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CAROTID DOPPLER INDICES WITH AGE AND BODY MASS INDEX IN A SAMPLED NIGERIAN POPULATION

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ABSTRACT

Background: Carotid doppler studies are frequently carried out to assess for possible stenosis resulting from presence of carotid plaques. The carotid peak systolic velocity (PSV) and end diastolic velocity (EDV) are key indices for determining the severity of the stenosis. However, normative values of these parameters may be dependent on anthropological variables like age and body mass index (BMI)

Objective: The study was aimed at assessing the variations of PSV and EDV with age and BMI in a sampled Nigerian population.

Materials and Methods: A total of 204 participants (72 males and 132 non-gravid females) aged between 20 and 70 years who were normotensive with no cardiovascular diseases were selected. Their ages, BMI, PSV and the EDV were measured using standard protocols for the four segments of the carotid artery: common carotid (CC), carotid bulb (CB), internal carotid (IC) and the external carotid (EC). Data obtained were presented using tables and line graphs while the analysis of variance (ANOVA) was used to determine significant difference in measurement across the groups.

Results: The mean PSV recorded were 88.25 ± 7.43 cm/s for the CC, 73.93 ± 6.23 cm/s for the IC, 51.01 ± 4.30 cm/s for the CB and 50.41 ± 4.25 cm/s for the EC. There was a steady increase of the PSV between 20 and 46 years from 74.91 cm/s to 98.78 cm/s for the CC, from 62.76 cm/s to 82.75 cm/s for the IC, from 42.80 cm/s to 56.43 cm/s for the EC and from 43.30 cm/s to 57.10 cm/s for the CB. The maximum EDV measured for the IC was (24.75 ± 2.11 cm/s). Others were 21.12 ± 1.8 cm/s for the CC, 19.38 ± 1.65 cm/s for CB and 16.92 ± 1.44 cm/s for the EC. The EDV also increased steadily between 20 to 46 years from 17.76 cm/s to 23.68 cm/s for the CC, from 21.04 cm/s to 27.75 cm/s for the IC, from 14.38 cm/s to 18.97 cm/s for the EC and from 16.48 cm/s to 21.73 cm/s for the CB. The PSV and EDV varied significantly with age ($p > 0.05$). Also, the PSV and EDV increased slightly with increasing BMI from 30 – 31.9 kg/m^2. For a BMI of 20 kg/m^2 to 32 kg/m^2, the increase in PSV were from 79.48 cm/s to 90.75 cm/s for the CC, from 66.58 cm/s to 76.03 cm/s for the IC, from 45.40 cm/s to 51.85 cm/s for the EC and from 45.94 cm/s to 52.46 cm/s for the CV. Similarly, the PSV and EDV values decreased at a BMI of 30 – 31.99 kg/m^2. Thus, the BMI was significantly associated with PSV and EDV across all segments of the carotid artery ($p > 0.05$).

Conclusion: There are significant variations in carotid PSV and EDV with age and BMI. These variations should be taken in to consideration when diagnosis on alterations in carotid artery flow are to be made using PSV and EDV values.

INTRODUCTION

The cardiovascular system functions to maintain a homeostatic environment in all tissues and fluids of the body for optimal survival and functioning of cells[1]. Like any other organ system of the body, it is susceptible to pathophysiological damage. Several factors and pathological conditions elicit disorders within the cardiovascular system. These disorders affect not only the heart but also the blood vessels. Some of these include hypertension, coronary heart disease, stroke, heart failure, peripheral vascular disease, myocardial infarction, rheumatic heart disease, cardiomyopathies and congenital heart disease[2].

Atherosclerosis, amongst other vascular diseases, is of cardinal importance and remains the foremost cause of mortality and morbidity worldwide[3]. Early detection of atherosclerotic changes in a blood vessel is of fundamental interest since this improves the chances of better management of the disease[4]. In advanced cases, atheromatous plaques develop which occlude the arterial lumen. The plaque can be of the stable type where they remain at the site of the plaque, or unstable where they can rupture and release contents that can elicit thrombogenic events[5]. Either way, the pathology alters the flow of blood in the artery concerned, leading to variation in peak systolic and end diastolic velocities. Two important risk factors for atherosclerosis include age and body mass index (BMI) [6,7], and there is paucity of information on how these parameters will likely affect the peak systolic velocity (PSV) and end diastolic velocity (EDV) measurements.

Ultrasound is an easily available imaging modality for assessment of the carotid artery, as carotid dimensions and blood velocities can be readily observed in real time and computed. Studies have reported variations of the PSV and EDV with age and BMI in Caucasians [7–9] but none in the Nigerian population. Clinical practice for Doppler studies relies on population specific nomograms for accurate diagnosis and interpretation of measurements. Consequently, this highlights the need to determine how the PSV and EDV are affected by age and BMI.

MATERIALS AND METHODS

A prospective study of 204 participants (72 males and 132 females) aged between 20 and 70 years was carried out in Port-Harcourt metropolis between June 2017 and May 2019. Ethical clearance was obtained from the University of Nigeria Teaching Hospital Research Ethics Committee (NHREC/05/01/2008B-FWA00002458-1RB00002323). Informed consent was obtained from each participant prior to the screening. Inclusion criteria for recruitment were normotensive subjects with no history of cardiovascular disease. Pregnant females were excluded from the study. Anthropometric measurements included weight and height obtained with the aid of a stadiometer (ZT -160, Midfield Scientific Equipment, England, 2016) and calibrated to the nearest 0.1kg. A 4D Doppler ultrasound equipment (DCN-3 Pro, Mindray, Shenzhen, 2016) with a variable frequency linear probe (5 – 12 MHz) was used to take measurements of the peak systolic velocity (PSV) and the end diastolic velocity (EDV) following previously described standard protocols[9]. The PSV and EDV were measured three times with the average used as the final measurement. Tables and line graphs were used for data presentation while the Analysis of Variance (ANOVA) was used to determine significant difference across groups. The level of significance was set to be 0.05.

RESULTS

The age, weight, height, and BMI of the participants are shown in Table1. There were more females (n = 128, 62.7%) than males (n = 76, 37.3%), with most of the sample population between 31 and 35 years. The mean ± SD values of the measured Doppler indices across the common carotid, carotid bulb, internal, and external carotid arteries are shown in Table 2. Females had higher PSV and EDV values across all the carotid artery segments.

Table 1: Description of participants

		Sex			
		Female		Male	
		Count	Mean	Count	Mean
Age Group (Years)	<= 20	14		11	
	21 - 25	18		9	
	26 - 30	11		10	
	31 - 35	36		16	
	36 - 40	20		11	
	41 - 45	16		12	
	46+	13		7	
Body Weight	Normal	82		44	
	Obese	42		32	
	Overweight	2		0	
Weight (kg)			64.9		67.3
Height (cm)			162.3		165.1

Table 2: Mean ± SD values of Doppler indices across carotid segments

	Sex			
	Female		Male	
	Mean	SD	Mean	SD
Common carotid PSV (cm/s)	88.25	7.43	87.87	7.71
Internal carotid PSV (cm/s)	73.93	6.23	73.61	6.46
External carotid PSV (cm/s)	50.41	4.25	50.20	4.40
Carotid bulb PSV (cm/s)	51.01	4.30	50.79	4.46
Common carotid EDV (cm/s)	21.16	1.78	21.06	1.85
Internal carotid EDV (cm/s)	24.79	2.09	24.68	2.17
External carotid EDV (cm/s)	16.94	1.43	16.87	1.48
Carotid bulb EDV (cm/s)	19.41	1.64	19.33	1.70

In both gender, the mean values of the PSV of the four segments of the carotid artery increased steadily with age (Figure 1). An ANOVA retuned F-values of less than 0.05 (Table 3) for all segments of the carotid artery, indicating that the PSV measurements across the four carotid segments varied significantly across age groups.

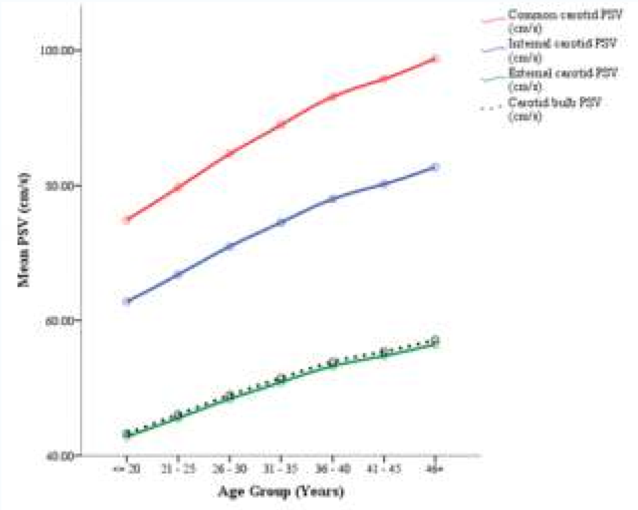

Figure 1: Variation of PSV with age

The EDV measurements and their variation across age for the four segments are shown in Figure 2. From the graph, the values increased steadily with age. The ANOVA revealed significant differences in measurements across various age groups (Table 3).

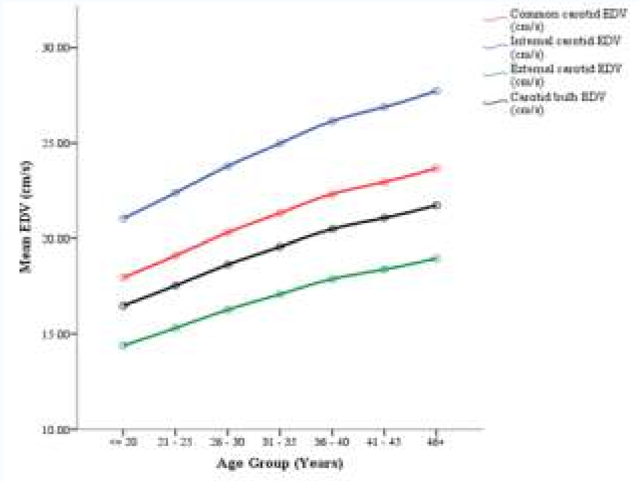

Figure 2: Variation of PSV and EDV across age

Table 3: ANOVA for variations in carotid PSV and EDV with age

	PSV (cm/s)				EDV (cm/s)			
	Sum Sq	M Sq	F	Sig.	Sum Sq	M Sq	F	Sig.
Common carotid	11231.95	1871.99	1456.18	0.00	645.52	107.59	1456.18	0.00
Internal carotid	7882.71	1313.78	1456.18	0.00	886.23	147.71	1456.18	0.00
External carotid	3665.76	610.96	1456.14	0.00	414.03	69.01	1456.18	0.00
Carotid bulb	3753.10	625.52	1456.18	0.00	543.64	90.61	1456.18	0.00

The variation of PSV with BMI is shown in Figure 3. The PSV increased as BMI increased but drops at BMI > 30. An ANOVA noted a significant variation between the mean values of PSV across BMI (Table 4). The EDV variation with BMI is shown in Figure 4, and has a similar trend with variations in the PSV with ANOVA demonstrating a significant difference between EDV measurements across various BMI ranges (Table 4).

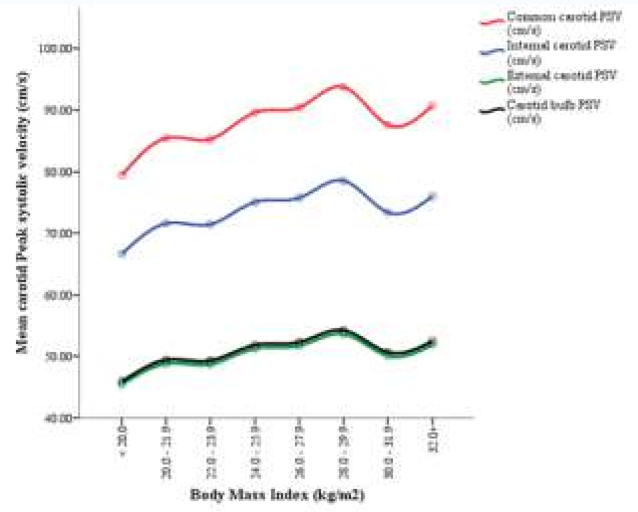

Figure 3: Variation of PSV with various BMI ranges

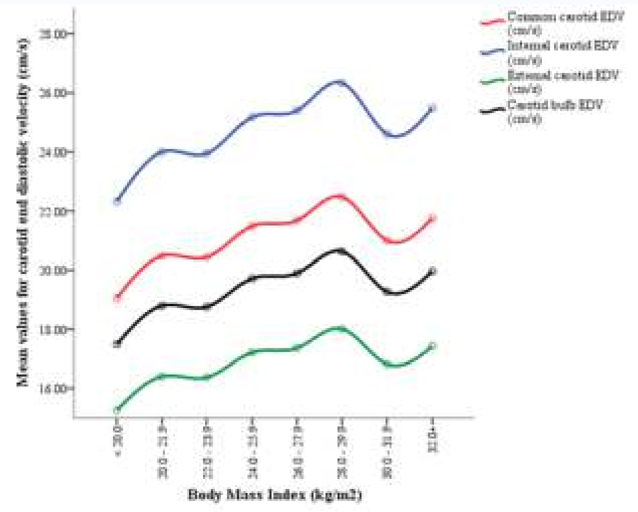

Figure 4: Variation of EDV with BMI ranges

Table 4: ANOVA for variations in carotid PSV and EDV with BMI values

	PSV				EDV			
	Sum Sq	M Sq	F	Sig.	Sum Sq	M Sq	F	Sig.
Common carotid PSV (cm/s)	2439.20	348.46	7.55	0.00	140.18	20.026	7.55	0.00
Internal carotid PSV (cm/s)	1711.86	244.55	7.55	0.00	192.46	27.494	7.55	0.00
External carotid PSV (cm/s)	796.08	113.72	7.55	0.00	89.91	12.845	7.55	0.00
Carotid bulb PSV (cm/s)	815.05	116.43	7.55	0.00	118.05	16.866	7.55	0.00

Discussion

Variations of Doppler velocities with age

From the results of this study, the highest mean PSV measurement was in the CC (88.25 ± 7.43 cm/s). This is followed by the IC with 73.93 ± 6.23 cm/s. The PSV measurements for the CB and the EC were 51.01 ± 4.30 cm/s and 50.41 ± 4.25 cm/s respectively. Expectedly, the PSV of the EC should be higher than the PSV for the bulb, but the closeness of PSV of the CB to that of the EC could be attributed to the turbulence experienced at the CB due to the hemodynamic recirculation of blood, which would lead to different measurements at different times. In general, the PSV increased steadily with age. For subjects < 20 to > 46 years, the increase in PSV for the various segments were from 74.91 cm/s to 98.78 cm/s for the common carotid artery, from 62.76 cm/s to 82.75 cm/s for the internal carotid artery, from 42.80 cm/s to 56.43 cm/s, from 43.30 cm/s to 57.10 cm/s the external carotid artery and from 43.30cm/s to 57.10 cm/s for the carotid bulb. ANOVA results further indicate that the differences in PSV measurements across the various age groups were statistically significant ($p > 0.05$). Similar to the findings of PSV variations with age, ANOVA analysis reported a significant difference in EDV with age ($p>0.05$) across all carotid segments. However, the maximum EDV was measured in the internal carotid artery with a value of 24.75 ± 2.11 cm/s, followed by the common carotid artery at 21.12 ± 1.8 cm/s. The carotid bulb EDV measured 19.38 ± 1.65 cm/s while the external carotid measured 16.92 ± 1.44 cm/s. In keeping with PSV variations with age, for subjects less than 20 years of age to more than 46 years, the increase in EDV for the various segments were as follows: common carotid artery: from 17.76 cm/s to 23.68 cm/s; the internal carotid artery: from 21.04 cm/s to 27.75 cm/s, the external carotid artery: from 14.38 cm/s to 18.97 cm/s; and for the carotid bulb: from 16.48 cm/s to 21.73 cm/s. Variations in PSV and EDV with age could be attributed to carotid artery remodelling, intima wall thickening, progressive loss of elasticity and arterial stiffening as age advanced, a reason which has earlier been suggested[10,11]. In the researcher's opinion, since the artery loses its compliance with increase in age [12] , the velocity across it increases because of the lack of the Windkessel effect[13], making blood flow more of a Poiseuille's flow than a physiological flow. With the lack of the Windkessel effect, the energy expended by the pulsating blood to distend the arteries are channelled towards velocity flow, which subsequently increases the PSV. Contrary to the findings of this study, several literatures, albeit in other populations, report that Doppler indices decreased significantly with age. Hirata et al [9] studied age-related changes in carotid artery flow and reported a flow augmentation which was 1.6 times more in the older population when compared with the younger population but noted that PSV and EDV decreased with age. Irace and colleagues [14] measured age related changes in blood flow in a 12-year follow up study and reported a decrease in flow velocities. At the time of this study, no research has been carried out on the population under study on how Doppler indices varied with age, hence the findings reported here could be considered novel.

Variations of Doppler velocities with BMI

This study revealed a slight increase in carotid doppler indices as BMI increased, reducing at a BMI range of 30 – 31.9 kg/m^2, before increasing again at BMI of 32 kg/m^2 and higher (Figure 3). For a BMI of 20 kg/m^2 to 32 kg/m^2, the increase in PSV were as follows: common carotid artery: from

79.48 cm/s to 90.75 cm/s; the internal carotid artery: from 66.58 cm/s to 76.03 cm/s; the external carotid artery: from 45.40 cm/s to 51.85 cm/s; and for the carotid bulb: from 45.94 cm/s to 52.46 cm/s. The PSV values of the carotid bulb and external carotid were close and follow a similar trend across all BMI groups, and ANOVA reported statistically significant differences between PSV values across various segments with respect to BMI (Table 4). Similar to PSV findings, ANOVA analysis reported a significant difference in EDV with BMI across the carotid segments, with a p-value of less than 0.05. With a BMI of between 20 kg/m^2 to 32 kgm^2, the increase in EDV for the various segments were as follows: common carotid artery: from 19.05 cm/s – 21.76 cm/s; the internal carotid artery: from 22.32 cm/s to 25.49 cm/s, the external carotid artery: from 15.26 cm/s to 17.42 cm/s; and for the carotid bulb: from 17.49 cm/s to 19.97 cm/s. The EDV measurements for the carotid bulb and external carotid artery are separated, unlike the PSV measurement. Similar to what was seen in the PSV measurements, the EDV values decreased at a BMI of 30 – 31.99 kg/m^2 before increasing again. The ANOVA results from this study revealed that BMI was significantly associated with EDV across all segments of the carotid artery, with a p-value of > 0.05. Hence, if BMI was associated with carotid artery dimensions, it would also affect the flow velocity across all segments. We report that as BMI increased, the flow velocity slightly increased, but reduced at BMI larger than 30kg/m^2. This finding is in keeping with a previous report by Pam and colleagues [8] who comparatively studied the effect of obesity on luminal diameter, blood flow velocity, and intima-media thickness. They reported significant differences in blood flow velocity between normal and obese subjects, with obese subjects presenting with higher flow velocities than their normal counterparts. Other authors like Selim et al[6], Ozdemir et al.[15], and Azhim et al.[7], reported continuous decrease in Doppler indices with BMI.

The strength of this study lies in the fact that a large population of participants were recruited and no study has been carried out in this locality to determine how Doppler indices vary with age and BMI. An area that this study could be improved on is studying the effect of interobserver variability on Doppler indices measurements since ultrasonography is operator dependent. Further work needs to be done to compare Doppler indices variations in populations from different geographical areas.

CONCLUSION

We conclude that there are significant variations of carotid doppler indices with age and BMI. Specifically, and contrary to several reports from previous studies involving populations from other geographical locations[6,7], the Doppler indices significantly increased with age. However, it increased to peak at a BMI of 32 kg/m^2, after which it decreased.

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Conflict of interest: Nil

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