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Influences of Body Composition on Carotid Artery Structure and function in Adult Humans

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Abstract

Objective: *The aim of this study is to investigate the influences of body composition on carotid artery structure and function in adult humans.* ***Methods:*** *50 volunteers were considered for carotid ultrasound scanning using Doppler ultrasound machine to measure their lumen diameter (LD), intima-media thickness (IMT), peak systolic velocity (PSV) and End Diastolic velocity (EDV), pulsatility index (PI) and resistivity index (RI) of their right and left common carotid artery (CCA). Body composition was classified using body mass index (BMI) and waist-to-height ratio (WHtR) values calculated from mass, height and waist measurements.* ***Results:*** *The right peak systolic velocity (RPSV) has a negative correlation with WHtR ($p<0.05$), right intima-media thickness (RIMT) ($p<0.01$), right lumen diameter (RLD) ($P<0.05$) and age ($p<0.05$) but positively correlated with Height ($p<0.01$). Right end diastolic velocity (REDV) is strongly correlated negatively with RLD ($p<0.01$), left lumen diameter (LLD) ($p<0.05$) while it is positively correlated with age ($p<0.05$). Left peak systolic velocity (LPSV) has a positive correlation with height while the left end diastolic velocity (LEDV) is positively correlated with WHtR.* ***Conclusion****: Measurements such as height, WHtR, IMT, LD and blood flow velocity (BFV) are significantly linked with cardiovascular diseases.*

Keywords: Intima-Media Thickness; Common Carotid Artery; Doppler ultrasound; Body Composition

1.0 Introduction

The measurement of human body composition plays an important role in qualifying health and nutritional status, the impact of disease, and change due to nutritional, therapeutic, or behavioral intervention. It is made up of components such as fat mass (FM) and fat-free mass (FFM) which consists of bone, water and protein (González, 2013). Anthropometrics involving waist circumference (WC), weight and height can be used to compute parameters such as body mass index (BMI), waist-to-height ratio (WHtR) and waist-to-hip ratio(WHR) which have been known to influence high metabolic risk and hypertension in both male and female adult Chinese population (Gu et al., 2018; Chen et al., 2018). Arterial distensibility has a strong association with body composition measurements such as BMI, percentage of body fats, WC in both women and men with a p-value; $p < 0.05$, (Fernberg et al., 2019). People who are tall have a larger absolute LD than those who are short, while IMT is independent of stature. These observations potentially add to the growing cardiovascular literature aimed at explaining the lower risk of ischemic strokes in tall people

(Hwaung et al., 2019). Body mass index (BMI), also called Quetelet index (Garabed, 2007) is considered to be useful in medicine because it provides a paradigm to understand and estimate the risk factors for health problems (Fareed & Afzal, 2014). Higher values of WHtR indicate higher risk of obesity-related cardiovascular diseases; it is correlated with abdominal obesity (Lee et al., 2008). The idea of using waist to height ratio to predict cardio metabolic risk is not new, but is coming to prominence as more studies reveal its value of predicting an accurate lifespan. It also has the simplicity of the health message "keep your waist circumference to less than your height" (Ashwell & Browning, 2011).

A research conducted in Iraq (Essa & Al-Sabbagh, 2019) shows an increment in IMT and LD in patients with both diabetes and hypertension than diabetes only. A significant difference was also found in the values of the PSV, EDV, PI and RI for diabetic and hypertensive patients. This means that IMT, PSV, EDV, PI and RI are profound predictive value of atherosclerosis, cardiovascular disease and ischemic changes in diabetic and hypertensive Iraqi patients. However, the usefulness of carotid artery IMT measurement by ultrasound method in clinical practice remains uncertain (Gee-Hee & Ho-Joong, 2017). IMT values in the common carotid artery progressively increased from 0.61 ± 0.10 mm in normal healthy people to 0.79 ± 0.09 mm in mild stenosis persons, to 0.96 ± 0.10 mm in moderate stenosis persons and 1.05 ± 0.10 mm in severe stenosis people, respectively (Rafati et al., 2017). Measurements of PSV, EDV, and PSV/EDV ratio are significant since the peak systolic velocity is the primary Doppler parameter considered majorly for categorizing degree of stenosis (Mehra, 2010). A normal PSV range in CCA is from 60–100 cm/s or 78–118 cm/s (<125 cm/s), above this range there may be some stenosis present in the CCA or some obstruction must have occurred (Roman et al., 2006; Govind et al., 2008; Roddy, 2010; Oglat et al., 2018), while normal EDV range in CCA is between 20 and 32 cm/s, the RI between 0.72 and 0.84, and PI between 0.98–1.94 (Govind et al., 2008; Oglat et al., 2018; Mikkonen et al., 1997; Oglat et al., 2018; Ammar et al., 2018).

Many researchers have discovered a relationship between carotid IMT with FM, FFM, BMI, WC, WHR, and WHtR (Dogan et al., 2010; Park et al., 2015; Melo et al., 2014), but to the best of our knowledge, not many studies have been conducted on the effects of these body compositions on blood flow and function in the human carotid artery. It is based on this that this study is aimed at investigating the effects of weight, height, Waist circumference, BMI and WHtR on BFV, LD and IMT in the CCA of averagely healthy subjects in Nigeria. This will help in comparing the impact of these risk factors on the health status of Nigerians and other parts of the world considering the fact that not many of such researches have been conducted in Africa.

2.0 Subjects, Materials and Methods

The study was carried out on 50 apparently healthy (living an active life) adult human subjects with ages ranging from 19 to 75 years made up of 25 males and 25 females among a cross section of Nigerians. Brightness-Mode (B-Mode) Doppler ultrasound machine Type LOGIQ 5 EXPERT operated at 6MHz with an insonation angle of 60^0 was used for taking measurements of the IMT, LD, PSV and EDV on the right and left CCA of the subjects by a professional consultant Radiologist. The researchers obtained written consent of the subjects to participate in the study which was approved by the ethical committee of Jos University Teaching Hospital (JUTH) where the measurements were taken.

Each subject was made to lie down in the supine position on an examination bed with the neck and chest of the person exposed and a few drops of water soluble semi-liquid ultrasound gel applied to the body surface around the neck. The probe was rotated on the right neck region until the carotid artery was displayed on screen (Figure 1). The IMT, LD, PSV, EDV on the right and left CCA were measured as displayed on the screen (Figure 2).

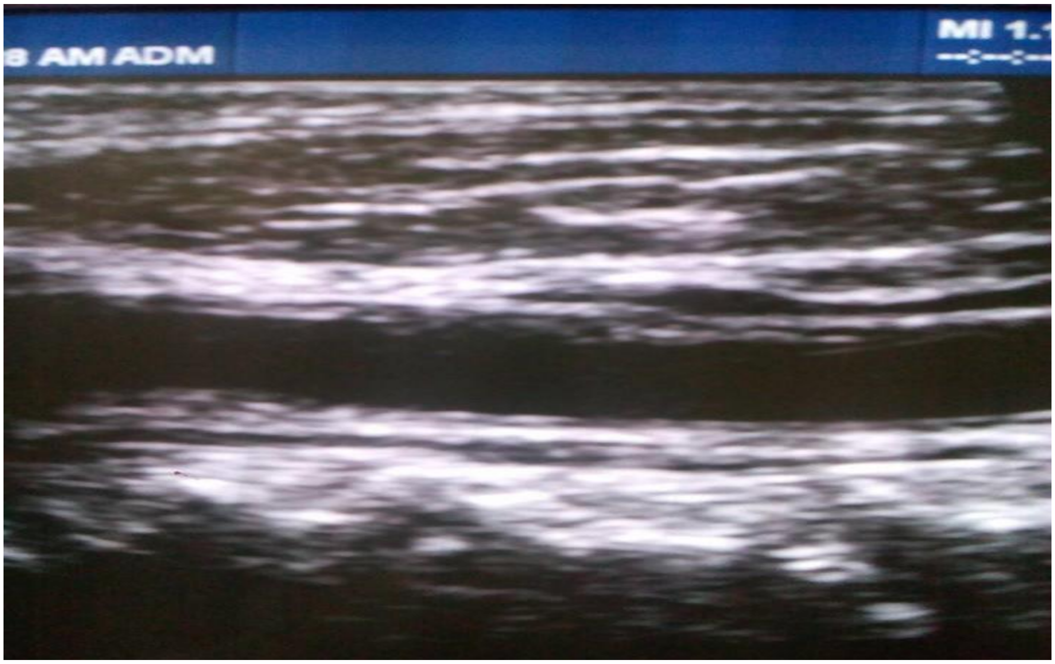

Figure 1: Structure of the common carotid artery (CCA) of the human subjects showing Lumen Diameter and Intima-Media Thickness.

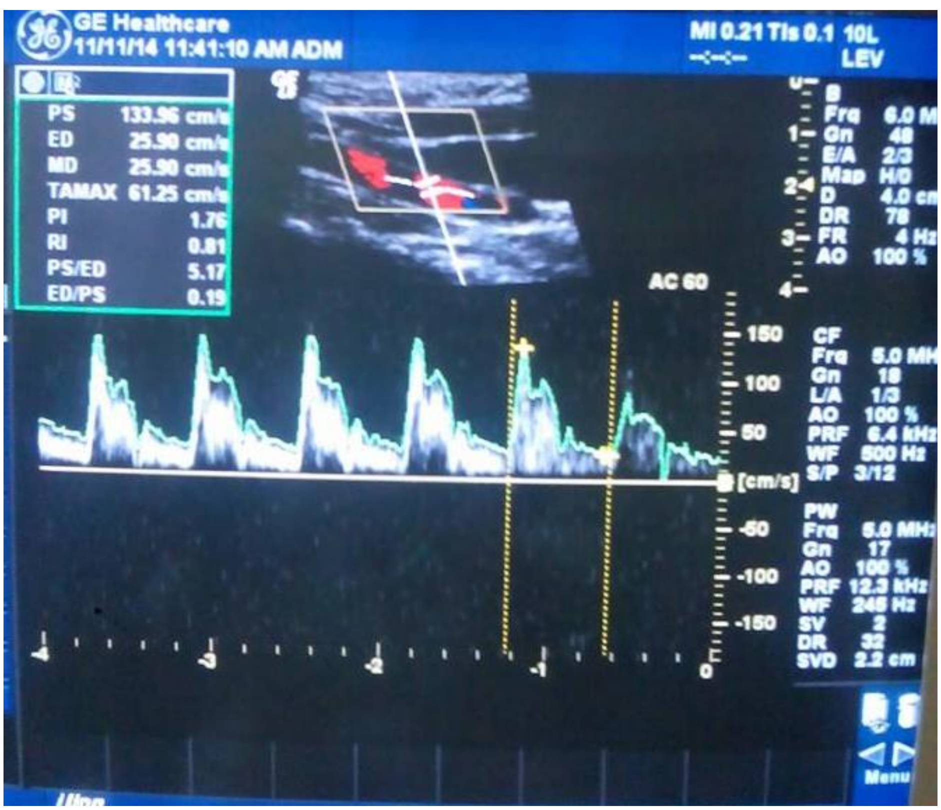

Figure 2: Measurements of peak systolic velocity (PSV), end diastolic velocity (EDV), pulsatility index (PI) and resistivity index (RI) from CCA of the human Subjects.

The luminal diameters of the Carotid arteries were measured on magnified B-mode images between the bright internal layers of the parallel vessel walls, on exactly the same location of velocity measurement. The IMT was measured as the distance between the leading edge of the luminal echo and the leading edge of the media/adventitia echo with the aid of the calipers embedded in the software. The values of fasting total Cholesterol (CHO), High Density Lipoproteins (HDL), Triglycerides (TRIG) and Low Density Lipoproteins (LDL) were also measured by a certified medical laboratory scientist. A disposable lancet was used to prick the tip of the finger and a small volume of blood was collected to the required level using a capillary tube which was then transferred into a strip already inserted into an electronic Cholesterol meter that automatically reads the blood cholesterol level in mol/dl. Other parameters measured are the Systolic Blood Pressures (SBP) and the Diastolic Blood Pressures (DBP) of the subjects carried out by a certified nurse. Each individual was made to sit on a chair with his/her arm at the chest level after resting for about 30 minutes. The upper part of the arm was cuffed with the sphygmomanometer pressure embedded cuffing strip. The arm was inflated and both the systolic and diastolic blood pressures were recorded in mmHg. The body weight of each subject was also measured using a weighing balance with participants wearing light clothes and no shoes, recorded to the nearest 0.1 kg, while the standing height was measured using a stadiometer recorded to the nearest meter. Their WC between the lowest rib margin and iliac crest were measured using a tape also recorded to the nearest meter. BMI was calculated as weight (kg) divided by the square of the height (m^2) while WHtR was defined as the WC divided by height. To increase the study accuracy, these measurements were repeated three (3) times and the mean values taken.

Statistical analyses were then applied on the results with IBM Statistical Package for Social Sciences (SPSS) Version 21 for windows. Descriptive analysis, including mean and standard deviation for quantitative variables and frequency, were performed with paired Student Test. Simple linear regression were used to study associations between carotid artery structure as dependent variables, while body composition measurements and blood pressure as independent variables respectively. Pearson's correlation coefficient test was used to find the correlation between two or more variables using the SPSS tool. The level of significance was considered at $p<0.05$ (2-tailed). If the level of significance was $p<0.01$ (2-tailed), then it was considered statistically highly significant. Regression line graphs were plotted for variables that were significantly related after which their respective regression equations were sorted out.

3.0 Results

The ultrasound parameters together with other readings taken from all the subjects were classified as normal weight (BMI values less 25.0 but greater than 18.5 Kg/m^2), over-weight (BMI values from 25.0 to 29.9 Kg/m^2) and obese (BMI values of 30.0 Kg/m^2 and above) as shown in Table 1. The readings were also classified according to sex as can be seen in Table 2.

Table 1: Ultrasound and anthropometric measurements for Normal weight, Over-weight and Obese subjects

Parameters	**Normal Weight**			**Over-weight**			**Obese**		
	No	**Mean**	**SD**	**No**	**Mean**	**SD**	**No**	**Mean**	**SD**
RPSV(cm/s)	27	98.48	±18.24	10	86.77	±19.02	13	90.14	22.95
REDV(cm/s)	27	25.37	±5.659	10	24.02	±5.426	13	27.35	9.513
LPSV(cm/s)	27	95.54	±18.70	10	94.95	±20.69	13	93.82	20.93
LEDV(cm/s)	27	25.03	±5.947	10	29.74	±8.409	13	28.37	6.976
RLD(cm)	27	0.584	±0.065	10	0.552	±0.066	13	0.625	0.087
LLD(cm)	27	0.558	±0.052	10	0.557	±0.072	13	0.592	0.082

RPI	27	2.064	±1.085	10	1.890	±0.837	13	1.661	0.636
RRI	27	0.734	±0.079	10	0.711	±0.054	13	0.699	0.070
LPI	27	1.986	±0.845	10	1.789	±0.618	13	1.671	0.541
LRI	27	0.734	±0.072	10	0.725	±0.109	13	0.691	0.073
RIMT(cm)	27	0.059	±0.018	10	0.058	±0.010	13	0.084	0.042
LIMT(cm)	27	0.057	±0.025	10	0.054	±0.011	13	0.071	0.017
Wt(Kg)	27	59.52	±7.759	10	72.60	±8.058	13	86.39	5.752
Ht(m)	27	1.626	±0.075	10	1.639	±0.100	13	1.622	0.080
WHtR	27	0.498	±0.049	10	0.590	±0.035	13	0.679	0.066
SBP(mmHg)	27	134.6	±22.65	10	143.5	±29.40	13	148.1	27.89
DBP(mmHg)	27	79.96	±12.67	10	86.60	±13.97	13	86.85	11.20
CHO(mol/dl)	27	3.731	±0.797	10	4.025	±0.804	13	4.509	0.621
HDL(mol/dl)	27	1.164	±0.483	10	1.006	±0.393	13	1.093	0.325
TRIG(mol/dl)	27	1.375	±1.057	10	1.568	±0.675	13	1.804	0.899
LDL(mol/dl)	27	2.001	±0.848	10	2.304	±0.872	13	2.595	0.527
Age(yrs)	27	42.37	±15.81	10	49.60	±7.575	13	49.77	10.32

RPSV, RED, LPSV, LEDV, RLD, LLD, RPI(Right Pulsatility Index), RRI(Right Resistivity Index), LPI(Left Pulsatility Index), LRI(Left Resistivity Index), RIMT, LIMT, Wt(Weight), Ht(Height), WHtR, SBP, DBP, CHO, HDL, TRIG, LDL

Table 2: Ultrasound and anthropometric measurements of the human subjects according to Sex

Parameters	**Male**			**Female**		
	No	**Mean**	**SD**	**No**	**Mean**	**SD**
RPSV(cm/s)	25	95.66	±19.97	25	92.29	±20.17
REDV(cm/s)	25	24.73	±6.696	25	26.90	±7.100
LPSV(cm/s)	25	95.98	±18.42	25	94.82	±19.82
LEDV(cm/s)	25	25.56	±7.248	25	28.11	±6.460
RLD(cm)	25	0.622	±0.068	25	0.564	±0.064
LLD(cm)	25	0.585	±0.062	25	0.548	±0.065
RPI	25	2.060	±1.036	25	1.788	±0.829
RRI	25	0.737	±0.075	25	0.704	±0.068
LPI	25	1.930	±0.726	25	1.800	±0.761
LRI	25	0.746	±0.088	25	0.697	±0.067
RIMT(cm)	25	0.068	±0.035	25	0.062	±0.017
LIMT(cm)	25	0.066	±0.273	25	0.054	±0.013
Wt(Kg)	25	69.02	±12.87	25	69.22	±14.51
Ht(m)	25	1.670	±0.075	25	1.585	±0.061
WHtR	25	0.529	±0.074	25	0.598	±0.097
SBP(mmHg)	25	138.00	±25.30	25	142.96	±24.91
DBP(mmHg)	25	81.12	±14.24	25	84.92	±11.06
CHO(mol/dl)	25	3.872	±0.863	25	4.176	±0.719
HDL(mol/dl)	25	1.014	±0.499	25	1.215	±0.318
TRIG(mol/dl)	25	1.279	±0.607	25	1.772	±1.166
LDL(mol/dl)	25	2.278	±0.778	25	2.154	±0.850
Age(yrs)	25	46.40	±13.64	25	45.08	±13.65
BMI(Kg/m^2)	25	24.64	±3.633	25	27.59	±5.609

Results from Table 1 show that only the RPSV differs from 98.48 cm/s to 86.77 cm/s and 90.14 cm/s in the normal weight, over-weight and obese subjects respectively (p-value = 0.257), even though these differences does not portend any health danger as all the values are within the normal range for PSV. The REDV, left peak systolic velocity (LPSV), RLD, LLD, RIMT and left intima-media thickness (LIMT) do not reveal any much difference across the 3 categories of BMI values. However, there is correlation between BMI with WHtR, CHO, and LDL ($p < 0.01$, $p < 0.05$, $p < 0.05$ respectively). Table 2 shows that women have more BMI (men; 24.64 ± 3.63, women; 27.59 ± 5.61), WHtR (men; 0.53 ± 0.07, women; 0.60 ± 0.10) and total Cholesterol (men; 3.87 ± 0.86, women; 4.18 ± 0.72) values than men, while men have more LD (men; 0.62 ± 0.07, women; 0.56 ± 0.07), IMT (men; 0.068 ± 0.035, women; 0.062 ± 0.017), PI (men; 2.06 ± 1.04, women; $1.78\pm5.0.83$) and RI (men; 0.74 ± 0.08, women; 0.70 ± 0.07) than women. The BFV are averagely the same for both male and female on the right and left CCA.

RPSV has a negative correlation with WHtR ($p<0.05$), RIMT ($p<0.01$), RLD ($P<0.05$), and age ($p<0.05$) and it has a strong positive correlation with Height ($p<0.01$). REDV is strongly correlated negatively with RLD ($p<0.01$), LLD ($p<0.05$) while it is positively correlated with age ($p<0.05$). LPSV has a negative correlation with RIMT, LIMT, LLD and a positive correlation with height; Left end diastolic velocity (LEDV) has negative correlation with RLD and LLD but positively correlated with WHtR. The RLD and LLD are both positively correlated with height and the RLD is negatively correlated both with RIMT and LIMT, while the LLD is negatively correlated with age. Systolic and Diastolic blood pressures have positive correlations with RIMT and LIMT. Among the indices of the common carotid artery, CHO, SBP and DBP has a positive correlation with only the IMT ($p<0.05$, $p<0.01$).

The results above show that RPSV (figure 3) and the LPSV are influenced by Ht ($p<0.01$, $p<0.05$ respectively) according to the equation;

$$RPSV = 96.05Height - 62.34 \quad \ldots\ldots \quad 1$$

$$LPSV = 83.99Height - 41.28 \quad \ldots\ldots \quad 2$$

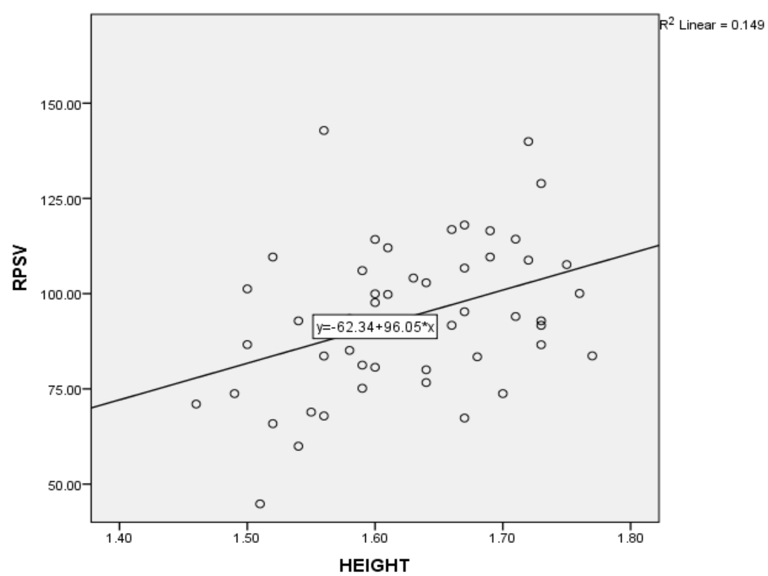

Figure 3: Linear regression graph of right peak systolic velocity (RPSV) against height (Ht)

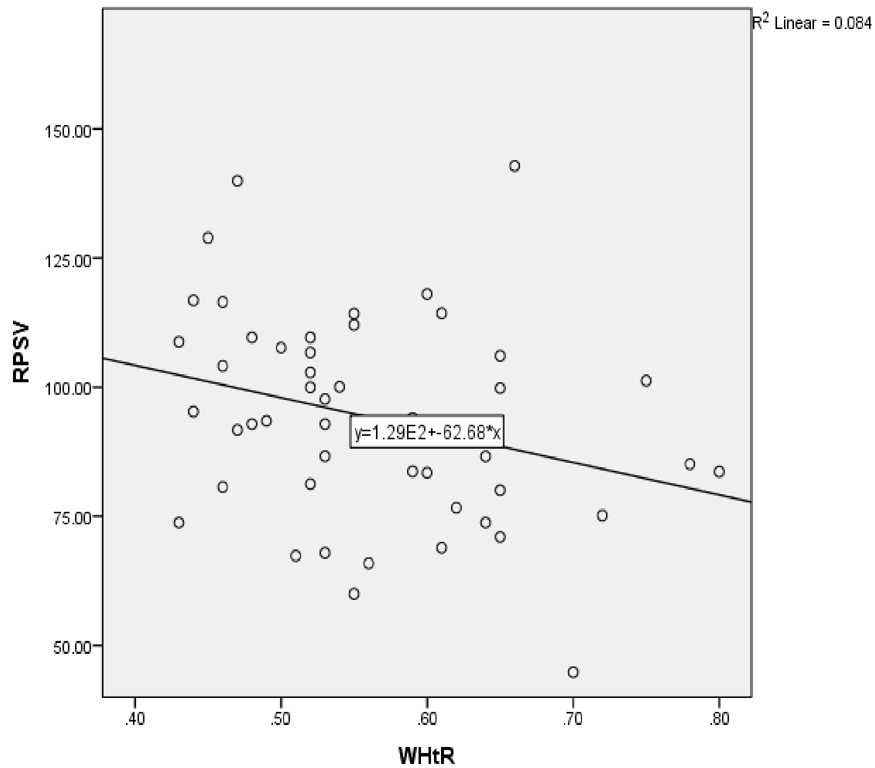

Figure 4: Linear regression graph of right peak systolic velocity (RPSV) against waist-to-height ratio (WHtR).

The regression graph (figure 4) and equation between RPSV and WHtR is;

$$RPSV = 129 - 62.68WHtR \quad \ldots\ldots\ldots\ldots \quad 3$$

Combining equations 1 and 2 gives a single relationship connecting the three variables as;

$$RPSV = 48.025Height - 31.34WHtR + 33.33 \quad \ldots\ldots\ldots\ldots \quad 4$$

The RLD (figure 5) and the LLD are both correlated with height as;

$$RLD = 0.31Height + 0.08 \quad 5$$

$$LLD = 0.27Height + 0.13 \quad 6$$

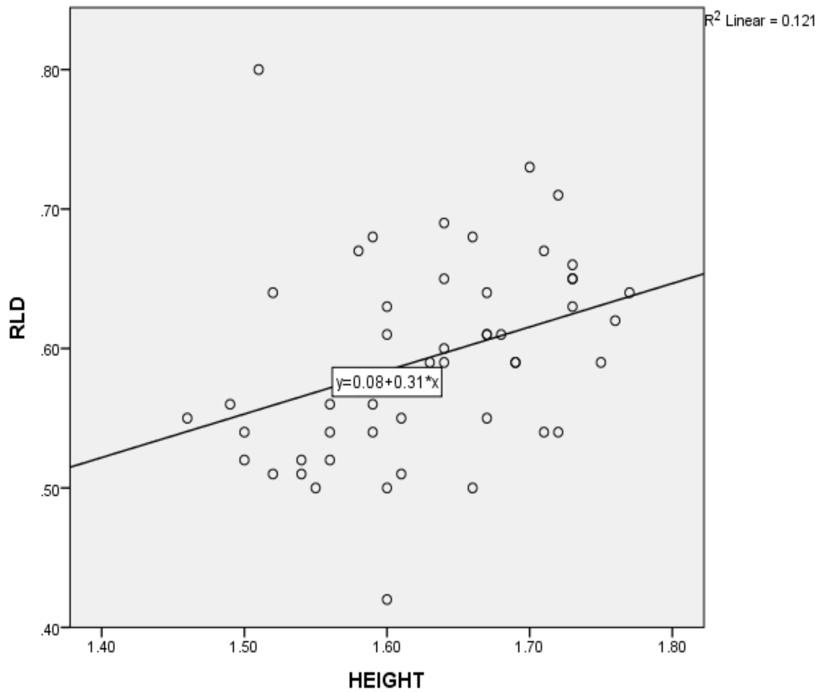

Figure 5: Linear regression graph of right lumen diameter (RLD) against height (Ht)

This study did not discover any relationship between IMT and Ht, but found a strong correlation between RIMT with WHtR given by the equation;

$$RIMT = 0.12WHtR - 2.36 \times 10^{-4} \quad 7$$

The relationship between RPSV and REDV with RLD can be shown by the following equations;

$$RPSV = 144 - 89.99RLD \quad 8$$

$$REDV = 50.89 - 42.3RLD \quad 9$$

4.0 Discussion

This research discovers that the height of the subjects influences PSV and the LD in the carotid artery. By equations 1 and 2, it means that for every 0.1m increase in height, the RPSV and LPSV increases by 9.6 cm/s and 8.4 cm/s respectively showing that height affects the RPSV more than the LPSV. Equations 5 and 6 show that the RLD and the LLD increase by 0.031cm and 0.027cm respectively for every 0.1m change in height, which is similar to what was discovered by (Hwaung et al., 2019), where the LD increases by 0.03cm for each 1cm rise in height. On the other hand, equation 2 reveals that an increment of 0.1 in the WHtR of the subjects results in a 6.27cm/s decrease in the blood velocity in the right CCA. By implication, these results suggest that people who are very tall have smaller WHtR ($p<0.05$) and BMI ($P<0.01$), therefore their RPSV increase which could contribute to stenosis of the carotid artery (Mehra, 2010; Makwana & Patel, 2019). Besides WC, WHtR affects the RIMT by 0.012cm increase for each 0.1 rise in its value (equation 7) without any significant effect on the LIMT. The LD and IMT have a great impact on the BFV in the CCA of human beings. BFV decreases with increase in the size of the LD and IMT, which suggest that larger LD and IMT are associated with a higher incidence of stroke (Sedaghat et al., 2018). Our research revealed that CHO, SBP and DBP were higher in the over-weight and obese groups causing the carotid IMT to increase in both men and women contrary to the findings of (Janet et al., 2006) whose research associated obesity with increased common carotid IMT in young and middle-aged women only. This means that besides height, WhtR and WC are other body composition measurements that can influence cardiovascular disorder or predictors of clinical coronary events and arterial stiffness (George et al., 2013; Budimir et al., 2012). In equations 8 and 9, it can be seen that for every 0.1cm increase in the LD, the PSV and EDV decreases by 8.99 cm/s and 4.23 cm/s respectively. This means that narrowing of the LD possibly by plaques could lead to high flow velocity and reduced blood volume flow rate which eventually results to stroke. The main discovery in this research is that body compositions such as WC, height, WHtR have a significant influence on the carotid artery structure and function in adult Nigerians, while obesity (high BMI values) and cholesterol level have no or little impact on hemodynamic indices of the CCA even though they affect the ITM. More research needs to be done considering FM, FFM and percentage body fats other than BMI to still investigate their effects on carotid artery structure and function. Equation 4 suggest that the PSV in the right CCA can be easily estimated once the height and WHtR of an adult human being is known without necessary using the Ultrasound system as preliminary diagnosis of blood flow deficiencies.

5.0 Conclusion

In conclusion, This research apart from confirming the fact that tall people have larger LD than short people, it was also discovered that men have higher LD, IMT, PI and RI than women, while women have more BMI, WHtR and CHO than men. This discovery puts women at higher risk of cardiovascular diseases than men. This assertion may not be obtainable all over the whole world due to differences in mode of life and proper orientation on health related issues. Since a relationship has been established between BFV and LD by equations 8 and 9, a need to simulate this equations to verify the effect of cholesterol on BFV in the CCA is needed to justify the findings in this research that no relationship exist between them even though it is known that cholesterol is one of the risk factor of cardiovascular diseases (Sharrett et al., 2001; Virani et al., 2011).

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Conflict of interest

There are no competing financial interests in relation to this work

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