Neck Circumference as an Indicator of Overweight and Obesity in Young Adults

Noora Shrestha[*]

Department of Mathematics and Statistics, Padma Kanya Multiple Campus, Tribhuvan University, Kathmandu, Nepal
*Corresponding author: shresthanoora@gmail.com

Abstract Neck circumference (NC) measurement is one of the simple screening measurements, that can be used as a marker of upper body fat distribution to notice overweight. The objective of this study is to evaluate the relationship between NC and overweight/obesity. In this cross-sectional study a total 198 college students (120 Female, 78 Male) aged 18-23 years were participated using convenience method. Anthropometric measurements of students were measured according to the guidelines of world health organization. Students with NC $\geq$37 cm for male and $\geq$34 cm for female and BMI $\geq$ 25 kg/m^2 are identified as overweight. The percentages of the male and female students with BMI $\geq$ 25 kg/m^2 were 9% and 15.8% respectively and with high NC were 47.4% and 23.3 % respectively. In both male and female students, there were significant and positive correlation of neck circumference with body weight (male, r=0.572; female, r=0.629; p=0.001), waist circumference (male, r= 0.407; female, r= 0.623; p=0.001), hip circumference (male, r=0.546; female, r=0.579; p=0.001), BMI (male, r= 0.532; female, r= 0.588; p=0.001), waist to hip ratio (female, r = .376; p= .001), and waist to height ratio (male, r= 0.33; female, r= 0.574; p=0.001). A significant and independent association was found between NC and overweight levels using multiple regression analysis in young adults. This study indicates neck circumference is a simple screening measure that can be used to identify overweight/obesity.

Keywords: neck circumference, body mass index, overweight, anthropometry

1. Introduction

Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health [1]. Overweight or obesity, significantly, once it happens in students, may be a major health problem. There are mainly four types of assessment to determine obesity: anthropometry, density, conductivity, and radiography. For health purposes, the percentage of body fat and its distribution are significant factors, but determining this factor is not easy. Different assessment methods yield different results, some more accurate than others [2,3].

The most widely used technique of calculating and identifying obesity is Body Mass Index (BMI). In adults Overweight, or pre-obesity, is defined as a BMI of 25-29.9 kg/m², while a BMI $\geq$ 30 kg/m² defines obesity [4]. BMI is a simple measure that is very useful for population not individual basis. It is considered as a rough guide for predicting risk in individuals because it provides ranges based on height and weight which often don't take into account differences in ethnicity, age, body build, and muscle development.

Other methods include neck circumference, waist circumference, hip circumferences, waist to height ratio, and waist to hip ratio. Waist circumference is an inexpensive and cool method of measurement that is considered a rational marker of intra-abdominal or visceral fat. This fat is diligently related with increased risk of comorbidity [5]. Obviously, waist circumference is based on averages, so if people are outside the average in height or body build; waist circumference alone may not be an accurate measure [6,7].

The waist to hip ratio (WHR) is a simple measure of central obesity. The score from the WHR predicts the risk of developing several conditions associated with excess abdominal fat [5]. Researches show that the amount of abdominal fat correlates with the degree of stress, so it is hard to determine which is the causative factor in health problems- the fat or the stress or some combination of both. Nevertheless, the WHR is an important determinant of risk [8,9]. Waist to height ratio (WHtR) is a measure of the distribution of body fat that indicates the risk of obesity related diseases depending on the value of WHtR. It is calculated dividing waist circumference by height of a person [10]. The people with WHtR value $\geq$ 0.53 in male and $\geq$ 0.49 in female are categorized as overweight. It is considered as a better marker of abdominal obesity that corrects the waist circumference according to the individual's height [11,12,13].

Neck circumference (NC) measurement has freshly been used to recognize overweight and obesity and is perceived to have significant correlation with age, body

weight, waist circumference, hip circumferences, waist/hip ratio, and BMI for both genders [14]. Researchers have shown the use of neck circumference as a simple screening method to identify obesity and overweight [15]. NC is reflected as a marker of upper body obesity and correlates significantly with changes in systolic and diastolic blood pressure [16]. Hence, the available literature review has not recognized the single paramount anthropometric measure or marker to verify the association with overweight and obesity.

Many researches conducted in different part of the world suggest that neck circumference can be used as a simple screening measure of overweight and obesity [14,17]. In this regard, the purpose of this study was to examine the relationship between neck circumference and overweight and obesity and also it examines the association of other anthropometric measures with BMI for the prediction of overweight and obesity in students.

2. Materials and Method

The cross sectional study using convenience sampling method was conducted in DAV College, Kathmandu, Nepal during July to August 2017. Out of 355 students of Bachelor's level, 198 students age between 18 to 23 years participated in this study comprising 120 (60.6%) female and 78 (39.4%) male who were free from major health problems. The written consent was received from the students before conducting the study, and the ethical approval was obtained from the Research and Ethics Committee of the college.

2.1. Anthropometric Measurements and Indices

Each student's demographic information along with body weight, height, neck circumference (NC), waist circumference, and hip circumference were measured by the researcher following WHO standard. All measurements were taken in the morning time. The student's body weight was measured to the nearest (0.1 kg) wearing light clothes and taking off shoes using analog weighing scale. Height was measured without shoes to the nearest (10 mm) using stadiometer. Body Mass Index was computed as dividing weight in kg by height in m^2. According to WHO classification [18], the students were classified into four categories in accordance with the BMI values of <18.5 kg/m^2 as underweight, 18.5 to 24.99 kg/m^2 as normal weight, 25.0 to 29.99 kg/m^2 as overweight and ≥ 30kg/ m^2 as obese.

Circumferences were measured (in cm) using regular inelastic plastic tape with 0.5 cm precision. The measurements were taken while students were standing erect with the arms hanging loosely at sides. The hip circumference (HC) was obtained at the level of the femoral trochanters and the neck circumference was measured below the cricoid cartilage, and afterwards, at the level of the mid cervical spine using plastic tape. While taking this reading, the subject was asked to look straight ahead, with shoulders down, but not hunched. Care was taken not to involve the shoulder/neck muscles in the measurement.

Waist circumference (WC) was taken horizontally to the nearest 10 mm, using plastic tape measure at midpoint between the costal margin and iliac crest with the subject in standing position. WC was then divided by HC to get the waist-to-hip ratio (WHR). Students with waist circumferences >94 cm for male and >80cm for female are categorized as central obesity and with waist/hip ratio >0.90 for male and >0.85 for female considered as abdominal obesity. Waist to height ratio was obtained by dividing waist circumference by height of students. With waist to height ratio ≥ 0.53 for male and ≥ 0.49 for female students are grouped as overweight. Students with NC ≥37 cm for male and NC ≥34 cm for female were categorized as overweight [7].

2.2. Statistical Analysis

The statistical analysis was performed with SPSS version 23.0 for Windows. The outcomes were expressed as the mean ± standard deviation, range, and percentages. Pearson's correlation coefficient was used to determine the relation between various anthropometric indices for continuous variables. A p-value <0.05 was considered to be significant. Multiple regression model was performed to determine the possible relationship of each predictor variables with the outcome variable. Goodness of fit was measured by coefficient of determination R^2.

3. Results

Of the 198 students that participated in the study, 78 (39.39%) were male and 120 (60.6%) females. The range of age of the participants was 18 to 23 years. The mean BMI was 21.24± 2.67 kg/m^2 for male, 21.68 ±2.9 kg/m^2 for female. The 8.97% of the male and 15.8 % of the female were overweight (BMI ≥25kg/m^2). The mean waist circumference and hip circumference of the male and female were 79.4±6.95 cm, 94.7±5.39 cm and 72.5±7.82 cm, 92.78±6.05 cm, respectively. This study has observed 1.3% of male and 15.8% of female students with high waist circumference. The mean waist/hip ratio was 0.837±0.046 in male, 0.781±0.059 in female. The male and female students with high waist//hip ratio were 9% and 12.5% respectively. The average waist to height ratio of male and female students were 0.46±0.041and 0.46±0.049 respectively. The percentage of male and female students with high waist to height ratio and categorized as overweight were 9% and 33.3% respectively. The mean neck circumference of male and female were 36.51±2.026 cm and 32.58±1.81cm respectively. The 47.4% of male and 23.3% of female students neck circumference measurements were higher and grouped as overweight students. The summary output described in Table 1 is produced using the options in the Linear Regression Statistics dialog box. This table tells the mean and standard deviation of each variable used in the study.

The Pearson's correlation coefficient is particularly useful for getting a jagged idea of the associations between predictor and the outcome variables. Table 2 presents the BMI is significantly and positively correlated with waist circumference, hip circumference, waist to hip ratio, waist to height ratio and neck circumference for male and female. The one-tailed significance of each correlation is demonstrated as p < 0.001.

Table 1. General Characteristics of the Study Subjects

Anthropo-metric Measurements	Male (n=78)	Female (n=120)
	Mean ±SD (Range)	Mean ±SD (Range)
Age (Years)	20.79±1.63 (18- 23)	20.7 ± 1.51 (18-23)
Weight (kg)	63.41± 8.6 (47-90)	53.54 ±7.58 (39-73)
Height (cm)	172.7±6.23(152.4-189)	157.21±6.66 (144.8-179.9)
BMI (kg/m^2)	21.24± 2.67 (15-28.5)	21.68±2.9 (16.2-28.2)
WC (cm)	79.4±6.95 (67-97)	72.5±7.82(57-95)
HC (cm)	94.7±5.39(85-113)	92.78±6.05 (80-110)
WHR	0.837±0.046 (0.72-0.95)	0.781±0.059 (0.67-0.98)
WHtR	0.459±0.041(0.38-0.56)	0.46±0.049 (0.37-0.58)
NC (cm)	36.51±2.026 (41-36.5)	32.58±1.81 (29-38)

SD-Standard deviation, BMI- Body Mass Index, WC- Waist Circumference, HC- Hip Circumference, WHR- Waist to Hip Ratio, WHtR- Waist to Height Ratio, NC- Neck Circumference.

Table 2. Pearson's Correlation Coefficient of BMI with Other Variables

Anthropometric Measurements	Male	Female
WC (cm)	0.683	0.676
HC (cm)	0.797	0.766
WHR	0.248	0.290
WHtR	0.736	0.759
NC (cm)	0.532	0.588

BMI- Body Mass Index, WC- Waist Circumference, HC- Hip Circumference, WHR- Waist to Hip Ratio, WHtR- Waist to Height Ratio, NC- Neck Circumference.

Table 3 demonstrates the value of Pearson's Correlation Coefficient of NC with other variables. NC was found moderately and significantly correlated with body weight, BMI, WC, HC, WHtR, and WHR for female but not significantly correlated with WHR for male.

Table 3. Correlation of Neck Circumference with Other Anthropometric Measures

Anthropometric Measurements	Male	Female
Weight (kg)	0.572	0.629
BMI (kg/m^2)	0.532	0.588
WC (cm)	0.407	0.623
HC (cm)	0.546	0.579
WHR	-	0.376
WHt R	0.33	0.574

BMI- Body Mass Index, WC- Waist Circumference, HC- Hip Circumference, WHR- Waist to Hip Ratio, WHtR- Waist to height ratio.

The model summary output (Table 4) of multiple regression analysis using enter method describes the overall model and tells the model is successful in predicting outcome BMI with predictors waist to height ratio, neck circumference, hip circumference, waist/hip ratio, and waist circumference.

Table 4. Model Summary

Gender	Model	R	R^2	Adjusted R^2	SE of the Estimate	Durbin-Watson
Male	1	.907[a]	.822	.809	1.168	1.758
Female	1	.896[a]	.802	.793	1.319	1.565

a. Predictors: (Constant), Waist to Height Ratio, Neck Circumference, Hip Circumference, Waist/ Hip Ratio, Waist Circumference
b. Dependent Variable: Body Mass Index

In the regression model for male, the multiple correlation coefficient between the predictors and the outcome variable BMI is R=0.907. The R square measures the strength of the relationship between the model and the dependent variable. The coefficient of determination R^2 is 0.82 which measures 82% of the variability in the BMI are accounted for by the predictor variables. In model summary, the adjusted R^2 =0.809 gives the idea of how well the model generalizes. The difference between the values of R^2 and adjusted R^2 is 0.822 - 0.809 = 0.013 about 1.3%. It means that if the model was derived from the population rather than a sample it would account for approximately 1.3% less variance the outcome.

In the regression model for female, the multiple correlation coefficient between the predictors and the outcome variable BMI is R=0.896. The value of R^2 = 0.80 indicates 80% variability in dependent variable BMI is explained by the predictors but remaining 20% is unexplained. The difference between R^2 and adjusted R^2 is 0.802 - 0.793 = 0.009 about 0.9%. It shows if the model was derived from the population rather than a sample it would account for nearly 0.9% less variance the outcome.

The p- value is less than the significance level in F test (ANOVA) it means sample data provide sufficient evidence to conclude that the regression model fits the data better than the model with no independent variable. In multiple regression analysis, multi-collinearity tested and only neck circumference (Beta: 0.153, 95% CI: 0.046-0.36, p<0.001) for male and (Beta: 0.129, 95% CI: 0.031-0.381, p<0.001) for female was found to be independently associated with BMI. The positive beta coefficient indicates that for every one-unit increase in the neck circumference, the BMI will increase by the beta coefficient value [19,20].

4. Discussion

World Health Organization [18] defines overweight and obesity as abnormal or excessive fat accumulation that presents a risk to health. Overweight and obesity are chief possibility factors for a number of prolonged diseases such as diabetes, cardiovascular diseases, and cancer. Once considered a problem only in high-income countries, overweight and obesity are now dramatically on the rise in low- and middle-income countries, particularly in urban settings. According to WHO report, in 2016, more than

1.9 billion adults, 18 years and older, were overweight. Of these over 650 million were obese. 39% of adults aged 18 years and over were overweight in 2016, and 13% were obese. Most of the world's population lives in countries where overweight and obesity kills more people than underweight [4].

Some Asian countries have mean BMIs that are among the lowest in the world. But even Bangladesh and other countries where under-nutrition remains a significant threat-Cambodia, China, India, Nepal, and Vietnam-have seen the prevalence of overweight and obesity in women increase from the 1990s through the mid-2000, by anywhere from 3.5 to 38.5 percent a year [21]. There are several methods of measuring overweight and obesity. Several sophisticated methods, such as magnetic resonance imaging, and bioelectrical impedance, can't be used in children or students due to safety concerns [22,32].

A study of 14,425 subjects in Nepal found that 32% were obese, 28% were overweight, 6.3% were diabetic, and 34% had hypertension. Prevalence was higher in the less educated, those working at home, and female [23]. On the basis of BMI, among Nepalese population, the proportion of male respondents who were overweight and obese was 11.8% and 1.5% and the proportion of overweight and obese in female respondent was found to be 12.3% and 2% in the age group 15 - 29 years [24].

In this study, the mean BMI was 21.24 kg/m^2 for male, 21.68 kg/m^2 for female. This shows the female students were more overweight than the male students. This result is consistent with the previous studies. This study result shows among the male students, 14.1% underweight, 76.9% normal weight, and 8.97% overweight. Among female students 15% underweight, 69.2% normal weight, and 15.8% overweight were obtained based on the BMI categories.

The most basic and common method to determine overweight is the body mass index (BMI). But BMI is considered as an indirect and insufficient measurement which does not distinguish between body fat and lean body mass [22,25]. For the evaluation of central obesity, other anthropometric measures are used. Among other anthropometric measures, waist circumference, hip circumferences, waist-to-hip ratio, waist to height ration and neck circumference are useful in clinics and community settings, as well as in large research studies [26,27].

Waist circumference is the easiest way to measure "abdominal obesity"-the additional fat found around the middle but the measurement procedure has not been standardized. On the basis of WHO report, the waist circumference cutoff for Asians was suggested as 90 cm for adult men and 80 cm for adult women, but it differs from one ethnic group to the other. Waist-to-hip ratio (WHR) is also used to measure abdominal obesity but it is more complex to interpret than waist circumference, since increased waist/hip ratio can be caused by increased abdominal fat or decrease in slender muscle mass around the hips. Turning the waist and hip circumference measurements into a ratio leads to a loss of information: Two people with very different BMIs could have the same waist to hip ratio [22,28,31].

This research shows the mean waist circumference and hip circumference of the male and female students were 79.4 cm, 94.7cm and 72.5 cm, 92.78 cm, respectively.

According to WHO standards (WC >94 cm for male, WC >80cm for female), this study found 1.3% of male and 15.8% of female had high waist circumference which indicates there could be increased risk of metabolic complications among the study subjects. In present study, the mean waist to hip ratio of male and female students was 0.837and 0.781respectively. The value of waist to hip ratio shows there is possibility of substantially increased risk of metabolic complications for 9% male and 12.5% female students. The mean waist to height ratio of male and female students was 0.459 and 0.46 respectively. The percentage of male and female students who are grouped as overweight on the basis of waist to height ratio were 9% and 33.3% respectively.

In one of the research paper it was mentioned that the waist to height ratio sustains significant and variable enduring correlation with height over adolescence [6]. The waist-to-height ratio has been suggested as a useful measure, with a suggested cut-off of 0.5 signifying excess risk [29]. In this study, the percentage of male and female students with excessive waist to height ratio and categorized as overweight were 9% and 33.3% respectively.

In present study, the mean neck circumference (NC) of male and female students was found to be 36.5 cm and 32.5 cm respectively. The 47.4% of male and 23.3% of female student's NC measurements were higher than the standards for male and female respectively. In both male and female, neck circumference was correlated significantly and positively with body weight, waist circumference, hip circumferences, BMI, and waist to height ratio but for female students only NC is correlated significantly with waist to hip ratio (p< 0.05). This is consistent with some researches that have observed the relationship of conventional anthropometric measures of overweight/obesity with neck circumference [15,30]. The multiple regression model shows that neck circumference is independent predictor for overweight based on BMI for both male and female. Hence, it can be concluded that neck circumference is an effective indicator for identifying overweight individuals and correlated significantly with other anthropometric measurements.

This study has limitations such as data related to student's dietary habits, physical activity, biochemical measurements etc. were not collected.

5. Conclusion

To sum up, this study presents, in both male and female, there was a significant correlation between neck circumference and specific anthropometric measurements such as body weight, waist circumference, hip circumferences, waist to height ratio, and BMI. The 8.97% of the male and 15.8 % of the female were observed as overweight. Neck circumference is a significant predictor of overweight based on BMI among the college students. So, it can be used as a simple screening measure to identify overweight and obese among students, remarkably for clinical practices and epidemiological investigation. Additionally, more extended researches including body fat and other biochemistry measurements can be conducted for identifying overweight and obesity.

Financial Support and Sponsorship

Conflict of Interest

There are no conflicts of interest.

References

[1] World Health Organization. (2018, June). Obesity and Overweight. Available:http://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

[2] Polymeris, A., Papapetrou, P. D., and Katsoulis, G. (2014). "An Average Body Circumference Can Be a Substitute for Body Mass Index in Women". *Advances in Medicine*, 2014, 6.

[3] Braulio, V. B., Furtado, V. C. S., Silveira, M. G., Fonseca, M. H., and Oliveira, J. E. (2010). "Comparison of body composition methods in overweight and obese Brazilian women". *Arquivos Brasileiros de Endocrinologia and Metabologia*, 54(4), 398-405.

[4] World Health Organization. (2016, June). Global strategy on diet, physical activity, and health. Available: http://www.who.int/dietphysicalactivity/childhood_what/en/.

[5] World Obesity. (2018, July). How is obesity measured? Available: https://www.worldobesity.org/data/cut-points-used.

[6] Tybor, D. J., Lichtenstein, A. H., Dallal, G. E., and Must, A. (2008). "Waist-to-height ratio is correlated with height in US children and adolescents aged 2-18 years". *International Journal of Pediatric Obesity: IJPO: An Official Journal of the International Association for the Study of Obesity*, 3(3), 148-151.

[7] World Health Organization. (2008). Report of a WHO expert consultation waist circumference and waist-hip ratio. Geneva. Borrud: http://www.who.int/nutrition/publications/obesity/WHO_report_waistcircumference_and_waisthip_ratio/en/

[8] Czernichow, S., Kengne, A.P., Huxley, R. R., Batty, G. D., de Galan, B., Grobbee, D., … Chalmers, J. (2011). "Comparison of waist-to-hip ratio and other obesity indices as predictors of cardiovascular disease risk in people with type 2 diabetes: a prospective cohort study from ADVANCE". *European Journal of Cardiovascular Prevention and Rehabilitation: Official Journal of the European Society of Cardiology, Working Groups on Epidemiology and Prevention and Cardiac Rehabilitation and Exercise Physiology*, 18(2), 312-319.

[9] Lawrence, D. K., Anwar, T. M., Janice, P., and Sonia, S. A. (2007). "Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies". *European Heart Journal*, 28(7), 850-856.

[10] Lee, C.M., Huxley, R.R., Wildman, R.P., and Woodward, M. (2008). "Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis". *Journal of Clinical Epidemiology,* 61(7), 646-653.

[11] Ashwell, M., Gunn, P., and Gibson, S. (2012). "Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardio metabolic risk factors: systematic review and meta-analysis". *Obesity Reviews*, 13, 275-286.

[12] Schneider, H.J. et al., (2010). "The predictive value of different measures of obesity for incident cardiovascular events and mortality". *The Journal of Clinical Endocrinology and Metabolism*, 95(4), 1777-85.

[13] Rezende, et al. (2018). "Is waist-to-height ratio the best predictive indicator of hypertension incidence? A cohort study". *BMC Public Health,* 18: 281.

[14] Ben-Noun, L.L., Sohar, E., and Loar, A. (2001). "Neck circumference as a simple screening measure for identifying overweight and obese patients". *Obesity Research*, 9: 470-7.

[15] Nafiu, O.O., Burke, C., Lee, J., Voepel-Lewis, T., Malviya, S., Tremper, K.K. (2010). "Neck circumference as a screening measure for identifying children with high body mass index". *Pediatrics*, 126(2).

[16] Laor, A., and Ben-Noun, L.L. (2004). "Relationship between changes in neck circumference and changes in blood pressure". *American Journal of Hypertension*, 17: 409-14.

[17] Asija, Z., Mehmed, E., Nermina. B., Nesina, A., Amela, D., and Jasminko, H. (2018). "Neck circumference as an indicator of central obesity in healthy young bosnian adults: Cross-sectional study". *International Journal of Preventive Medicine*, 9: 42.

[18] World Health Organization. (2000). Obesity: preventing and managing the global epidemic. Report of a WHO Consultation. WHO Technical Report Series 894. Available: http://www.who.int/topics/obesity/en/.

[19] Field, A. P. (2009). *Discovering statistics using SPSS: (and sex and drugs and rock 'n' roll).* SAGE Publications, Thousand Oaks, Calif.: Los Angeles.

[20] Barton, B. and Peat, J. K. (2014). *Medical Statistics: a guide to SPSS, data analysis, and critical appraisal.* Wiley Blackwell/BMJ Books, Chichester, West Sussex; Hoboken, NJ.

[21] Popkin, B.M., Adair, L.S., and Ng, S.W. (2012). "Global nutrition transition and the pandemic of obesity in developing countries". *Nutrition Reviews*, 70:3-21.

[22] Hu, F. (2008). *Measurements of Adiposity and Body Composition. In: Hu F, ed. Obesity Epidemiology*, Oxford University Press, New York City, 53-83.

[23] Sharma, S. K., Ghimire, A., Radhakrishnan, J., Thapa, L., Shrestha, N. R., Paudel, N., … Brodie, D. (2011). "Prevalence of Hypertension, Obesity, Diabetes, and Metabolic Syndrome in Nepal". *International Journal of Hypertension*, 821971.

[24] World Health Organization. (2013). Non-Communicable Disease Risk Factor Survey Nepal 2013, Kathmandu: World Health Organization. Available: http://www.searo.who.int/nepal/mediacentre/non_communicable_diseases_risk_factors_steps_survey_nepal_2013.pdf.

[25] Flegal, K. M., Shepherd, J. A., Looker, A. C., Graubard, B. I., Borrud, L. G., Ogden, C. L., … Schenker, N. (2009). "Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults". *The American Journal of Clinical Nutrition*, 89(2).

[26] Duren, D. L., Sherwood, R. J., Czerwinski, S. A., Lee, M., Choh, A. C., Siervogel, R. M., and Cameron, C.W. (2008). "Body Composition Methods: Comparisons and Interpretation". *Journal of Diabetes Science and Technology*, 2(6), 1139-1146.

[27] Nkeh-Chungag, B. N., Mxhosa, T. H., and Mgoduka, P. N. (2015). "Association of waist and hip circumferences with the presence of hypertension and pre-hypertension in young South African adults". *African Health Sciences*, 15(3), 908-916.

[28] Chong, H. K. (2016). "Measurements of Adiposity and Body Composition". *Korean Journal of Obesity*, 25(3), 115-120.

[29] Ashwell, M., and Hsieh, S.D. (2005). "Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity". *International Journal of Food Sciences and Nutrition*, 56, 303-7.

[30] Janosen I, Heymsfield SB, et al. (2002). "Body mass index and waist circumference independently contribute to the prediction of non-abdominal, abdominal subcutaneous and visceral fat". *American Journal of Clinical Nutrition*, 75, 683-8.

[31] Kumar, S., Gupta, A., and Jain, S. (2012). "Neck circumference as a predictor of obesity and overweight in rural central India". *International Journal of Medicine and Public health*, 2(1).

[32] Papandreou, D., Noor, Z. T., Rashed, M., and Jaberi, H. A. (2015). "Association of Neck Circumference with Obesity in Female College Students". *Open Access Macedonian Journal of Medical Sciences*, 3(4), 578-581.