Onagbiye, S.O. et al. (2017). Body circumference parameters predict body mass index in children aged 2-5 years.
Anthropologist 30(2): 147-152.
http://dx.doi.org/10.1080/09720073.2017.1377885

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Body circumference parameters predict body mass index in children aged 2-5 years

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Abstract

Body circumference parameters have become simple screening measurements that can be used as an indicator of body fat distribution to detect pediatric obesity. The purpose of this study was to determine the relationships that exist between body circumference parameters of head, neck, arm, forearm, waist, hip, mid-thigh, front-thigh and body mass index (BMI). A total of forty randomly selected children with the mean age of 2.97 years participated in this study. Stature, body mass, and body circumferences were measured according to the protocol of the International Society for the Advancement of Kinanthropmetry (ISAK). All the participants' parents completed informed consent forms before their children could be allowed to participate in the study. There was a significant correlation between the hip and neck circumferences and BMI. Regression analyses revealed that BMI was best predicted by the combined effect of neck and hi neck circumferences. Combined effects of hip and neck circumferences were significant predictors of BMI in children.

Introduction

The prevalence of pediatric obesity has increased in the Western world, and has become a great concern in the unindustrialised and recently industrialised countries (Blasingame 2017; Sahoo et al. 2015; Maffeis et al. 2001). Pediatric obesity and overweight on the other hand have become public health issues (Maffeis et al. 2001). The main likely cause of pediatric obesity is the enhancement in the standards of living, technology advancements and automations, nutritional variations, other lifestyle variations such as smoking, alcohol abuse, and insufficient physical activity levels (IPAL) (Kaur and Walia 2007). These have led to an increase in body weight and obesity for many, and have reduced the quality of life (QoL) (Onagbiye et al. 2016) in both children and adults. Obesity and overweight in children is associated with risk factors for cardiovascular and metabolic disorders, and require careful observations (Magalhães et al. 2014). It does not only affect the children physically, but also has a big negative impact on the personal and psychosocial life (Maffeis et al. 2001).

In the United States, the medical care cost of obesity was high. The medical care cost of obesity was estimated to be USD 147 billion dollar (Finkenstein et al. 2009). In Nigeria, overweight and obesity is rapidly increasing among the youths. As stated in the study of

Akarolo-Anthony et al. (2014), the data from the World Health Organization revealed that the prevalence of overweight and obesity increased by approximately twenty percent, between the year 2002 and year 2010 in Nigeria. Furthermore, obesity is an ailment that is frequently challenging in terms of treatment (Maffeis et al. 2001). Therefore, aiming at early detection and proffering intervention could reduce the difficulties in later life (Magalhães et al. 2014; Wadden 1999; Maffeis et al. 2001).

Increased levels of BMI have known to be a risk factor for many illnesses and disorders (Booth et al. 2000). Fat deposit in excess around abdominal area is associated with the metabolic disorders, while authors recommend measures of abdominal adiposity as the preferred measures (Vanltallie 1998; Booth et al. 2000). On the other hand, it was reported that waist circumference (WC) was the utmost practical and precise assessment of abdominal obesity that could be used in public health research (Booth et al. 2000). Meanwhile, BMI and WC could show relatively diverse types of adiposity, and should not be expected that they are associated (Booth et al. 2000). In addition, both BMI and WC were indirect assessment of body adiposity, which stands as prediction of health risks (Ojoawo et al. 2014). A study had also shown that apart from WC, there are other body circumference parameters such as the circumference of the neck that was understood to be associated with the BMI (Saka et al. 2014). Therefore, the purpose of this study was to examine the relationships between BMI and body circumferences, and to find out which of the body circumference parameters have higher prediction power among children aged 2-5 year old.

Methodology

Research Design and Participants

The descriptive survey, which involves a cross-sectional design method was used to collect data on anthropometric variables. The participants comprise of forty (20 male and 20 female) healthy children ranging from 2 to 5 years of age (mean ± SD: 2.97±0.91 years) who were randomly selected participated in this study. The age of the participants were verified from the school register during the recruitment.

Anthropometric Measurements

Stature, body mass and body circumferences (head, neck, arm, forearm, waist, hip, mid-thigh, and front-thigh) were measured according to the protocol of the International Society for the Advancement of Kinanthropmetry (ISAK) (Marfel-Jones et al. 2006). Stature was measured to the nearest 0.1 cm in bare feet with participants standing upright against the improvised wall ruler, which was correlated with the stadiometer. A correlation of 0.89 at $p < 0.001$ was obtained. A digital bathroom weighing scale calibrated regularly to the nearest 0.1 kg after every 10 measurements was used to measure body mass with participants lightly dressed. The body mass index (Quetelet's Index) of each participant was computed using Lohman (1987) equation: Weight (Kg) / $[\text{Height (m)}]^2$

Measurement Procedure

Permission to conduct the measurements was granted by the school proprietor and the teacher in charge of sporting activities and health. Permission was also sort from the parents of the participants as all of them agreed to allow the participation of their children in the study. All the participants' parents or guardian completed informed consent forms before their children could participate in the study. On the other hand, the children gave verbal assent to partake in the study. This was after the purpose of the study has been explained to them. On the participants' arrival in the morning, the participant's height, weight and circumferences (head, neck, arm, forearm, waist, hip, mid-thigh, and front-thigh) were measured. The ethical standard of the Helsinki pronouncement for study that involved human (World Medical Association 2013) subjects were followed.

Data Analyses

Independent sample *t*-test was performed to determine the significant differences in the variables. Normality test were performed for all variables using the Shapiro-Wilk test and visual inspection of Q-Q plots. In order to determine the relationships between body circumference and BMI, the spearman's rho correlation coefficient analysis or Pearson's correlation was performed if the data distribution was skewed or normal, respectively. Dancey and Reidy's (2004) categorization of correlations interpretation was used. Correlations among independent variables (predictors) were examined in order to identify highly correlated variables for consideration in regression modeling. Univariate regression analysis was performed in order to identify significant predictors of BMI. Multiple linear (backward) regression modeling was used to determine the relative influence of variables. Only the variable that was significant in the bivariate correlation was put in the model. Test for interaction was performed among variables that conceptually made sense. Hence, regression models also included significant interaction variables as predictors. Alpha level was set at 0.05 and data was analyzed using the statistical software of SPSS version 23.0 for Microsoft Windows (IBM SPSS Inc., Chicago, IL).

Results

A total of forty [(male, n = 20 (50%); and female, n = 20 (50%)] children participated in the study. Table 1 shows physical characteristics of participants. Table 2 compared the body circumference of male and female participants, while Table 3 gives a summary of relationship between body circumference parameters and body mass index. There were no significant differences in the age of the participant, although the mean age value for girls was higher than that of their male counterpart. There were significant differences between the weight of male (12.6±1.03 kg) and female (11.6±1.18 kg) participants. Also, waist and hip circumference of male (52.9±2.30 cm and 53.9±2.29 cm) was significantly higher than that of their female (50.8±2.11 cm and 51.6±2.01 cm) counterpart, respectively (Table 1). Compared to females (50.8±2.11 cm), the male (52.9±2.30 cm) waist circumference was statistically significantly higher. Hip circumference in males (53.9±2.29 cm) was also statistically significantly higher than that of their female (51.6±2.01 cm) counterpart. Furthermore, the mean value for the neck circumference of male (25.1±1.26 cm) participants was statistically significantly more than that of females (24.3±0.80 cm) (Table 2). A bivariate correlation showed that there was a statistically significant correlation between the hip circumference and BMI (r = 0.398, p = 0.011) of the participant. On the other hand, neck circumference (r = 0.315, p = 0.048) was statistically significantly correlated with the

BMI, while no correlation was found for head (r = 0.075, p = 0.646) and arm circumference (r = - 0.034, p = 0.837) with BMI (Table 3). Univariate analysis showed that neck circumference and hip circumference were significant predictors of BMI (β= 0.605; p = 0.016 and β = 0.296; p = 0.011, respectively). The interaction between neck circumference and hip circumference (Neck*Hip) also significantly predicted BMI (β= 0.009; p = 0.002). Using backward regression, six possible models were created as shown in Table 4. The results revealed that the model with Neck*Hip variable (model 6) was the best of all possible models since it had the highest value of adjusted R^2, which represents the amount of variance (20.7%) in the BMI predicted by the model.

Table 1: Physical characteristics of the participant (Mean ± SD) (n=40)]

Variables	*Male (n=20)*	*Female (n=20)*	*Total (n=40)*	*Max. – Min.*	*p-value*
Age (yr)	2.95±0.94	3.00±0.91	2.97±0.91	2.00 -5.00	0.866
Height (m)	0.87±0.04	0.85±0.04	0.86±0.04	0.80 -0.96	0.318
Weight (Kg)	12.6±1.03	11.6±1.18	12.1±1.21	10.0 -14.0	0.007*
BMI (Kg/m^2)	16.7±1.91	15.8±1.61	16.2±1.80	12.3 -0.3	0.140
Waist Circ (cm)	52.9±2.30	50.8±2.11	51.8±2.44	47.0 -58.0	0.004*
Hip Circ (cm)	53.9±2.29	51.6±2.01	52.7±2.42	49.0 -58.0	0.002*
WHR	0.98±0.03	0.98±0.02	0.98±0.03	0.94 -1.10	0.877

Significant; BMI-Body Mass Index, Circ.-circumference

Table 2: Comparison of body circumferences of male and female participants (Mean ± SD) (n=40)

Variables	*Male*	*Female*	*Total*	*t*	*p-value*
Waist circumference	52.9±2.30	50.8±2.11	51.8±2.44	3.072	0.004*
Hip circumference	53.9±2.29	51.6±2.01	52.7±2.42	3.374	0.002*
Head circumference	48.8±1.08	48.2±1.85	48.5±1.53	1.353	0.184
Neck circumference	25.1±1.26	24.3±0.80	24.7±1.13	2.534	0.016*
Chest circumference	53.0±2.06	52.2±1.06	52.6±1.67	1.539	0.132
Arm circumference	15.6±0.94	15.2±0.96	15.4±0.95	1.161	0.253
Forearm circumference	16.2±1.00	16.0±0.94	16.1±0.96	0.486	0.630
Mid-thigh circumference	27.7±1.55	27.7±2.33	27.7±1.95	0.000	1.000
Front-thigh circumference	24.5±1.14	24.3±2.23	24.4±1.75	0.267	0.791

Significant

Table 3: Correlation matrix showing relationship between BMI and body circumferences (n=40)

Variables	*BMI*	*Waist C*	*Hip C*	*Head C*	*Neck C*	*Chest C*	*Arm C*	*Forearm C*	*Mid-thigh C*	*Front-thigh C*
BMI [a]	1.000	.225	.398*	.075	.315*	.190	-.034	.179	.144	.269
Waist circumference [a]	.225	1.000	.702**	.325*	.379*	.377*	.076	.016	.353*	.349*
Hip circumference [a]	.398*	.702**	1.000	.322*	.339*	.188	.123	.130	.400*	.501**
Head circumference [a]	.075	.325*	.322*	1.000	.327*	-.035	-.081	.036	.373*	.508**
Neck circumference [a]	.315*	.379*	.339*	.327*	1.000	.218	-.029	.084	.282	.207
Chest circumference [a]	.190	.377*	.188	-.035	.218	1.000	.258	.023	-.071	-.111
Arm circumference [a]	-.034	.076	.123	-.081	-.029	.258	1.000	.625**	-.065	-.041
Forearm circumference [a]	.179	.016	.130	.036	.084	.023	.625**	1.000	-.094	-.028
Mid-thigh circumference [a]	.144	.353*	.400*	.373*	.282	-.071	-.065	-.094	1.000	.762**
Front-thigh circumference [b]	.259	.366*	.472**	.563**	.216	-.088	-.049	-.002	.809**	1

Note: * Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)
[a]p value calculated from spearman rho
[b]p value calculated from Pearson correlation coefficient
C-Circumference

Discussion

The purpose of this study was to examine the relationships between BMI and waist circumference, and to know which of the body circumference parameters is with the highest prediction power among children aged 2-5 years old. Evaluation of the body composition of individuals are essential for having a health related quality health status. On the other hand, body composition assessment provides valuable data on people's health status (Ojoawo et al. 2014). Body mass index and the circumference of the waist were understood to have been regularly used variables in assessing obesity (Kaur and Walia 2007) and or adiposity (Maffeis et al. 2001). However, the negative effect of having an increased norm for the BMI and waist circumference is that, it could lead to numerous cardiometabolic disorders (Kaur and Walia 2007).

However, waist circumference has been most favourably used to measure abdominal obesity. It has also been found to positively correlate with the BMI in children, and could provide anthropometric assessment information about total body fatness (Magalhães et al. 2014). Considering the findings regarding the physical characteristics of the participants, the value for BMI was below normal norm according to the International Obesity Task Force (IOTF) cut-off point (Valerio et al. 2013). In total, all the participants fell within the thinness grade three category, which is also regarded as underweight. The reason for this could be due to low socioeconomic background and under nutrition. Other suggested reasons are the limited or no access to high-calorie nibbles and fast food, which is not inexpensive (Goon et al. 2012).

In this study, the researchers found that the hip had a significant relationship with BMI. These findings were in agreement with findings of Giugliano and Melo (2004) who found that a relationship exists between BMI and waist and hip measurements. In an Iranian study, which compared BMI and inverted BMI in evaluating body measurement, resting blood pressure, dual energy X-ray absorptiometry (DEXA) parameters of fat mass, and metabolic risk factors among children also found a significantly positive correlation between BMI and hip circumference (Saki et al. 2016).

This study's findings also showed a significant positive relationship between the BMI and the neck circumference of the participant. Neck circumference has been understood to be an evolving indicator of fatness and connected disease risks. Furthermore, its use as a screening tool in children could pose a challenge as age and gender cut-offs are yet to be established (Katz et al. 2014). Evidences have shown that an individual with a larger neck size could foretell if that individual is overweight or obese (Katz et al. 2014; Mazicioglu et al. 2010; Nafiu et al. 2010). This includes other illnesses such as the metabolic, cardiovascular disease, and obstructive sleep apnea (Katz et al. 2014). Mazicioglu et al. (2010) and Nafiu et al. (2010) who found similar results also supported these findings. Findings from the regression analysis showed that neck circumference and hip circumference were significant predictors of BMI. Furthermore, the effect of neck circumference on BMI prediction was significantly modified or depended on hip circumference and vice versa (interaction effect). The use of backward regression analysis to determine which of the variables in the model is most predicting revealed that either neck or hip circumference could predict BMI. These findings revealed that with an increase in neck circumference (Saka et al. 2014), and hip circumference, the likelihood of cardiovascular risk factor increases. Saka et al. (2014) stated further that an individual with higher value for neck circumference was more likely to have cardiovascular and metabolic disorder.

Table 4: Backward regression analysis presenting the best model that predicts BMI

Model	*Variables in the model*	*Unstandardized coefficient*	*P-value*	*R^2*	*Adjusted R^2*
1	(constant)	97.129	0.576	0.234	0.17
	Neck*Hip	0.078	0.551		
	Hip circumference	-1.705	0.598		
	Neck circumference	-3.763	0.593		
2	(constant)	5.648	0.36	0.227	0.186
	Neck*Hip circumference	0.009	0.053		
	Neck circumference	-0.058	0.887		
3	(constant)	-0.653	0.354	0.226	0.184
	Hip circumference	0.226	0.056		
	Neck circumference	0.441	0.08		
4	(constant)	1.343	0.822	0.144	0.121
	Neck circumference	0.605	**0.016**		
5	(constant)	0.701	0.905	0.158	0.136
	Hip circumference	0.296	**0.011**		
6	(constant)	4.932	0.156	0.227	**0.207**
	Neck*Hip circumference	0.009	**0.002**		

Conclusion

The findings of this study indicates that among the body circumference parameters, a combination of neck and hip circumference significantly predicts BMI among Nigerian children aged 2-5 year old.

Recommendations

It was recommended that future studies to establish these facts with larger sample size should be considered. Furthermore, regular health screening for children should be embarked on, in other to prevent any future occurrences of unwanted diseases, emanating from overweight and obesity.

Limitations

This study limitation is that its findings should be interpreted with cautions and cannot be generalised, considering the small sample size that was used.

Acknowledgements

The authors acknowledge the participants of this study, and the assistance of the proprietor and the teachers during the data collection.

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