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RELATIONSHIP BETWEEN BODY ANTHROPOMETRY AND SELECTED COMPONENTS OF PHYSICAL FITNESS IN YOUNG ADULTS – A SINGLE INSTITUTIONAL STUDY

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ABSTRACT

Anthropometry and physical fitness characteristics provide relevant information about ones health condition. A reduced risk of chronic diseases has been associated with high fitness level often measured by cardio – respiratory fitness parameters leaving out the other measures of physical fitness. Our study therefore investigated the relationship between anthropometric indices and other selected health-related components of fitness. A cross-sectional survey design was used to recruite 400 undergraduate university students (192 males and 208 females) within 18-35 years. The selected anthropometric indices [height (HT), waist-height ratio (WHtR), forearm girth (FAG)] and health-related components of fitness [handgrip strength (HGS), spinal flexibility (SF) and lean body mass (LBM)] were measured using standard procedures. Pearson‘s product correlation shows a significant relationship between HT and HGS ($p = 0.001$), HT and LBM ($p = 0.001$), HT and SF ($p = 0.012$), WHtR and LBM ($p = 0.001$), FAG and HGS ($p = 0.001$); and FAG and LBM ($p = 0.001$). Regression analysis shows that every one unit rise in HT causes 0.056 unit increase in HGS; every one unit rise in FAG causes 0.120 unit increase in HGS. There is a relationship between selected anthropometric indices and health-related fitness indices. Hence, one can be inferred from the other.

1. Introduction

Anthropometry and physical fitness characteristics provide relevant information about normality of body size, shape and health condition [19]. Anthropometric indices are good predictors of physical fitness and vital predictors of non-communicable diseases [25], [27], [8]. Waist-to height ratio is an anthropometric measure which has been shown to be closely related with cardiometabolic risks and disorders for both genders and in different age bands [32]. Physiological factors such as age, sex, body fat as well as lean body mass related to cardiorespiratory fitness, muscular endurance, flexibility and agility, all influence physical fitness [2]. The studies of [37], [39], reported waist circumference to be a predictor of cardiovascular diseases. When compared with waist circumference, waist-height ratio (WHtR) can account for differences in height, and has been proposed a better predictor of CVD risk factors [28]. Since growth and body dimensions at all ages reflect the overall health and welfare of individuals and populations, anthropometry may also be used to predict performance, health and survivals [38], [14].

Physical fitness is generally considered as "the ability to perform daily tasks without fatigue" and it includes several components such as cardiorespiratory fitness, muscular endurance, muscular strength, flexibility, coordination, and speed Most studies on physical fitness in relation to body anthropometry have focused on cardiorespiratory fitness as a measure of physical fitness. Other components of physical fitness have not been thoroughly investigated [13], [33]. The aim of this study is to therefore investigate the relationship between body anthropometry (height, weight, and forearm girth) and selected indices of health related components of fitness (flexibility, muscular strength and body composition).

2. Materials and Methods

2.1 Participants and Data Collection

This study utilized a cross sectional survey design. Four hundred undergraduate students of the University of Nigeria Enugu Campus, aged 18-35 years (192 males and 208 females) who were willing to participate in the study were recruited. They were recruited from the halls of residence, departmental class rooms and faculty auditoriums on campus. The aim of the study and the procedures involved were explained to the participants, and a signed consent was also obtained from the participants prior to the collection of data.

2.2 Inclusion and exclusion criteria

Selection of participants were based on the inclusion and exclusion criteria. Only students of the University of Nigeria Enugu Campus, who fall with the age range of 18-35 years were recruited for the study. Excluded from this study were those with lower limb length discrepancy and musculoskeletal spinal deformities such as scoliosis and kyphosis. These have been reported to affect spinal posture, height measurement, body composition and spinal flexibility [7], [31], [5], [9]. Those with recent hand injury or surgery were also excluded as oedematous, vascular, or inflammatory condition of the hand could affect assessment of handgrip strength and forearm girth [3].

2.3 Research Materials

1. Stadiometer (Detecto Beam Medical Scale, D-439, Detecto): Used for measuring the heights of the participants. The heights of participants were measured to the neatest 1.0cm from the height meter to the vertex of the head using a balanced. The measurement was taken with the participants putting on light clothing, standing erect with no shoes, arms hanging freely, and with the heels and occiput touching the stadiometer.
2. Tape: Non-elastic tape was used to assess for waist circumference and forearm girth. For waist circumference, the reference point used is the umbilicus, which is the midpoint between the anterior superior iliac crest and the lowest rib [21]. The forearm Girth was assessed by taking the measurement along the forearm at the point of the largest circumference, which is usually close to the elbow [40]. The measurement was taken at the right side of the body with the subject's arm held out and the palm facing upward.
3. Calculator: Waist-Height Ratio was calculated by dividing the waist circumference by height in

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centimetres. Lean body mass was calculated using the Boer's formula [29].

LBM for men = (0.407 * weight) + (0.267 * height * 100) – 19.2

LBM for women = (0.252 * weight) + (0.473 * height * 100) – 48.3

4. Floor touch test: The spine was used as a measure of flexibility for the participants. The spinal flexibility was measured using the floor touch test which is part of the Kraus weber fitness protocol [16]. The participants were asked to slowly bend from an erect position and touch the floor with their finger tips for 10 seconds without flexing or hyper extending the knees [30]. This test was graded on a pass/fail basis.

5. Handgrip dynamometer: This was used to assess for muscular strength (handgrip strength) [13] and was read off to the nearest 0.1kg. The classification of the handgrip strength was based on gender and age according to [23]. This classification was grouped into weak, normal and strong using the Camry Electronic Hand Dynamometer Instruction Manual [40].

2.4 Statistical analysis

The data obtained was analysed using Statistical Package for Social Sciences (SPSS), version 23.0. Descriptive statistics was used to calculate the frequency, mean, and standard deviation. Pearson product moment correlation was used to determine the relationship between body anthropometry and the selected components of health related physical fitness. Multiple regression analysis was used to provide the p-value and r2-value for the prediction of physical fitness from body anthropometry. Binary logistic regress was used to provide the p-value and likelihood ratio for the prediction of spinal flexibility class from height and WHtR class. Ordinal logistic regression was used to provide the p-value and likelihood ratio of HGS from height, FAG and WHtR class.

2.5 Ethics statement

Ethical approval was obtained from the Health Research Ethics Committee of University of Nigeria Teaching Hospital Enugu, Nigeria (NHREC/05/01/2008B-FWA00002458-1RB00002323). All the participants for the study gave informed consent and they were all kept anonymous.

3. Results

After data was collected and synthesized, it was analyzed based on the specific objectives of the study.

Table 1 show that the mean age of participants involved in the study is 21.32 ± 2.62, mean height is 171.12 ± 8.51, mean WHtR is 0.46 ± 0.05, and the mean FAG is 26.43 ± 2.99. The mean LBM for the study is 51.06 ± 7.40, the mean SF (in seconds) is 8.35 ± 3.04, and the mean HGS is 56.94 ± 25.67.

Table 1 Descriptive Analysis of Anthropometric indices and Components of Physical Fitness Variables of the participants (n = 400)

Anthropometry	Minimum	Maximum	Mean ± SD
Age (years)	18	32	21.32 ± 2.62
Height (m)	147	196	171.12 ± 8.51
WHtR	0.194	0.722	0.46 ± 0.05
FAG (cm)	20.0	51.6	26.43 ± 2.99

Physical Fitness			
LBM	29.66	73.67	51.06 ± 7.40
SF (in secs)	1	10	8.35 ± 3.04
HGS (kg)	5.00	113.33	56.94 ± 25.67

Key: WHtR - Waist Height Ratio, FAG - Forearm Girth, LBM – Lean Body Mass, SF – Spinal flexibility, HGS – hand grip strength

Table 2 revealed a statistically significant moderate positive correlation between height and HGS (r = 0.448, *P* = 0.001); a statistically significant weak negative correlation between height with SF (r = -0.125, *P* = 0.001) and a statistically significant strong positive correlation between height and LBM (r = 0.821, *P* = 0.001). The table also shows a statistically significant weak positive correlation between WHtR and LBM (r = 0.146, *P* = 0.003). There is a statistically significant moderate positive correlation between FAG and HGS (r = 0.421, *P* = 0.001), statistically significant strong positive correlation between FAG and LBM (r = 0.665, *P* = 0.001).

Table 2. Pearson Product Moment Correlation of all Variables

	Height	**WHtR**	**FAG**	**LBM**	**HGS**	**SF**
Height	1					
WHtR	r = -0.259** p = 0.001	1				
FAG	r = 0.396** p = 0.001	r = 0.361** p = 0.001	1			
LBM	r = 0.821** p = 0.001	r = 0.146** p = 0.003	r = 0.665** p = 0.001	1		
HGS	r = 0.448 p = 0.001	r = -0.011 p = 0.828	r = 0.421** p = 0.001	r = 0.528** p = 0.001	1	
SF	r = -0.125* p = 0.012	r = 0.072 p = 0.151	r = 0.060 p = 0.234	r = - 0.022 p = 0.664	r = 0.052 p = 0.296	1

Keys: WHtR – Waist Height Ratio, LBM – Lean Body Mass, SF – Spinal Flexibility, HGS – hand grip Strength, FAG – Forearm girth
** Correlation is significant at 0.01; *Correlation is significant 0.05

Table 3 revealed that the independent variables (height and FAG) statistically predict HGS, $F(2, 397) = 73.810$, $P<0.05$, $r^2 = 0.271$. The unstandardized coefficient for height is 1.004 ($P = 0.001$), for FAG is 2.485 ($P = 0.001$). This reveals that as height and FAG increases, HGS increases. The table also show that height statistically predict spinal flexibility, $F(1, 398) = 6.359$, $P<0.05$, $r^2 = 0.016$. The unstandardized coefficient for height is -0.045 ($P = 0.012$). This result reveals that as height increases, spinal flexibility decreases. From the table, height, WHtR and FAG statistically predict LBM, $F(3, 396) = 779.632$, $P<0.05$, $r^2 = 0.001$. The unstandardized coefficient for height is 0.680 ($P = 0.001$), for FAG is 0.653 ($P = 0.001$), and for WHtR it is 35.223 ($P = 0.001$). The results from this table show that LBM can be predicted from height, WHtR and FAG.

Table 3 Linear Regression of Physical Fitness and body Anthropometry (n = 400)

Variables	Df	F-ratio	r^2	P value	B
Linear Regression Analysis to Predict Handgrip from Height and FAG					
Overall Significance	2 397	73.810	0.271	0.001	
Independent Significance					
Height				0.001	1.004
FAG				0.001	2.485
Linear Regression Analysis to Predict Spinal Flexibility from Height					
Overall significance	1 398	6.359	0.016	0.012	
Independent significance					
Height				0.012	-0.045
Linear Regression Analysis to Predict Lean Body Mass from Height, WHtR and Forearm Girth					
Overall significance	3 396	779.632	0.891	0.001	
Independent significance					
Height				0.001	0.680
WHtR				0.001	35.223
FAG				0.001	0.653

Key: FAG – Forearm girth, df – degree of freedom, B – unstandardized coefficient, FAG – Forearm girth, WHtR – waist-height ratio

Table 4 show that there is a significant effect of height on handgrip strength, LR: $X^2(1) = 17.147$, *P* = 0.001. For every one unit increase in height there would be 0.056 unit increase in grip strength. The table also shows a significant effect of forearm girth on grip strength, LR: $X^2(1) = 8.442$, *P* = 0.004. For every one unit increase in height there would be 0.120 unit increase in grip strength. The table also revealed that WHtR have no significant effect on hand grip strength category of the participants, LR: $X^2(3) = 2.697$, *P* = 0.441. The wald's test and estimate for each of WHtR class also shows no significant effect handgrip strength. WHtR (obese) is set to zero as the data is not large enough for the ordinal regression.

Table 4 Ordinal Logistic Regression (n = 400)

HGS Class Vs Height		**B**	**SE**	**Wald**	**CI**	**P value**
Threshold	HGS (weak)	7.458	2.400	9.655	(2.752) – (12.163)	0.002*
	HGS (normal)	8.602	2.408	12.767	(3.883) – (13.321)	0.001*
Location	Height (cm)	0.056	0.014	15.708	(0.028) – (0.084)	0.001*
LR: $X^2(1) = 17.147$, p = 0.001						
HGS Class Vs FAG						
Threshold	HGS (weak)	1.036	1.101	0.886	(-1.122) – (3.193)	0.347
	HGS (normal)	2.166	1.102	3.865	(0.007) – (4.325)	0.049*
Location	FAG (cm)	0.120	0.042	8.149	(0.038) – (0.203)	0.004*
LR: $X^2(1) = 8.442$, p = 0.004						
HGS Class from WHtR classs						
Threshold	HGS (weak)	-1.250	0.559	4.996	(-2.346) – (0.154)	0.025
	HGS (normal)	-0.135	0.553	0.059	(-1.218) – (0.949)	0.808
Location	WHtR(underweight)	0.762	0.606	1.582	(-0.425) – (1.950)	0.208
	WHtR(normal)	0.916	0.570	2.583	(-0.201) – (2.032)	0.108
	WHtR(overweight)	0.886	0.624	2.013	(-0.338) – (2.109)	0.156
	WHtR(obese)	0^a				
LR: $X^2(3) = 2.697$, p = 0.441						

LR: Likelihood ratio, FAG – Forearm girth, HGS – hand grip Strength, B – Estimate, SE – Standard error, WHtR – Waist Height Ratio

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. *Significant at $P < 0.01$. a: parameter is set to zero because it is redundant

Table 5 show that there is no significant effect of height on spinal flexibility, LR: $X^2(1) = 2.936$, $P = 0.087$. The wald's test also shows no significant effect of height categories on spinal flexibility, $X^2(1) = 2.930$, $P = 0.087$. The table also shows there is no significant effect of WHtR on spinal flexibility, LR: $X^2(3) = 0.336$, $P = 0.953$. The wald's test also shows no significant effect of WHtR categories on spinal flexibility, $X^2(3) = 0.328$, $P = 0.955$.

Table 5 Binary Logistic Regression to Predict Spinal Flexibility Class from Height and WHtR classs (n = 400)

SF Vs Height		**B**	**SE**	**Wald**	**Exp(B)**	**CI**	**P value**
Step1a	Height	0.023	0.014	2.930	1.023	(0.997) – (1.051)	0.087
	Constant	-5.076	2.332	4.737	0.006		0.030*
LR: $X^2(1) = 2.936$, p = 0.087							
SF Vs WHtR class							
Step1a	WHtR class			0.328			0.955
	WHtR class(1)	0.018	0.718	0.001	1.018	(0.249) – (4.154)	0.980
	WHtR class(2)	0.031	0.682	0.002	1.032	(0.271) – (3.927)	0.963
	WHtR class(3)	-0.165	0.737	0.050	0.848	(0.200) – (3.594)	0.823
	Constant	-1.099	0.667	2.716	0.333		
LR: $X^2(3) = 0.336$, p = 0.953							

*Significant at $P < 0.05$. LR: Likelihood ratio, WHtR – Waist Height Ratio, SF – Spinal Flexibility

4. DISCUSSION

Analysis of the data revealed a statistically significant positive correlation between height and handgrip strength as well as prediction of handgrip strength from height. This implies that as height increases, handgrip strength also increases. This could be attributed to the increase in length of lever arm with increased height. The greater the distance of the force arm (muscle) from the axis (joint), the greater is the force generated [11]. The finding from this study is in line with that of [35], which showed that height correlated positively with right and left hand grip strength. The study conducted by [18], also showed a positive correlation of height with hand grip strength. However, the study of [26] showed that height correlated positively with right hand grip strength and negatively with left hand grip strength. This could be as a result of Lamarck's principle of use and disuse [10], as the dominant hand of most individuals is the right. Further analysis of our data showed that height could be used to predict if an individual would have weak, normal or strong handgrip strength.

Findings from the study revealed a statistically significant negative correlation between height and spinal flexibility. Linear regression also revealed that spinal flexibility can be predicted from height. This implies that as height increases, spinal flexibility decreases. This could be as a result of increased lower limb length and change in body mechanics with increase in body height. This is explained in the study done by [20], where he reported that spinal mobility is affected by height; with longer lower limbs, there is reduced spinal flexibility which is probably as a result of increased distance to the feet. In the study conducted by [34], leg length correlated negatively with flexibility. Increased moment arm could also be a factor to decreased spinal mobility. Muscles with long moment arm produce less angular excursion unlike muscles with short moment arm. In contrast, according to [26], there is a significant positive correlation between height and flexibility when sit and reach test is used. A difference in modality could be the reason for the contrasting result since sit and reach test majorly assesses the hamstring while the floor touch test assesses the trunk [15]. Another reason to the contrasting result could be the difference in interpretation of the result as the floor touch test makes use of time in seconds. Further analysis using binary logistic led us to infer that the ability of an individual to pass or fail the spinal flexibility test using the finger to floor is not dependent on height.

Results from the study show a statistically significant positive correlation between height and lean body mass. This study also revealed that height is a predictor of lean body mass. A possible reason to this could be an increased organ size, increased muscle mass, bigger bones and more water associated with increased body height [24]. The findings from this study backs up that of [17], which showed a positive correlation between height and lean body mass. The study by [12], also revealed that height is a strong predictor of lean body mass. Findings from our study as well showed that there is a statistically significant positive correlation between waist-height ratio and lean body mass. This result corroborates the findings of [22], which showed a positive association between waist-height ratio and lean body mass.

From the study, there is no statistically significant correlation between waist-height ratio and handgrip strength. In contrast to this result, findings from [36], showed a significant negative association between handgrip strength and waist-height ratio. The reason for this discrepancy could be attributed to the difference in sample size. Findings from the study also revealed that there is no statistically significant correlation between waist-height ratio and flexibility. This result support the findings of [6], which also reported no significant relationship exists between waist-height ratio and flexibility in both male and female. In the study conducted by [34], using body weight, no significant relationship with flexibility. Our findings also revealed that an individual's WHtR class or category has no significant effect on spinal flexibility.

Results show a statistically significant correlation between forearm girth and hand grip strength. Findings from this study also revealed that handgrip strength can be predicted from forearm girth and that the likelihood ratio of forearm girth predicting weak, normal or strong handgrip strength is positive. The findings from this study is in line with that of [4]. Which revealed that forearm circumference predicted maximum handgrip strength for men. The increased forearm circumference could be as a result of increased muscle mass leading to a greater generation of force as there are more muscle fibres contracting. The increased muscle fibres would lead to increase in muscle proteins [3]. Stated that the muscles which are used to produce grip force predominate in the forearm, and findings from their study showed a positive correlation between handgrip strength and forearm circumference. [1], further stated that handgrip dominance is associated with increased forearm girth. This study revealed no statistically significant correlation between forearm girth and spinal flexibility. This implies that, though forearm girth and flexibility have a linear relationship, an increase in forearm girth does not cause an increase in flexibility of the spine and vice versa.

Findings from this study show a statistically significant relationship between forearm girth and lean body mass. An increased muscle mass which is one of the components of lean body mass could be the cause of an increased lean body mass with increase in forearm girth. Further analysis of data revealed that lean body mass can be predicted from forearm girth. This is in line with the study by [12]. Which showed that forearm girth is a positive predictor of lean body mass.

5. Conclusions

There is a relationship existing between the selected anthropometric indices and health-related fitness indices. Height is a predictor of HGS, LBM and SF. Weak, normal and strong hand grip strength can be predicted from height and FAG. Therefore, FAG, height, WHtR may be useful for functional assessments of health related components of fitness.

6. Study Limitations

Data was collected randomly from participants with no consideration for their active or inactive participation in sports or any structured regular exercise. Level of physical activity and fitness was also not assessed. This could have affected the relationship between variables.

7. Acknowledgement

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