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Comparative Study on Luminal Diameter, Blood Flow Velocity and Intima Media Thickness of Carotid Arteries in Obese and Non- Obese Humans

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Abstract
Studies leading to the determination of the onset of atherosclerosis, a major parameter in cardiovascular diseases has dominated the academic community concerned with heart diseases. This study is aimed at investigating the difference in blood flow velocities, lumen diameters and intima-media thickness of the carotid arteries of over-weight/obese and non-obese human subjects. Doppler ultrasound measurements of the carotid arteries was performed in 50 adults, aged between 18-76 years old. The Body Mass Index (BMI), Waist to Height Ratio (WHtR) of the subjects were calculated from their weight, height and waist measurements. Results show significant differences between group 1 (normal weight) and group 2 (over-weight/obese): luminal diameters on the right (RLD) and left (LLD), intima media thickness on the right (RIMT) and left (LIMT) of the carotid arteries were significantly larger in group 2 than in group 1; peak systolic velocities on the right (RPSV) and the left (LPSV) of the carotid arteries were significantly lower in group 2 than in group 1, while the end diastolic velocities on the right (REDV) and left (LEDV) were significantly larger in group 2 than in group 1. In the over-weight/obese subjects, the increased RLD, LLD, RIMT, LIMT, RPSV, LPSV and high REDV and LEDV points at the early stage of atherosclerosis. These effects mean that over-weight and obesity increase the chances of atherosclerosis and stroke**.**
Keywords: Atherosclerosis, luminal diameter, obese, carotid artery, intima media thickness.

1. Introduction

Obesity is steadily becoming the greatest health problem in the world. The prevalence of over-weight and obesity has reached pandemic proportions worldwide. It was estimated that over a billion people are overfed and over-weight (Gardner and Halweil, 2000). Obesity causes impaired function of the large arteries, which might be the consequence of metabolic deregulation, inflammatory pathways, obstructive sleep apnea, or other mechanisms (Jelic *et al.,* 2002; Hall, 2003). Over-weight becomes obesity when excess fat has accumulated to the extent that it may adversely affect health and is most commonly defined by the use of criteria involving the body mass index (BMI = kg/m^2) and waist to height ratio (WHtR). The North American Association for the study of obesity, Bethesda reported in the year 2000 that, BMI $\geq$ 25 and WHtR $\geq$ 0.55 can be associated with a reduced life expectancy and a risk of exacerbating many diseases

Non-invasive ultrasonic duplex Doppler examination has been a standard method for the clinical evaluation of the carotid arteries for a third of a century (Barber *et al*., 1974; Blackshear *et al*., 1979). Doppler velocity waveforms are gathered from the common and internal carotid arteries to detect local elevated blood flow velocity as a marker of arterial stenosis allowing categorical classification of the right and left common and internal carotid arteries into clinically useful categories. Carotid intima media thickness (IMT) is considered an intermediate phenotype of atherosclerosis suitable for use in large-scale population studies (Salonen and Salonen, 1993), since its increase has been associated with higher cardiovascular risk (Paul *et al.,* 2005; Oren *et al.,* 2003) and with the presence of advanced stage of atherosclerosis in peripheral, cerebral and coronary arteries (Geroulakos *et al.,* 1994; Amato *et al.,* 2007). Some have argued that common carotid IMT below certain levels may not reflect atherosclerosis but is merely an adaptive response to changes in shear stress and tensile stress (Glagov *et al.,* 1988).It has therefore been suggested that an increased IMT should be considered relative to its diameter. From studies on coronary arteries, it has been suggested that in the early development of atherosclerosis the outer diameter of the artery increases to preserve the inner lumen diameter (Glagov et al., 1987). For the common carotid artery, an increase in outer diameter with increasing IMT has indeed been demonstrated (Crouse et al., 1994; Bonithon-Kopp et al., 1996), while increased common carotid IMT was associated with an increased inner lumen diameter. It has been shown that the lumen diameter and the intima media thickness of the carotid arteries indicate a significant positive association with all indicators of body composition and fat repartition (Czernichow *et al.,* 2005). A recent study by Elsa *et al.,* (2014), showed a strong correlation between blood flow velocity in the carotid arteries with IMT, LD and obesity. Another research reveals that blood velocity increases by 25% in obese adults and a rapid increase in lumen diameter and intima media thickness in the over-weight/obese adults (Frida *et al.,* 2013; Nafikudin, *et al*., 2003). A gradual increase in common carotid IMT was observed from normal weight (0.94±0.01mm) to over-weight

(0.98±0.01mm) to obese (1.02±0.02mm) and in the lumen diameter from normal weight (5.71±0.06mm) to over-weight (5.76±0.04mm) to obese (5.99±0.08) as reported by Mario *et al.,* (2002). This study is aimed at investigating the blood flow velocities, lumen diameter and intima-media thickness in the carotid arteries of normal and over-weight/obese subjects as parameters of atherosclerosis and to express atherosclerosis as functions of the parameters.

2. Materials and Method

B-Mode Doppler ultrasound machine Type LOGIQ 5 EXPERT operated at 6MHz frequency with an insonation angle of 60^0 was used for taking measurements of the Intima Media Thickness (IMT), Lumen Diameter (LD) and Blood flow Velocity (BV) of their carotid arteries of 50 adults aged 19-75 years residing in Jos, Plateau State, Nigeria. All the subjects were apparently healthy living an active life. 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. The BMI and WHtR of each subject was calculated from their weight (kg), height (m) and waist circumference measured with the aid of a balance and a tape. 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 (monitor). The IMT, the LD, The peak Systolic (PS) velocity and End Diastolic (ED) velocity of the blood on the right and left carotid arteries were measured as displayed on the screen in plate 1. 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. The measurements were revised three (3) times and the mean value taken. Statistical analyses were then made with IBM SPSS (Statistical Package for Social Sciences) Version 21 for Windows. Descriptive analysis, including mean and standard deviation for quantitative variables and frequency, were performed with paired Student T-test. The correlation of all parameters was determined using Pearson's correlation coefficient.

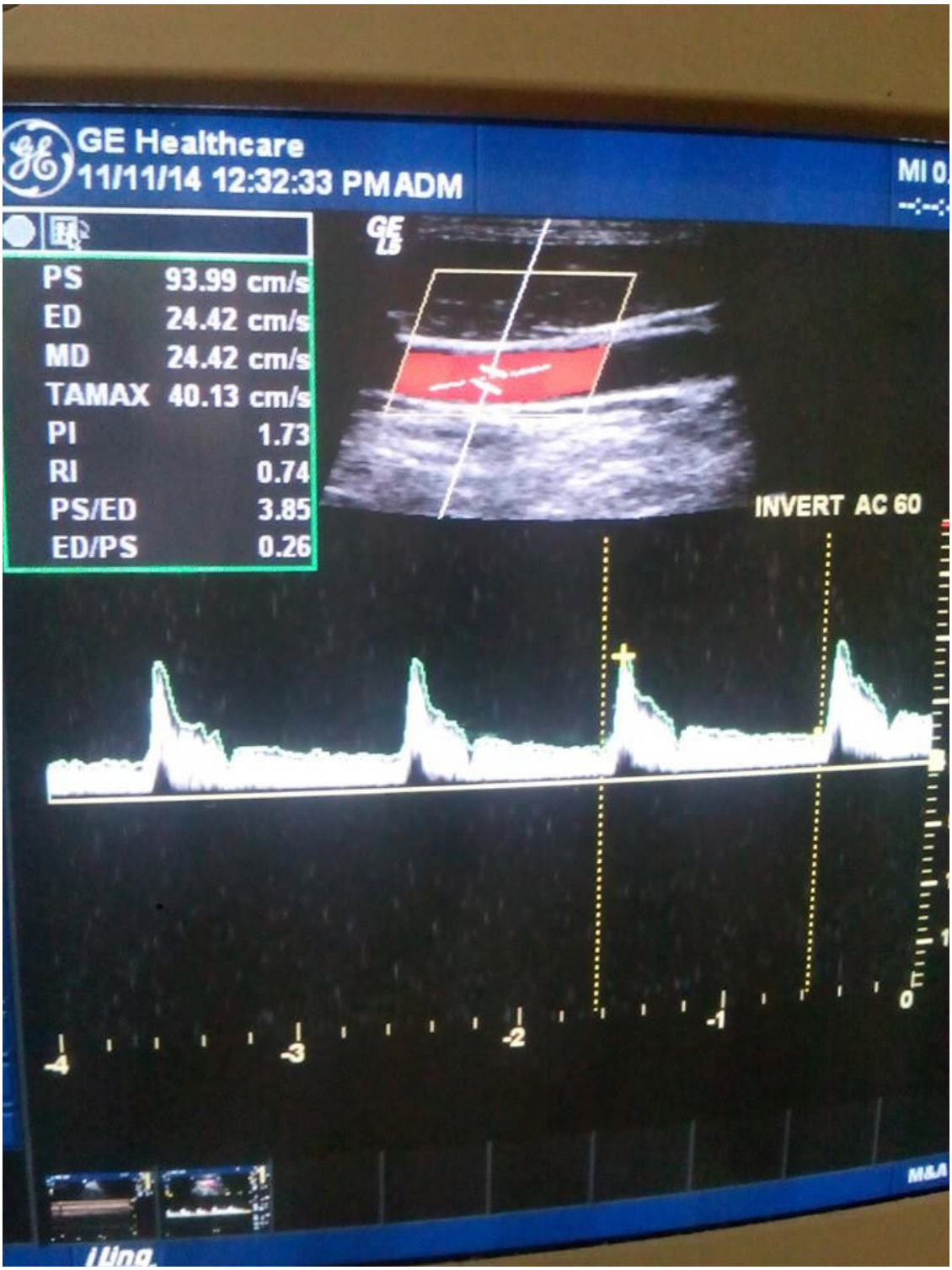

Plate 1: Peak Systolic and End Diastolic Blood Velocities of the Carotid Artery

3. Results and Discussion

The research on BMI, WHtR and Doppler Ultrasound examination of luminal diameter, blood velocity and IMT measurements were performed on 50 adults. Results show that 27 of the subjects had average normal BMI of 22.5±1.8 kg/m^2 and WHtR of 0.50±0.05 classified as group 1, while 23 of them had average over-weight/obese BMI of 30.4±3.8 kg/m^2 and WHtR of 0.64±0.07 classified as group 2.The statistical analysis of the results using IBM SPSS 21 are shown in tables 1 to 4. In group 1, the average Lumen Diameter on the right carotid artery (RLD) was 0.58±0.07cm against 0.56±0.05cm on the left (LLD) while the average Intima Media Thickness on

the right carotid artery (RIMT) was 0.059±0.018cm against 0.057±0.025cm on the left artery (LIMT). The average Peak Systolic Velocity of blood flow on the right artery (RPSV) was 98.48±18.24cm/s against 96.31±17.97cm/s on the left artery (LPSV), while the average End Diastolic Velocity of blood on the right artery (REDV) was 25.37±5.66cm/s against 25.03±5.95cm/s on the left artery (LEDV).

In group 2, the average Lumen Diameter on the right carotid artery (RLD) was 0.60±0.08cm against 0.58±0.08cm on the left (LLD) while the average Intima Media Thickness on the right carotid artery (RIMT) was 0.073±0.034cm against 0.063±0.017cm on the left artery (LIMT). The average Peak Systolic Velocity of blood flow on the right artery (RPSV) was 88.54±21.41cm/s against 93.70±20.64cm/s on the left artery (LPSV), while the average End Diastolic Velocity of blood flow on the right artery (REDV) was 26.34±8.26cm/s against 28.96±7.48cm/s on the left artery (LEDV).

Table 1: Paired Samples Statistics for non-obese (group 1)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	BMI	22.4785	27	1.78678	.34387
	WHtR	.4981	27	.04852	.00934
Pair 2	RLD	.5837	27	.06511	.01253
	LLD	.5581	27	.05219	.01004
Pair 3	RIMT	.0589	27	.01805	.00347
	LIMT	.0570	27	.02539	.00489
Pair 4	RPSV	98.4815	27	18.24135	3.51055
	LPSV	96.3126	27	17.96891	3.45812
Pair 5	REDV	25.3648	27	5.65975	1.08922
	LEDV	25.0333	27	5.94649	1.14440

Table 2: Paired Sample Statistics for Non-Obese (Group1)

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	BMI - WHtR	21.980	1.763	.339	21.283	22.678	64.797	26	.000
Pair 2	RLD - LLD	.026	.056	.0109	.003	.048	2.355	26	.026
Pair 3	RIMT - LIMT	.002	.026	.005	-.009	.012	.364	26	.719
Pair 4	RPSV - LPSV	2.169	13.115	2.524	-3.019	7.357	.859	26	.398
Pair 5	REDV - LEDV	.331	5.965	1.148	-2.028	2.691	.289	26	.775

Table 3: Paired Samples Statistics for obese (group 2)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	BMI	30.381	23	3.826	.797
	WHtR	.640	23	.070	.015
Pair 2	RLD	.604	23	.079	.017
	LLD	.577	23	.078	.016
Pair 3	RIMT	.073	23	.034	.007
	LIMT	.063	23	.017	.004
Pair 4	RPSV	88.539	22	21.411	4.565
	LPSV	93.700	22	20.635	4.399
Pair 5	REDV	26.343	23	8.256	1.721
	LEDV	28.964	23	7.480	1.560

Table 4: Paired Samples Test for obese (group 2)

		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	BMI - WHtR	29.74136	3.76534	.78513	28.11311	31.36961	37.881	22	.000
Pair 2	RLD - LLD	.02696	.06138	.01280	.00041	.05350	2.106	22	.047
Pair 3	RIMT - LIMT	.00957	.02688	.00560	-.00206	.02119	1.707	22	.102
Pair 4	RPSV - LPSV	-5.16136	13.88640	2.96059	-11.31825	.99552	-1.743	21	.096
Pair 5	REDV - LEDV	-2.62130	7.70960	1.60756	-5.95519	.71258	-1.631	22	.117

Results in tables 1 and 3 show no significant difference between the Intima Media Thickness, Peak Systolic Velocity and End Diastolic Velocity on the right and left common carotid arteries for both groups 1 and 2. However, a significant difference was observed between the Lumen Diameter on the right carotid arteries and the left carotid arteries for both groups 1 and 2 with p-values of p=0.026 and p=0.047 respectively. Results in tables 2 and 4 show paired difference between groups 1 and 2. Significant differences were found between groups 1 and 2; the luminal diameter and the IMT on the right and left common carotid arteries were significantly larger in group 2 than in group 1, peak-systolic blood flow velocities on the right and left carotid arteries were significantly lower in group 2 than in group1. These observations are similar to the research conducted by Hüseyin *et al.,* (2006), except that a significantly large End Diastolic Velocities on the right and left carotid arteries in group 2 than in group 1. Hüseyin *et al.,* (2006), observed otherwise. No any correlation among the carotid artery parameters between groups 1 and 2 were observed.

4. Conclusion and Recommendation

Obesity damages health, reduces quality of life, and leads to premature death. Adiposity increases oxygen consumption through increased tissue mass and metabolic demands; therefore, it increases cardiac output, stroke volume, and total blood volume. Atherosclerosis develops in association with the dyslipidemia of obesity. The increase in the prevalence of myocardial infarction and stroke are the two major causes of premature death in the obese (Rexrode *et al.,* 1997). Several studies have suggested that arterial wall area, or arterial diameter in conjunction with wall thickness, may provide useful information for understanding atherosclerosis progression, vascular injury, or vascular vulnerability (Bots *et al*., 2003; Burke *et al.,* 2002). It is well-known that atherosclerosis and atherosclerotic risk factors are associated with arterial diameter (Polak *et al*., 1996) and some studies have suggested arterial remodeling frequently occurs in association with vulnerable plaques (Burke *et al.,* 2002). It was observed there were significant decreases in the peak systolic velocities and an increase in the end diastolic velocities of the carotid arteries in the overweight/obese subjects. This shows that increased luminal diameter, end diastolic velocities, IMT and a decreased in peak systolic velocities in the carotid arteries may be an indicator of early stage atherosclerosis.

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