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Estimation of Body Mass Index Using Body Circumferences among Girls and Women of Kumana Chiefdom, Kauru Local Government Area of Kaduna State, Nigeria

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ABSTRACT

Body mass index (BMI) is a handy tool for categorizing individuals as underweight, normal weight, overweight, or obese based on tissue mass and height. Body circumferences are of great importance in determining body weight and tissue composition due to the limitation of BMI, especially when used to predict individual's health. The study aimed at estimating body mass index (BMI) using body circumferences among girls and women of Kumana Chiefdom, Kauru Local Government Area of Kaduna State, Nigeria. A total of 678 subjects residing in Kumana Chiefdom, Kauru Local Government Area of Kaduna State, were selected for this study, all of them ranging between 10 – 78 years of age and devoid of any physical abnormalities or deformities. The anthropometric measurements were done using direct method. Statistical analysis was performed using SPSS software version 21. Pearson correlation was used to determine the correlation between the study variables, simple linear and multiple linear regression analyses were performed to derive population specific equations for predicting BMI and ANOVA followed by Tukey post-hoc test was used to differentiate between the studied variables. $P < 0.005$ was deemed statistically significant. There were significant increases in all the parameters studied among the overweight individuals when compared with those that were normal and underweight, but foot circumferences showed no significant difference when compared among the body mass index. The studied parameters had a peak increase at age 40 – 49 years followed by a gradual decline from age 50 – 79 years old. There were positive significant correlations between body mass index and other parameters studied excluding the foot circumference which was negative and not significant. It was evident that all the studied parameters excluding foot circumference have the ability of predicting body mass index.

KEYWORDS; Body Mass Index, Body Circumferences, Kumana Chiefdom, Girls, Women

INTRODUCTION

Body mass index (BMI) is a metric currently in use for defining anthropometric height/weight characteristics in adults and for classifying them into groups. BMI was created by a Belgian astronomer, Adolphe Quetelet (1796 – 1874), and it was initially called the Quetelet index. The Quetelet index was adopted by the World Health Organization (WHO) and renamed Body Mass Index (BMI) in the year 1995 [1]. BMI was developed and categorized into quartiles; underweight (<18.5), normal (18.5 – 24.99), overweight (25 – 29.99), and obese (30+) [1,2]. It is commonly used to represent an individual's body fat. It also serves as a risk factor for the development or prevalence of several health issues [3].

Several controversies about the usefulness of BMI in predicting body fat had been raised as discovered from reports of cross-sectional and prospective epidemiological survey which provided evidence that the cut-offs of BMI provided by WHO, do not adequately reflect the overweight or obesity status of a population [4]. For instance, a higher body fat percentage is correlated with lower BMIs among Asians while among Pacific Islanders, higher BMIs tend to be associated with more muscle mass and less body fat [5]. Apart from ethnicity, the universal applicability of BMI has also been raised concerning age, physical activity and most importantly, as a less reliable predictor of cardiovascular risks [6]. Simple measurements of body weight and body mass index which do not yield good assessments of either the body composition or distribution of body fat, other tools such as the body circumferences can be an alternative to assess the distribution of adiposity [7].

Anthropometry technique is a major tool in quantifying body size and proportions. Earlier 1990s, equations for predicting body fat were being developed from measurements of body circumference, length, width, and skinfold thickness [8]. The distinct advantages of this technique are that it is portable, noninvasive, inexpensive, useful in field studies, and clinically for the estimation of fat distribution, and prediction of metabolic diseases [9, 10.] Circumferences measured at mid arm, mid-thigh, waist, and hip are mostly studied than others because they indicate differences among people in major regions of the body [8].

Body circumferences such as mid-upper-arm, arm, elbow, hip, and waist are of great importance in determining body weight and tissue composition. In children and adolescents, studies has shown that nutritional status, prepubertal and pubertal obesity can be determined using the various body circumference measurements [11,12,13]. Individuals with normal body weight as defined by body mass index (BMI) might still be at risk of metabolic syndrome, insulin resistance and increased mortality if they have a high body content [14], even people with normal body mass index (BMI) but enlarged waist circumference have a higher rate of cardiovascular events and death [15].

The importance of the knowledge of the different body circumferences and their relationship with BMI cannot be over emphasis in both clinical and anthropometry studies. This study, however, aimed to investigate the different body circumferences of girls and women in Kumana Chiefdom, Kauru Local Government Area of Kaduna State, Nigeria.

MATERIALS AND METHODS

A randomized cross-sectional sampling was employed in the selection of the samples. A total of 678 females were selected for this study, all of them ranging between 10 – 78 years of age and devoid of any physical abnormalities or deformities. This study was conducted in Kumana Chiefdom, Kauru Local Government Area of Kaduna State, Nigeria. Measurement of the body

circumferences was taken using a measuring non-stretchable tape-measure (0.1 cm accuracy). The measuring tape was used to measure the arm circumference, forearm circumference, foot circumference, hand circumference, neck circumference, waist circumference, hip circumference, calf circumference [8]. A weighing balance was used for taking weight of the subjects and stadiometer was used for taking the height. Body mass index was calculated as follows: weight (kg)/ height^2 (m^2). The study protocol was reviewed and approved by Health Research Ethics Committee on Human Subjects of the Ahmadu Bello University Zaria (ABUTHZ/HREC/N09/2015) and permission to conduct the study was obtained from the authorities of the participating communities as well as, only subjects who gave informed consent to participate in the research were included in the study. Statistical analysis was performed using the SPSS software version 21. All results were expressed as Mean ± Standard deviation. Pearson correlation was used to determine the correlation between the study variables, simple linear and multiple linear regression analyses were performed to derive population specific equations for predicting BMI and ANOVA followed by Tukey post-hoc test was used to differentiate between the studied variables. $P < 0.005$ was deemed statistically significant.

RESULTS

This study was able to show the difference of the body circumferences at different age group and BMI categories. The result obtained from this study revealed that 78.5% of the study population is between the ages of 10 to 39 years old and 67.7% being normal weight (Table 1). The average age of the studied population was 27.69±15.58 years old with a BMI of 22.21±3.79. The waist, hip, and foot circumferences were discovered to be 76.39±9.55, 89.77±9.89, 21.48±2.76 respectively. The neck circumference was reported to be (30.96±2.89), while the mid arm, elbow, forearm, arm, and hand circumferences were discovered to be 25.49±2.93, 23.54±2.08, 20.90±2.15, 25.58±2.89 and 22.71±1.62 (Table 2). There were significant increases in all the parameters studied among the overweight individuals when compared with those that were normal and underweight, but foot circumferences showed no significant difference when compared among the body mass index. Weight, mid arm, elbow circumferences showed significant differences when compared between overweight and obese individuals, while the others were not significantly different (Table 3). The studied parameters had a peak increase at age 40 – 49 years followed by a gradual decline from age 50 – 79 years old (Table 4). There were positive significant correlations between body mass index and other parameters studies excluding the foot circumference which was negative and not significant (Table 5). It was evident that all the studied parameters excluding foot circumference have the ability of predicting body mass index.

Table 1: Descriptive statistic of the Age group and Body mass index quartiles

Age Range	Frequency	Percent
Age Group		
10 – 19	333	49.1
20 – 29	80	11.8
30 – 39	115	17.0
40 – 49	67	9.9
50 – 59	35	5.2
60 – 69	39	5.8
70 – 78	9	1.3
Body Mass Index Quartiles		
Under weight	89	13.1
Normal weight	446	67.7
Over weight	102	15.0
Obese	28	4.1

Table 2: Baseline Characteristics of the study population

Parameters	N	Mean	Std. Deviation	Minimum	Maximum
Age	678	27.69	15.58	10.00	78.00
Weight	678	52.01	10.24	28.00	94.00
Height	678	1.53	0.06	1.32	1.84
BMI	678	22.21	3.79	13.42	37.65
Waist circumference	678	76.39	9.55	16.00	118.00
Mid arm circumference	678	25.49	2.93	18.00	38.00
Forearm circumference	678	20.90	2.15	2.00	30.00
Elbow circumference	678	23.54	2.08	16.00	39.30
Foot circumference	678	21.48	2.76	8.50	32.00
Neck circumference	678	30.96	2.85	7.50	49.50
Arm circumference	678	25.58	2.89	18.00	39.30
Calf circumference	678	30.27	3.16	16.00	44.00
Hand circumference	678	22.71	1.62	15.30	32.00
Hip circumference	678	89.77	9.89	39.00	189.00

Table 3: Body mass index quartiles differences in the studied parameters

	Under Weight	Normal Weight	Over Weight	Obese	f	p
Age	19.28±1.60[a]	26.33±0.70[b]	38.18±1.39[c]	38.79±1.59[c]	34.282	<0.001
Weight	39.17±4.67[a]	50.28±5.38[b]	63.77±6.56[c]	77.43±8.59[d]	502.679	<0.001
Height	1.51±0.08[a]	1.53±0.06[ab]	1.54±0.07[b]	1.54±0.06[ab]	3.060	0.028
WC	68.51±9.98[a]	75.95±6.94[b]	82.73±8.82[c]	85.64±19.29[c]	55.270	<0.001
MAC	22.89±2.46[a]	25.21±2.13[b]	27.52±2.60[c]	29.52±4.73[d]	82.489	<0.001
FAC	20.06±1.55[a]	20.82±2.17[b]	21.53±1.98[c]	22.11±2.67[c]	11.113	<0.001
EC	21.95±1.88[a]	23.31±1.72[b]	25.10±1.86[c]	26.20±2.52[d]	71.258	<0.001
FC	21.17±1.19	21.61±2.56	21.10±3.90	21.32±4.30	1.333	0.263
NC	29.44±3.27[a]	30.65±2.49[b]	32.86±2.55[c]	33.69±3.05[c]	39.402	<0.001
AC	23.00±2.43[a]	25.41±2.34[b]	27.42±2.65[c]	28.43±3.93[c]	61.311	<0.001
CC	28.49±2.59[a]	30.35±2.97[b]	30.82±3.02[b]	32.50±4.97[c]	16.321	<0.001
HaC	21.94±1.32[a]	22.68±1.56[b]	23.16±1.81[c]	23.61±1.63[c]	12.878	<0.001
HiC	82.67±6.45[a]	89.20±9.37[b]	96.18±8.26[c]	98.61±12.58[c]	44.752	<0.001

BMI: body mass index, WC: waist circumference, MAC: mid arm circumference, FAC: forearm circumference, EC: elbow circumference, FC: foot circumference, NC: neck circumference, AC: arm circumference, CC: calf circumference, HaC: hand circumference, HiC: hip circumference. *One-way ANOVA test followed by Tukey post hoct test; Results expressed as mean ± SEM, cells carrying different superscripts on each row are significantly different ($p<0.05$).*

Table 4: Differences among the age-groups

	10 - 19 yrs.	20 - 29 yrs.	30 - 39 yrs.	40 - 49 yrs.	50 - 59 yrs.	60 - 69 yrs.	70 – 79 yrs.	f	P
Weight	46.45±6.84^{a}	55.80±8.42^{b}	56.79±7.80^{cb}	62.07±12.69^{d}	58.26±11.60^{bcde}	55.44±10.47^{bcf}	48.67±9.73^{bca}	52.798	<0.001
Height	1.51±0.06^{a}	1.53±0.06^{ac}	1.54±0.06b^{cd}	1.56±0.08^{b}	1.55±0.06^{bcd}	1.55±0.07^{bce}	1.56±0.12^{bca}	8.322	<0.001
BMI	20.23±2.44^{a}	23.89±3.34^{b}	24.10±3.42^{bc}	25.48±4.64^{c}	24.24±4.27^{bc}	23.10±3.36^{bd}	20.11±4.58^{ad}	47.222	<0.001
WC	73.22±6.72^{a}	77.08±8.25^{b}	78.34±7.73^{bd}	82.62±14.89^{c}	82.54±11.15^{cd}	81.74±10.01^{bc}	68.67±18.10^{abe}	19.939	<0.001
MAC	24.14±2.20^{a}	26.13±2.25^{b}	27.03±2.52^{bc}	27.90±3.67^{c}	27.66±3.87^{bc}	26.11±2.40^{b}	24.11±1.76^{a}	36.073	<0.001
FAC	20.97±1.95^{ab}	20.57±2.18^{ab}	21.18±2.04^{a}	21.24±3.15^{a}	21.00±2.16^{ab}	19.95±1.58^{ab}	19.06±1.63^{ab}	3.441	0.002
EC	22.75±1.71^{ac}	24.10±1.69^{bc}	24.42±2.00^{bc}	24.93±2.45^{b}	24.63±2.66^{bc}	23.53±1.75^{ac}	22.67±1.41^{ac}	23.040	<0.001
FC	21.78±1.39^{a}	19.12±5.42^{b}	21.59±3.34^{a}	22.38±1.90^{a}	21.99±1.11^{a}	21.56±1.37^{a}	20.78±1.54^{ab}	13.268	<0.001
NC	30.00±2.59^{a}	31.53±2.15^{b}	31.62±2.60^{b}	33.01±3.48^{c}	32.33±2.89^{bc}	31.53±2.61^{bc}	30.00±1.87^{ab}	17.723	<0.001
AC	24.56±2.59^{a}	25.85±1.99^{b}	26.81±2.76b^{c}	27.53±3.38^{c}	26.73±3.22^{bc}	25.51±2.36^{b}	24.67±2.87^{b}	18.781	<0.001
CC	30.42±2.77^{a}	30.38±3.15^{ac}	29.98±3.12^{ac}	31.03±4.03^{a}	30.62±3.80^{ac}	28.71±3.55^{bc}	27.44±2.40^{ab}	3.889	0.001
HaC	22.66±1.55^{a}	22.54±1.58^{a}	22.89±1.35^{a}	22.91±1.71^{a}	23.07±1.95^{a}	22.49±2.34^{a}	21.67±1.22^{a}	1.646	0.132
HiC	86.67±6.81^{a}	89.80±8.31^{ab}	92.95±8.11^{b}	97.89±15.78^{c}	93.63±8.47^{bc}	90.54±15.33^{ab}	85.44±9.79^{ab}	18.525	<0.001

BMI: body mass index, WC: waist circumference, MAC: mid arm circumference, FAC: forearm circumference, EC: elbow circumference, FC: foot circumference, NC: neck circumference, AC: arm circumference, CC: calf circumference, HaC: hand circumference, HiC: hip circumference. *One-way ANOVA test followed by Tukey post hoct test; Results expressed as mean ± SEM, cells carrying different superscripts on each row are significantly different (p<0.05)*.

Table 5: Correlation matrix table showing the correlation coefficient of the study population

	Age	Weight	Height	BMI	WC	MAC	FAC	EC	FC	NC	AC	CC	HaC	HiC
Age	1													
Weight	0.438**	1												
Height	0.256**	0.495**	1											
BMI	0.387**	0.911**	0.102**	1										
WC	0.325**	0.536**	0.290**	0.472**	1									
MAC	0.388**	0.671**	0.346**	0.606**	0.515**	1								
FAC	-0.051	0.314**	0.228**	0.248**	0.178**	0.432**	1							
EC	0.285**	0.616**	0.335**	0.549**	0.419**	0.782**	0.422**	1						
FC	0.022	0.063	0.166**	-0.012	0.023	0.187**	0.227**	0.174**	1					
NC	0.281**	0.486**	0.277**	0.430**	0.369**	0.519**	0.247**	0.506**	0.090*	1				
AC	0.270**	0.571**	0.295**	0.514**	0.443**	0.854**	0.431**	0.744**	0.177**	0.473**	1			
CC	-0.077*	0.320**	0.220**	0.262**	0.215**	0.375**	0.252**	0.369**	0.178**	0.382**	0.371**	1		
HaC	0.023	0.337**	0.266**	0.257**	0.170**	0.352**	0.309**	0.362**	0.189**	0.214**	0.352**	0.301**	1	
HiC	0.278**	0.540**	0.321**	0.463**	0.605**	0.490**	0.229**	0.443**	0.088*	0.366**	0.426**	0.192**	0.224**	1

BMI: body mass index, WC: waist circumference, MAC: mid arm circumference, FAC: forearm circumference, EC: elbow circumference, FC: foot circumference, NC: neck circumference, AC: arm circumference, CC: calf circumference, HaC: hand circumference, HiC: hip circumference. *One-way ANOVA test followed by Tukey post hoct test; Results expressed as mean ± SEM, cells carrying different superscripts on each row are significantly different ($p<0.05$).*

Table 6: Linear regression equations for estimation of body mass index from different body circumferences

	Predictive Equations	R	R^2	SEE	f	p
Age	BM1 = 19.51 + (0.096*Age)	0.39	0.15	3.59	117.531	<0.001
Weight	BMI = 4.69 + (0.337*WT)	0.91	0.83	1.56	3289.660	<0.001
Height	BMI = 12.86 + (6.094*HT)	0.10	0.01	3.87	6.511	0.011
WC	BMI= 7.11 + (0.197*WC)	0.48	0.23	3.42	195.633	<0.001
MAC	BMI= 1.31 + (0.820*MAC)	0.61	0.37	3.15	367.455	<0.001
FAC	BMI = 12.36 + (0.469*FAC)	0.24	0.06	3.77	42.483	<0.001
EC	BMI = -1.89 + (1.022*EC)	0.55	0.29	3.26	286.579	<0.001
NC	BMI = 4.33 + (0.576*NC)	0.42	0.18	3.52	146.744	<0.001
AC	BMI = 4.21 + (0.703*AC)	0.52	0.27	3.36	237.360	<0.001
CC	BMI= 12.63 + (0.316*CC)	0.26	0.07	3.67	49.470	<0.001
HaC	BMI= 8.55 + (0.601*HC)	0.26	0.07	3.67	47.508	<0.001
HiC	BMI= 6.02 + (0.180*HiC)	0.46	0.21	3.46	179.119	<0.001

BMI: body mass index, WC: waist circumference, MAC: mid arm circumference, FAC: forearm circumference, EC: elbow circumference, NC: neck circumference, AC: arm circumference, CC: calf circumference, HaC: hand circumference, HiC: hip circumference.

DISCUSSION

Body mass index in respect to obesity is not only an important public health concern but also a psychosocial issue among humans. This study has been able to evaluate the estimation of body mass index using different body circumferences among Girls and Women of Kumana Chiefdom, Kauru Local Government Area of Kaduna State, Nigeria.

The result obtained from this study revealed a significant increase in all the body circumferences excluding FC in the overweight quartile of BMI when compared with the normal and underweight quartile which is in agreement with the report of Banik *et al*. [16]. This shows that there is a corresponding increase in the body circumferences as the BMI increases, also there was a consistent significant linear increase as the age group increases in all the body circumferences evaluated and peaking at age 40 – 49 years before a further decline starting from 50 years. Fryar and colleagues [17] also reported a significant linear increase in waist circumference over time among adults in the United States. Żegleń *et al*., [18] also reported a trend increase in mid upper arm circumferences of India male children and adolescents. The outcome of this result could be attributed to the significant changes in body composition that occur with ageing, with a substantial reduction in fat-free-mass and muscle mass and an increase in visceral fat even if body weight remains unaltered [4].

Waist circumference (WC) is a major parameter that have been studied to have a consign relationship with central obesity. This study revealed that WC has a positive correlation with BMI and also increases with the level of BMI quartiles. Freedman and Ford, [19] also reported a strong correlation between BMI and WC meanwhile, Griffiths *et al*. [20], had recommended that WC rather than BMI as an index obesity-health risks in adults as well as in the pediatric population since WC is a highly sensitive and specific measure of truncal adiposity and a strong predictor of visceral obesity [4].

MAC, FAC, EC, NC, AC, CC, HaC and HiC all showed significant positive correlation with BMI. This is in agreement with the works of Ben-Noun *et al*. [21], Hingorjo *et al*. [22], Sultana [23], Benítez-Brito *et al*. [24], Alahmari *et al*. [25], Alzeidan *et al*. [26], Sisay *et al*. [27], Gonzalez *et al*. [28]. Anthropometric characteristics such as but not limited to body circumferences are widely used to diagnose overweight/obesity, as well as to accurately assess the tissue composition of the body [29]. For example, upper-arm girth is reported to be 90% sensitive and specific as an indicator of overweight and obesity [30].

CONCLUSION

Obesity is a concerned public health issue among all races, gender and tribe. It is therefore imperative to frequently monitor the body parameters to prevent the accumulation of excess body fat and its associated morbidities. BMI as a tool commonly used to monitor obesity has its own limitations, has it does not take into consideration factors such as bone density, size of muscle tissue, varying proportions of fat, body water and bone tissue. Anthropometry parameters such as body circumferences could be a better alternative.

Conflict of Interest: The authors declare that there was no conflict of interest.

REFERENCES

1. WHO Expert Committee. WHO physical status: The use and interpretation of anthropometry: Report of a World Health Organization (WHO) Expert Committee. Geneva. 1995. Retrieved from

http://www.who.int/childgrowth/publications/physical_status/en/

2. Markowitz, J. S. *Body Mass Index (BMI). Mortality and Its Risk Factors Among Professional Athletes*, 2018; 39–49.
3. Nuttall, F. Q. Body mass index: obesity, BMI, and health: a critical review. *Nutrition today*, 2015; *50*(3), 117.
4. Bhurosy, T., & Jeewon, R. Pitfalls of using body mass index (BMI) in assessment of obesity risk. *Current Research in Nutrition and Food Science Journal*, 2013; *1*(1), 71-76.
5. Weisell, R. C. Body mass index as an indicator of obesity. *Asia Pacific journal of clinical nutrition*, 2002; *11*: S681-S684.
6. Muralidhara, D. V., Bhat, M. R., & Ahmed, M. N. Body composition in subjects of different age and body mass index. *Journal of Physiological and Biomedical Sciences*, 2009; *22*: 23-28.
7. Klimek-Piotrowska, W., Koziej, M., Hołda, M. K., Piątek, K., Wszołek, K., Tyszka, A., ... & Walocha, J. Anthropometry and body composition of adolescents in Cracow, Poland. *PLoS One*, 2015; *10*(3), e0122274.
8. Wang, J., Thornton, J. C., Kolesnik, S. & Pierson, R. N. Anthropometry in Body Composition: An Overview. *Annals of the New York Academy of Sciences*, 2006; 904(1), 317–326.
9. Gu, Z., Li, D., He, H., Wang, J., Hu, X., Zhang, P., ... & Ji, G. Body mass index, waist circumference, and waist-to-height ratio for prediction of multiple metabolic risk factors in Chinese elderly population. *Scientific reports*, 2018; *8*(1), 1-6.
10. Lahav, Y., Epstein, Y., Kedem, R., & Schermann, H. A novel body circumferences-based estimation of percentage body fat. *British Journal of Nutrition*, 2018; *119*(6), 720-725.
11. Cândido AP, Freitas SN & Machado-Coelho GL. Anthropometric measurements and obesity diagnosis in schoolchildren. *Acta Paediatrica*. 2011; 100(9), e120–e124
12. Kryst L, Żeglen M, Wronka I, Woronkowicz A, Bilińska-Pawlak I. Das R, Saha R, Das S. & Dasgupta P. Anthropometric variations in different BMI and adiposity levels among children, adolescents and young adults in Kolkata, India. *Journal of Biosocial Science* 2019b ; 51(4), 603–618.
13. Żegleń, M., Kryst, Ł., Dasgupta, P., Saha, R., Das, R., & Das, S. Time trends in mid-upper-arm anthropometry from 1982 to 2011 in male children and adolescents from Kolkata, India. *Journal of Biosocial Science*, 2020; 53(1), 71–81.
14. Musa, D.I., Toriola, A.L., Monyeki, M.A.& Lawal, B. Prevalence of childhood and adolescent overweight and obesity in Benue State, *Nigeria. Tropical Medicine and Internal Health*, 2012; 17(11):1369-1375.
15. Romaro- Corral, A., Somers, V.K., Sierra-Johnson, J., Korenfield, Y., Boarin, S., Korinek, J., Jensen, M.D., Parati, G. & Lopez-Jimenez, F. Normal weight obesity: A riskfactor for cardiometabolic dysregulation and cardiovascular mortality. *European Hearts*. 2010; 31(6): 737-746
16. Banik, S. D., Ghosh, M., & Bose, K. Anthropometric and body frame size characteristics in relation to body mass index and percentage body fat among adult Bengalee male brick-kiln workers from Murshidabad, West Bengal, India. *Anthropologischer Anzeiger*, 2016; *73*(4), 313-321.

17. Fryar, C. D., Kruszan-Moran, D., Gu, Q., & Ogden, C. L. Mean body weight, weight, waist circumference, and body mass index among adults: United States, 1999–2000 through 2015–2016. 2018.
18. Żegleń, M., Kryst, Ł., Dasgupta, P., Saha, R., Das, R., & Das, S. Time trends in mid-upper-arm anthropometry from 1982 to 2011 in male children and adolescents from Kolkata, India. *Journal of Biosocial Science*, 2021; *53*(1), 71-81.
19. Freedman, D. S., & Ford, E. S. Are the recent secular increases in the waist circumference of adults independent of changes in BMI? *The American journal of clinical nutrition*, 2015; *101*(3), 425-431.
20. Griffiths, C., Gately, P., Marchant, P. R., & Cooke, C. B. *A five-year longitudinal study investigating the prevalence of childhood obesity: comparison of BMI and waist circumference. Public Health,* 2013; *127(12), 090–1096*
21. Ben-Noun, L., Sohar, E., & Laor, A. Neck circumference as a simple screening measure for identifying overweight and obese patients. *Obesity research*, 2001; *9*(8), 470-477.
22. Hingorjo, M. R., Qureshi, M. A., & Mehdi, A. Neck circumference as a useful marker of obesity: a comparison with body mass index and waist circumference. *JPMA-Journal of the Pakistan Medical Association*, 2012; *62*(1), 36.
23. Sultana, T., Karim, M. N., Ahmed, T., & Hossain, M. I. Assessment of under nutrition of Bangladeshi adults using anthropometry: can body mass index be replaced by mid-upper-arm-circumference? *PloS one*, 2015; *10*(4), e0121456.
24. Benítez-Brito, N., Suárez Llanos, J. P., Fuentes Ferrer, M., Oliva García, J. G., Delgado Brito, I., Pereyra-García Castro, F., ... & Palacio Abizanda, E. Relationship between mid-upper arm circumference and body mass index in inpatients. *PloS one*, 2016; *11*(8), e0160480.
25. Alahmari, K. A., Silvian, S. P., Reddy, R. S., Kakaraparthi, V. N., Ahmad, I., & Alam, M. M. Hand grip strength determination for healthy males in Saudi Arabia: A study of the relationship with age, body mass index, hand length and forearm circumference using a hand-held dynamometer. *Journal of International Medical Research*, 2017; *45*(2), 540-548.
26. Alzeidan, R., Fayed, A., Hersi, A. S., & Elmorshedy, H. Performance of neck circumference to predict obesity and metabolic syndrome among adult Saudis: a cross-sectional study. *BMC obesity*, 2019; *6*(1), 1-8.
27. Sisay, B. G., Haile, D., Hassen, H. Y., & Gebreyesus, S. H. Performance of mid-upper arm circumference as a screening tool for identifying adolescents with overweight and obesity. *PloS one*, 2020; *15*(6), e0235063.
28. Gonzalez, M. C., Mehrnezhad, A., Razaviarab, N., Barbosa-Silva, T. G., & Heymsfield, S. B. *Calf circumference: cutoff values from the NHANES 1999–2006. The American Journal of Clinical Nutrition*, 2021; *113(6), 1679–1687.*
29. Debnath S, Mondal N & Sen J. Use of upper arm anthropometry, upper arm muscle area-by-height (UAMAH) and midupper-arm-circumference (MUAC)-for-height as indicators of body composition and nutritional status among children. *Anthropological Review* . 2017; 80(1), 85–102

30. Jaiswal M, Bansal R & Agarwal A. Role of mid-upper arm circumference for determining overweight and obesity in children and adolescents. *Journal of Clinical and Diagnostic Research.* 2017; 11(8), SC05–SC08