significantly correlated with weight, BMI and percent of ideal body weight. Similarly, the James et al. study also demonstrated an excellent linear relationship between MUAC and BMI [*6*]. A study in Nigeria [*7*] found similar results.

MUAC and CC can be used to estimate BMI. The following formulae are suggested:

$$BMI = 0.1036\ MUAC\ (mm) - 3.9, \text{ or}$$
$$BMI = 0.07745\ MUAC\ (mm) + 0.03795\ CC\ (mm) - 9.7578$$

Compared with actual BMI, BMI estimated with the first formula has a unit difference of 0.182 ± 1.805, and with the second, a unit difference of 0.00141 ± 1.26. Multiple regression analysis revealed an independent association between MUAC and BMI, but not between age and BMI.

As with the James et al. study [*6*], a cut-off point of 24 cm was optimal for screening of underweight women in our

Table 6 **Validity of various cut-off points of MUAC for detecting BMI > 29 in women of reproductive age**

MUAC[a]	29.5 cm	30.0 cm	30.5 cm	31.0 cm
Sensitivity	95.8	91.1	88.8	73.6
Specifity	88.4	83.4	94.5	97.3
PPV[b]	55.2	67.5	70.9	80.3
NPV[c]	99.3	98.6	98.3	96.1

[a]Mid upper arm circumference; [b]Positive predictive value; [c]Negative predictive value.

study. By using this cut-off point, only 6.4% of malnourished women were undetected (false negative). In Nigeria, a MUAC cut-off point of 23 cm was optimal for the north of the country, while a 24 cm cut-off point was more appropriate for the south [7].

This study confirms the usefulness of anthropometric measurements as simple methods of detecting nutritional disorders. Our findings indicated that MUAC and CC were highly correlated to weight and BMI and that CC measured while the subject was standing more strongly correlated than when the subject was seated.

Using the appropriate cut-off points and the previously mentioned formulae, MUAC and CC can usefully estimate BMI and screen women for nutritional disorders. In developing countries where MUAC changes in pregnancy are very low, MUAC and CC may provide an accurate and simple means for calculating pre-pregnancy BMI, at least during the first months of pregnancy. Further study is recommended.

Acknowledgements

This study was supported by a grant from the Vice-Chancellor for Research Affairs at Mashed University of Medical Sciences. We appreciate the contribution of our colleagues Dr S. Parsai, Dr M. Al-Reza Hdjzadeh, M. Kolivand and S. Reza Mazloom. We also appreciate the contribution of women who participated in this study.

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