Original Article

POPULATION-SPECIFIC VARIATION IN CAROTID ARTERY MORPHOMETRY: A COMPARATIVE ANALYSIS OF NIGERIAN DATA ON LUMINAL DIAMETER AND INTIMA-MEDIA THICKNESS WITH GLOBAL POPULATIONS

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Abstract

Background: Human anatomy exhibits population-level variations influenced by genetic and environmental factors. This study compares sonographic measurements of *carotid artery luminal diameter and intima-media thickness* from a Nigerian cohort with published data from other global populations to quantify morphological variation.

Methods: Normative data for the common carotid artery (CCA) diameter from 104 healthy Nigerians were compared with values from published studies in Sweden, the United States, Norway, Brazil, Sudan, Peru, Germany, Spain and Iraq.

Results: The mean CCA diameter among Nigerians (male = 6.2±0.09 mm vs female = 6.0±0.07 mm) had significant difference with many other values compared globally but did not demonstrate sexual dimorphism seen in other climes especially among western countries USA (5.7±0.79 mm vs 6.2±0.88 mm), Swedish (6.3±0.60 mm vs 5.6±0.50 mm) and Norway (6.7±0.90 mm vs 6.2±0.70 mm). Equally, intima-media thickness of CCA among Nigerians (0.49±0.01 mm vs 0.48±0.01 mm in male and female respectively) was significantly lower than was obtained across the globe with Sudan (0.60±0.10 mm vs 0.61±0.10 mm), Spain (0.67 mm vs 0.65 mm) and only similar to Germany (0.47 mm vs 0.47 mm) with no sexual difference. A key finding was the consistent absence of sexual dimorphism in the Nigerian cohort, which was variable in most Western populations.

Conclusion: Significant population-level variations in carotid artery morphometry exist. The Nigerian data are distinct, lacks sex-based difference and significantly lower IMT values. This comparative analysis underscores the critical importance of using population-specific normative data in clinical practice and research to avoid misdiagnosis.

Keywords: Population-Specific Variation, Nigerian Data, Carotid luminal diameter, Carotid intima-media thickness, Duplex ultrasound scan

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INTRODUCTION

Anthropological studies have long established that human anatomy is not uniform across populations but varies due to a complex interplay of genetic, environmental, and nutritional factors.[1,2] The vascular system is no exception. While the gross anatomy of the carotid arteries is constant, morphometric parameters like *luminal diameter and intima-media thickness (IMT)* can show significant inter-population differences.[3,4,5] The uncritical application of normative data from one population to another can lead to clinical errors, such as over-diagnosis of stenosis or under-appreciation of pathological dilation in addition to cerebrovascular risk assessment with wall thickness or stiffness.

Carotid luminal diameter alongside *and intima-media thickness* play vital role in cerebrovascular and coronary risk stratification in adults as a subclinical surrogate marker for atherosclerosis and serves as prognostic index for those who are likely to be morbid with cardiovascular disease before even the formation of plaque later in life.[6]

Ignoring their values and changes that occur with medical intervention puts further risk for vascular events that could lead to mortality. It is important to note that whereas in hypertensives carotid luminal diameter stenosis and IMT increases signify target organ (vessel) damage, notwithstanding in normotensives it predicts hypertension.[7,8] Hence duplex measurement of diameter or IMT values of the common carotid artery based on population normative values could be a useful adjunct in the monitoring of adults at risk due to either weight, age, occupational stress or sleep patterns to enable lifestyle modification activities that would postpone the evil day.

Although several studies have reported carotid diameters *and intima-media thickness* from different countries, a direct comparative analysis highlighting the extent of this global variation is lacking. This study aimed to *directly* compare the carotid artery luminal diameters *and intima-media thickness* of a Nigerian population with published data from other parts of the world.

MATERIALS AND METHODS

Data Source: All data were primary research data from across 5 continents. Nigerian data for both luminal diameter and intima-media thickness of the common carotid arteries were obtained from a prospective study of 104 healthy adults by the author, as previously reported.[8,9] The mean and standard deviation for the right Common Carotid Artery (CCA) diameter *and intima-media thickness* were used for comparison. For global comparison on carotid luminal diameter, Swedish data was from a study by Jensen-Urstad *et al* on 104 participants,[3] US data was retrieved from a study by Hwaung *et al* on 231 recruits,[10] the Norwegian data was pulled from the Tromso study by Johnsen et al on 6,400 participants,(11) the Iraqi data was retrieved from a report on 140 healthy participants by Rashid & Mahmud,[12] while that of Brazil was from a study on healthy population by Tolezani et al.[13] Data for intima-media thickness of carotid arteries for global comparison were pulled from Sudanese data 440 participants by Mahmoud,[14] Peruvian data by Paotorius et al on 472 healthy participants on a population based study.[15] Spanish data by Jarauta et al on 138 enrollees,[16] German data by Randrianarisoa et al on 801 subjects[17] and Japanese data by Takase on 867 participants.[7]

Literature Search and Selection: All selected literature are population-based studies on healthy adult participants who were non-hypertensive, non-obese individuals from 11 countries across the globe. A non-systematic review of literature from Google scholar database was conducted to identify studies that reported mean CCA diameters *and intima-media thickness* in healthy adult populations from different geographical regions. Five countries per each index (diameter or IMT) were randomly selected from each continent without bias according to available Google search results and were compared with our local data. Studies from these countries were selected for comparison based on data availability and methodological similarity (use of ultrasonography).

Comparative Analysis: The *values of* mean CCA diameters *and intima-media thickness* from the different studies were tabulated alongside the Nigerian data. The presence or absence of statistically significant sexual dimorphism, as reported in each study, was noted as a key point of comparison. More importantly, p-value comparing the Nigerian mean CCA diameter and IMT with values from each country selected for significant difference was calculated using the formular for independent sample t-test with unequal variance on Microsoft Excell:[18] Statistical significance was set at $p < 0.05$.

RESULTS

The results of the comparative analysis for luminal diameters *and intima-media thickness* with values across the globe are summarized in table 1 and table 2 respectively. The mean CCA luminal diameter for Nigerians (6.1 ± 0.08 mm) was not strikingly distinct from other populations numbers but demonstrated significant statistical contrast. We found similar values with the US and slightly higher values in Norway and Brazil (table 1). The most striking comparative finding was the consistent report of significant sexual dimorphism in Western studies (Sweden, US, Norway), where men had larger diameters, which was completely absent in the Nigerian and Brazilian cohorts. However, the mean CCA intima-media thickness for Nigerians (0.49 ± 0.08) was clearly distinct from other populations that were higher in value compared to Nigerians except Germans (table 2). Contrastingly as above, sexual dimorphism was not reported in any except in the Peruvian data.

Table 1. Comparison of normal luminal diameters (LD) of carotid artery across the globe

Country	Sample size	CCA diameter (male) in mm	CCA diameter (female) in mm	Mean total LD in mm	Comparison with Nigerian data (p-value)	Significance diff. b/w sex	Authors
Nigeria	104	6.2±0.09	6.0±0.07	6.1±0.08	-	None	Kpuduwei (index study)[9]
Sweden	104	6.3±0.60	5.6±0.50	5.9±0.55	$p < 0.001$	Yes	Jensen-Urstad et al., 1999[3]
Iraq	140	5.80	5.46	5.63±0.10	$p < 0.001$	No	Rashid & Mahmud, 2015[12]
US	231	5.7±0.79	6.2±0.88	6.0±1.23	$p = 0.22$	Yes	Hwaung et al., 2019[10]
Norway	6,400	6.7±0.90	6.2±0.70	6.5±0.80	$p < 0.001$	Yes	Johnsen et al., 2009[11]
Brazil	210	-	-	6.7± 0.08	$p < 0.001$	-	Tolezani et al., 2014[13]

Table 2. Comparison of normal intima-media thickness (IMT) of carotid artery across the globe

Country	Sample size	CCA IMT (male) in mm	CCA IMT (female) in mm	Mean total IMT in mm	Comparison with Nigerian data (p-value)	Significance diff. b/w sex	Authors
Nigeria	104	0.49±0.01	0.48±0.01	0.49±0.08	-	None	Kpuduwei (index study)[8]
Sudan	440	0.60±0.10	0.61±0.10	0.61±0.10	$p < 0.001$	None	Mahmoud, 2013[14]
Peru	472	0.63	0.57	0.60±0.10	$p < 0.001$	Yes	Pastorius et al., 2010[15]
Spain	138	0.67	0.65	0.66±0.10	$p < 0.001$	None	Jarauta et al., 2010[16]
Germany	801	0.47	0.47	0.47±0.10	$p = 0.09$	None	Randrianarisoa et al., 2015[17]
Japan	867			0.75±0.16	$p < 0.001$	None	Takase et al., 2017[7]
Brazil	210	-	-	0.60±0.1	$p < 0.001$	-	Tolezani et al., 2014[13]

DISCUSSION

This analysis provides quantitative evidence of significant population-level variation in carotid artery morphometry. Generally, the review shows that the normative carotid artery values for luminal diameter and intima-media thickness among Nigerians from the index study are significantly different from values across the globe as shown both tables 1 and 2. In addition, there were clear differences in patterns between how *luminal diameter and intima-media thickness* performed in both ethnicity (populations) and gender.

On carotid diameter, the differences between genders were widely reported especially across western populations. This was not found in the Nigerian data (table 1). From a mere look it would appear as though the carotid diameters from Nigeria are similar to others across the globe until they are subjected to a statistical scrutiny. Obviously, there was statistically significant difference in carotid diameter between Nigeria and Sweden, Iraq, Norway and Brazil. However, the Nigerian data was similar to the US data as the p-value was 0.22 unlike others (where $p < 0.001$). Whereas, on intima-media thickness, differences in gender were largely absent while the morphometric values across these populations varied widely maintaining the same significant difference with Nigerian data (table 2). The differences observed are unlikely to be due to methodological variations alone, as the ultrasound techniques were broadly similar as reported.

Notwithstanding, age brackets of the studied populations, varying sample sizes, machine specifications and sonographers' or radiologists' level of experience might have played some role. The distinct lack of sexual dimorphism in luminal diameter in the Nigerian (and Brazilian) population is a particularly important anthropological and clinical finding. It suggests that the factors driving sex-based differences in vascular size in Western populations—which may include lifelong patterns of physical activity, dietary habits, or genetic determinants of body composition—may operate differently in other ethnic contexts. Rockman et al. demonstrated racial differences in stenosis prevalence,[5] and our findings suggest that underlying anatomical norms contribute to these epidemiological patterns.

On the other hand, why this pattern of difference in sex is not recorded on intima-media thicknesses across the globe may point to the fact that the structural and functional anatomy of luminal size and wall thickness are not the same. Histological studies on the wall of the carotid arteries reveal that there are forces (longitudinal and vertical or circumferential forces) that act on the wall of the artery. Although these forces affect both the radius (half of diameter) and wall thickness of the vessel, their remodeling responses to the pulsatile flow of blood may be different due to maladaptation. The arterial wall contains smooth muscle cells, fibroblast cells and collagens, which respond to the force or pressure exerted by blood flow by remodeling but are prone to pathological changes in old age when most cardiovascular diseases are manifest.[19,20] Carotid luminal diameter tend to increase alongside increase in wall thickness till a certain point where further increases in IMT especially due to atherosclerosis or maladaptive wall remodeling produces vessel stenosis, which is widely noted in old age.[21,22] Because IMT is a surrogate marker for cardiovascular disease, the presence or absence of hypertension, atherosclerosis and other risk factors that demonstrate significance in wall thickness morphology and eventual cerebrovascular events that may determine its population normative values.[23]

Generally, carotid IMT of 0.6 mm to 0.7 mm is considered normal among healthy adults in middle age.[6] Within this range fall data from Sudan, Peru, and Spain. However, data from the Nigerian cohort and Germany are below 0.6 mm while that from Japan is above 0.7 mm. This variation pattern distinct from that of diameter may suggest that ethnicity may not be the only reason for population differences in intima-media thickness of carotid arteries but also lifestyle because there is no identifiable ethnic or racial similarity between Nigeria and Germany (table 2) whereas their values were similar while they differ with Japan. Furthermore, these obvious variations in normative values of non-hypertensive individuals suggests cerebrovascular risk in these populations may also differ. It is opined that increase of cIMT by 1 mm could pose significant risk requiring medical intervention based on racial/ethnic or age-related biases.[6]

Clinically, this reinforces the imperative for population-specific reference values. Anthropologically, it adds to the understanding of human biological diversity and how common clinical parameters can vary across the species.

Limitations

The comparison was not based on a systematic review of global normative values. In addition, there was no uniformity of selected populations between luminal diameter *and intima-media thickness* in that populations used for one valuable (LD) were not the same populations used for the other valuable (IMT). However, this study has demonstrated population-based variations in anatomy that can guide clinical decision making either diagnostically or therapeutically in some populations with distinct normative values compared to western data.

Conclusion

Carotid artery diameter *and intima-media thickness* demonstrate significant variation across global populations, with the Nigerian data presenting a distinct profile characterized by a lack of sexual dimorphism. This work highlights the necessity of developing and using local normative data in clinical practice and provides a valuable dataset for future comparative anthropological studies of human vascular anatomy.

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