Establishing Sexual Dimorphism in Diameter of Carotid Arteries among Normotensive Adult Nigerians

Selekeowei Peter Kespi Kpuduwei[1], Hakeem B. Fawehinmi[1], Gabriel Sunday Oladipo[1]

[1]Department of Anatomy, University of Port Harcourt, Port Harcourt, Nigeria

Abstract

Background: The Doppler scan serves as an early and non-invasive diagnostic tool for carotid artery disease due to its location, which is significant for cerebrovascular accidents. The carotid diameter has been associated with hypertension just as a sexual variation in hypertensives is documented. However, the difference among healthy individuals with normal pressure and body weight with relation to the diameter of the carotid is not proven among healthy Nigerians. **Objective:** The objective of the study is to identify a sexual dimorphism in the diameter of the carotid artery and its association with body mass index and blood pressure among normotensive Nigerians. **Materials and Methods:** A total of 104 were sampled with the average age of 28 years comprising 62 males and 42 females. Doppler ultrasound scans of common, internal, and external carotid arteries were made by an experienced radiologist using a linear transducer with a frequency of 7.0 Mhz. Diameter measurements were taken in end-diastolic alongside blood pressure, pulse, height, weight, and neck and waist circumference. **Results:** The total diameter measurements of the common carotid artery for male and female were 0.62 ± 0.09 and 0.60 ± 0.07 cm, respectively, internal carotid artery were 0.60 ± 0.08 and 0.61 ± 0.08 cm, respectively, and external carotid artery were 0.48 ± 0.11 and 0.50 ± 0.08 cm, respectively. Although the differences were not statistically significant, their associations with the measured biophysical and clinical parameters showed significant differences in both sexes. **Conclusion:** we opine that sexual dimorphism should not be ruled out by the mere absence of significant difference in the descriptive analysis but also in the associations with other parameters.

Keywords: Carotid artery diameter, sexual dimorphism, ultrasound scan

Introduction

Carotid artery Doppler scans are important in the obese, hypertensives, and those at risk of cerebrovascular events. The Doppler scan serves as an early and non-invasive diagnostic tool for carotid artery disease due to its location, which is significant for cerebrovascular accidents.[1] In the obese and hypertensive middle age group, the proportion of males to females is significantly higher.[2-4] Hypertensive participants have been noted to have wider arterial diameters, which is attributed to arterial wall stretch from the stimuli of baroreceptors activated by increased pressure.[5,6] These factors predispose the two sexes to stroke differently just as carotid artery stenosis (CAS) was projected differently in both sexes among African Americans.[7] However, the emphasis currently is on the diameter of carotid arteries in a population of normal healthy individuals who originally may not show sexual dimorphism in the descriptive analysis of the measured organ but correlate to physical and clinical parameters differently. The objective of the study is to identify sexual dimorphism in the diameter of the carotid artery not just in its pure form but also when it is concealed by having significant sexual differences in its association with body mass index and blood pressure among normotensive Nigerians.

Materials and Methods

One hundred and four normal healthy participants in Nigeria were sampled for this prospective cross-sectional study. There were 62 males and 42 females who participated in the study within the ages of 18 and 65 years. Doppler scans of their carotid arteries on both sides were done with measurement of the diameters of the common carotid artery (CCA), internal

Access this article online	
Quick Response Code:	**Website:** www.njmonline.org
	DOI: 10.4103/NJM.NJM_6_21

Address for correspondence: Dr. Selekeowei Peter Kespi Kpuduwei, Department of Anatomy, University of Port Harcourt, Port Harcourt, Nigeria. E-mail: dr.kpuduwei@gmail.com

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How to cite this article: Kespi Kpuduwei SP, Fawehinmi HB, Oladipo GS. Establishing sexual dimorphism in diameter of carotid arteries among normotensive adult Nigerians. Niger J Med 2021;30:176-81.

Submitted: 06-Jan-2021 **Revised:** 01-Feb-2021
Accepted: 12-Feb-2021 **Published:** 22-Apr-2021

carotid artery (ICA), and external carotid artery (ECA) by an experienced radiologist after informed consents were obtained. In addition to the above, measurements of height, weight, neck and waist circumference, pulse, blood pressure, calculation of body mass index (BMI), and mean arterial pressure (MAP) were made. The study was approved by the Research Ethics Committee of the University of Port Harcourt.

Results

Measurements of diameter in its pure form showed a slight difference between the two sexes; however, it was not statistically significant [Tables 1 and 2]. Hence, sexual dimorphism could not be established purely on diameter measurements alone. Interestingly, female total values were higher than males in ICA and ECA, except in CCA, where male values were higher. However, with regard to correlation (r) of the measured diameter with physical and clinical parameters, we noted obvious sexual differences which were statistically significant to establish sexual dimorphism. *Post hoc* analysis were made, which showed where the significant difference laid. It is important to state that, the data did not show consistency in any obvious direction in any of the differences noted.

Tables 1 and 3 show that sexual dimorphism was not observed in all measured parameters except height ($t_{[df = 102]} = 4.31; P = 0.00$), neck circumference ($t_{[df = 102]} = 4.28; P = 0.00$), pulse rate ($t_{[df = 102]} = -3.55; P = 0.00$), and diastolic blood pressure ($t_{[df = 102]} = -2.15; P = 0.03$) at $P < 0.05$ where no significant difference was observed; there was no need for *post hoc* analysis [Table 4].

Significant association between waist circumference and arterial diameter was only observed for the right CCA among females ($F = 6.99; P = 0.00$) at $P < 0.05$ [Table 5]. In certain values as shown in Table 6, the *post hoc* shows that between the low risk and the increased risk, there was no significant difference at $P < 0.05$.

Table 1: Descriptive statistics of the measured dimensions of the different parts of the carotid artery

Carotid artery diameter (cm) Total	Mean±SD	
	Male (62)	Female (42)
CCA diameter	0.62±0.09	0.60±0.07
ICA diameter	0.600.08	0.61±0.08
ECA diameter	0.48±0.11	0.50±0.08

SD: Standard deviation, CCA: Common carotid artery, ICA: Internal carotid artery, ECA: External carotid artery

Table 2: Comparing the male and female carotid artery diameter with *t*-test for difference

Carotid artery diameter (cm)	Comparison	MD				*t*-test for equality of means		
		MD	SEM	95% CI of the difference		*t*	df	*P*
				Lower	Upper			
Right								
CCA	Male versus female	0.02	0.02	−0.01	0.05	1.23	102.00	0.22
ICA	Male versus female	−0.01	0.02	−0.04	0.03	−0.34	102.00	0.73
ECA	Male versus female	−0.02	0.02	−0.05	0.01	−1.29	102.00	0.20
Left								
CCA	Male versus female	0.01	0.01	−0.02	0.04	0.75	102.00	0.46
ICA	Male versus female	−0.01	0.01	−0.03	0.02	−0.37	102.00	0.71
ECA	Male versus female	−0.02	0.02	−0.07	0.02	−1.02	102.00	0.31

MD: Mean difference, SEM: Standard error of MD, CI: Confidence interval, df: Degree of freedom, CCA: Common carotid artery, ICA: Internal carotid artery, ECA: External carotid artery

Table 3: *T*-test comparing the male and female anthropometric and physiological parameters

Measured parameters	Comparison	MD				*t*-test for equality of means		
		MD	SEM	95% CI of the difference		*t*	df	*P*
				Lower	Upper			
Height (m)	Male versus female	0.05	0.01	0.03	0.07	4.31	102.00	0.00*
Weight (kg)	Male versus female	0.04	2.62	−5.18	5.25	0.01	73.21	0.99
BMI (kg/m²)	Male versus female	−1.37	0.90	−3.17	0.42	−1.53	62.23	0.13
NC (cm)	Male versus female	3.42	0.43	2.57	4.28	7.93	102.00	0.00*
Waist (cm)	Male versus female	−1.23	2.21	−5.64	3.18	−0.56	60.68	0.58
Pulse rate	Male versus female	−8.01	2.26	−12.49	−3.53	−3.55	101.68	0.00*
Systolic BP	Male versus female	1.11	2.70	−4.25	6.47	0.41	102.00	0.68
Diastolic BP	Male versus female	−4.16	1.93	−7.99	−0.32	−2.15	102.00	0.03*
MAP	Male versus female	−2.40	1.97	−6.31	1.51	−1.22	102.00	0.23

*Significant. BP: Blood pressure, MD: Mean difference, SEM: Standard error of MD, CI: Confidence interval, df: Degree of freedom, BMI: Body mass index, NC: Neck circumference, MAP: Mean arterial pressure

Table 4: Analysis of variance comparing the left carotid artery parameters according to body mass index categories in female participants

Left carotid artery parameters	BMI category	*n*	Descriptive statistics			ANOVA		
			Minimum	Maximum	Mean±SD	df	*F*	*P*
CCA diameter	Underweight	7	0.49	0.70	0.58±0.08	3	0.29	0.83
	Normal	18	0.49	0.69	0.59±0.05			
	Overweight	9	0.54	0.64	0.59±0.04			
	Obese	8	0.47	0.68	0.57±0.08			
ICA diameter	Underweight	7	0.44	0.74	0.59±0.09	3	0.19	0.90
	Normal	18	0.50	0.81	0.61±0.07			
	Overweight	9	0.43	0.75	0.62±0.10			
	Obese	8	0.57	0.65	0.61±0.03			
ECA diameter	Underweight	7	0.26	0.56	0.44±0.09	3	1.79	0.17
	Normal	18	0.40	0.64	0.49±0.07			
	Overweight	9	0.41	0.59	0.52±0.06			
	Obese	8	0.41	0.66	0.51±0.07			
	Normal	18	0.03	0.07	0.04±0.01			
	Overweight	9	0.03	0.05	0.04±0.01			
	Obese	8	0.03	0.14	0.06±0.04			

BMI: Body mass index, SD: Standard deviation, CCA: Common carotid artery, ICA: Internal carotid artery, ECA: External carotid artery, ANOVA: Analysis of variance

Table 5: Analysis of variance comparing carotid artery diameter according to waist circumference in female participants

Carotid artery diameter (cm)	WC (cm)	*n*	Descriptive statistics			ANOVA		
			Minimum	Maximum	Mean±SD	df	*F*	*P*
Right								
CCA	Low risk	23	0.46	0.76	0.60±0.06	2	6.99	0.00*
	Increased risk	7	0.43	0.65	0.55±0.06			
	High risk	12	0.55	0.77	0.66±0.06			
ICA	Low risk	23	0.27	0.79	0.58±0.11	2	1.12	0.34
	Increased risk	7	0.51	0.72	0.63±0.07			
	High risk	12	0.46	0.79	0.63±0.10			
ECA	Low risk	23	0.33	0.79	0.50±0.10	2	0.31	0.73
	Increased risk	7	0.45	0.58	0.52±0.04			
	High risk	12	0.36	0.69	0.53±0.09			
Left								
CCA	Low risk	23	0.49	0.70	0.59±0.06	2	0.02	0.98
	Increased risk	7	0.54	0.65	0.58±0.04			
	High risk	12	0.47	0.68	0.59±0.07			
ICA	Low risk	23	0.44	0.81	0.61±0.08	2	0.00	1.00
	Increased risk	7	0.59	0.62	0.61±0.01			
	High risk	12	0.43	0.75	0.61±0.09			
ECA	Low risk	23	0.26	0.64	0.48±0.08	2	0.33	0.72
	Increased risk	7	0.42	0.55	0.49±0.05			
	High risk	12	0.41	0.66	0.51±0.07			

*Significant. CCA: Common carotid artery, ICA: Internal carotid artery, ECA: External carotid artery, WC: Waist circumference, SD: Standard deviation, ANOVA: Analysis of variance

Discussion

From the descriptive analysis of the data on diameter, a nonstatistically significant difference between the two sexes was noted in the carotid arteries. We set out to see, if such a similar difference could exist in other measured parameters in both sexes. The ranking correlations between diameter and the physical parameters such as weight, neck and waist circumferences and also between diameter clinical parameters such as blood pressure and pulse varied based on sex [Table 7-10]. The index study did not show sexual dimorphism in all the measured diameters of the carotid arteries on both sides except a few [Tables 1 and 2]. Tolezani *et al.* had also reported similar findings in healthy participants in Brazil, where the significant sexual difference in diameter was not noted.[8] However, Jensen-Urstad noted sexual

Table 6: Post hoc multiple comparison test of left carotid artery parameters in male subjects

Left carotid artery parameters	BMI (I)	BMI (J)	95% C.I		M.D (I-J)	S.E of M.D	*P*
			Lower	Upper			
CCA diameter	Underweight	Normal	-0.07	0.15	0.04	0.04	0.810
		Overweight	-0.18	0.08	-0.05	0.05	0.730
		Obese	-0.17	0.20	0.02	0.07	0.994
	Normal	Overweight	-0.16	-0.01	-0.09	0.03	**0.016***
		Obese	-0.17	0.13	-0.02	0.06	0.986
	Overweight	Obese	-0.10	0.23	0.07	0.06	0.709
ICA diameter	Underweight	Normal	-0.20	-0.02	-0.11	0.03	**0.007***
		Overweight	-0.26	-0.05	-0.15	0.04	**0.001***
		Obese	-0.34	-0.04	-0.19	0.06	**0.006***
	Normal	Overweight	-0.10	0.02	-0.04	0.02	0.271
		Obese	-0.20	0.04	-0.08	0.05	0.334
	Overweight	Obese	-0.17	0.09	-0.04	0.05	0.872

*Significant, C.I: Confidence interval, M.D: Mean difference, S.E: Standard error of mean difference, ICA: Internal carotid artery, ECA: External carotid artery

Table 7: Analysis of variance comparing the right carotid artery parameters according to body mass index categories in male participants

Right carotid artery parameters	BMI category	*n*	Descriptive statistics			ANOVA		
			Minimum	Maximum	Mean±SD	df	*F*	*P*
CCA diameter	Underweight	4	0.55	0.77	0.63±0.11	3	1.02	0.39
	Normal	46	0.46	0.80	0.62±0.08			
	Overweight	10	0.47	0.83	0.67±0.13			
	Obese	2	0.58	0.65	0.62±0.05			
ICA diameter	Underweight	4	0.35	0.58	0.48±0.10	3	3.88	0.01*
	Normal	46	0.43	0.81	0.60±0.09			
	Overweight	10	0.52	0.72	0.64±0.06			
	Obese	2	0.65	0.69	0.67±0.03			
ECA diameter	Underweight	4	0.31	0.43	0.36±0.05	3	5.29	0.00*
	Normal	46	0.37	0.71	0.50±0.07			
	Overweight	10	0.39	0.57	0.51±0.07			
	Obese	2	0.51	0.52	0.52±0.01			
	Normal	46	0.02	0.17	0.05±0.02			
	Overweight	10	0.03	0.07	0.05±0.01			
	Obese	2	0.05	0.05	0.05±0.00			

*Significant. SD: Standard deviation, CCA: Common carotid artery, ICA: Internal carotid artery, ECA: External carotid artery, ANOVA: Analysis of variance, BMI: Body mass index

Table 8: *Post hoc* multiple comparison test of right carotid artery parameters in male participants

Right Carotid artery parameters	BMI (I)	BMI (J)	95% CI		MD (I-J)	SE of MD	*P*
			Lower	Upper			
ICA diameter	Underweight	Normal	−0.23	0.00	−0.12	0.04	0.045*
		Overweight	−0.28	−0.03	−0.15	0.05	0.013*
		Obese	−0.38	0.00	−0.19	0.07	0.052
	Normal	Overweight	−0.12	0.04	−0.04	0.03	0.527
		Obese	−0.23	0.09	−0.07	0.06	0.621
	Overweight	Obese	−0.20	0.14	−0.03	0.06	0.955
ECA diameter	Underweight	Normal	−0.23	−0.04	−0.14	0.04	0.002*
		Overweight	−0.26	−0.05	−0.15	0.04	0.002*
		Obese	−0.31	0.00	−0.16	0.06	0.059
	Normal	Overweight	−0.08	0.05	−0.02	0.02	0.896
		Obese	−0.15	0.11	−0.02	0.05	0.984
	Overweight	Obese	−0.14	0.14	0.00	0.05	1.000

*Significant. CI: Confidence interval, MD: Mean difference, SE: Standard error, ICA: Internal carotid artery, ECA: External carotid artery, BMI: Body mass index

Table 9: Analysis of variance comparing the left carotid artery parameters according to body mass index categories in male participants

Left carotid artery parameters	BMI category	*n*	Descriptive statistics			ANOVA		
			Minimum	Maximum	Mean±SD	df	*F*	*P*
CCA diameter	Underweight	4	0.51	0.69	0.62±0.08	3	3.26	0.03*
	Normal	46	0.42	0.77	0.58±0.08			
	Overweight	10	0.51	0.75	0.67±0.08			
	Obese	2	0.59	0.61	0.60±0.01			
ICA diameter	Underweight	4	0.44	0.55	0.49±0.05	3	6.46	0.00*
	Normal	46	0.39	0.73	0.60±0.07			
	Overweight	10	0.59	0.71	0.64±0.04			
	Obese	2	0.64	0.72	0.68±0.06			
ECA diameter	Underweight	4	0.33	0.53	0.41±0.09	3	1.14	0.34
	Normal	46	0.09	0.71	0.48±0.09			
	Overweight	10	−0.43	0.56	0.41±0.30			
	Obese	2	0.49	0.52	0.51±0.02			
	Normal	46	0.01	0.08	0.05±0.02			
	Overweight	10	0.03	0.07	0.05±0.02			
	Obese	2	0.02	0.05	0.04±0.02			

*Significant. SD: Standard deviation, CCA: Common carotid artery, ICA: Internal carotid artery, ECA: External carotid artery, ANOVA: Analysis of variance, BMI: Body mass index

Table 10: *Post hoc* multiple comparison test of left carotid artery parameters in male participants

Left carotid artery parameters	BMI (I)	BMI (J)	95% CI		MD (I-J)	SE of MD	*P*
			Lower	Upper			
CCA diameter	Underweight	Normal	−0.07	0.15	0.04	0.04	0.810
		Overweight	−0.18	0.08	−0.05	0.05	0.730
		Obese	−0.17	0.20	0.02	0.07	0.994
	Normal	Overweight	−0.16	−0.01	−0.09	0.03	0.016*
		Obese	−0.17	0.13	−0.02	0.06	0.986
	Overweight	Obese	−0.10	0.23	0.07	0.06	0.709
ICA diameter	Underweight	Normal	−0.20	−0.02	−0.11	0.03	0.007*
		Overweight	−0.26	−0.05	−0.15	0.04	0.001*
		Obese	−0.34	−0.04	−0.19	0.06	0.006*
	Normal	Overweight	−0.10	0.02	−0.04	0.02	0.271
		Obese	−0.20	0.04	−0.08	0.05	0.334
	Overweight	Obese	−0.17	0.09	−0.04	0.05	0.872

*Significant. CI: Confidence interval, MD: Mean difference, SE: Standard error, ICA: Internal carotid artery, ECA: External carotid artery, BMI: Body mass index

dimorphism in Sweden with a mean common carotid diameter of males and females 0.63 ± 0.6 and 0.56 ± 0.5, respectively.[9] Krejza *et al*. had also reported sexual dimorphism in the US, where mean diameters of the common and internal carotid arteries for males were higher than those of females.[10] While these differences appear to be more of males higher than females, our study has shown that luminal diameter is not always sex-dependent, as was reported by Hwaung *et al*., where the values for men were lower than that of women in the US.[11] However, is it possible that such sexual differences are merely concealed in the data, probably due to the sampled population, where age, blood pressure and body build of the participants are within a certain range. Where correlations of nonsexually dimorphic data are made and statistically significant sexual differences in association become obvious, there is a need to probe this further. We could not identify the cause for the lack of significant difference in pure diameter of the carotid between the two sexes in our study and its presence in other studies. It could be an occurrence by chance or due to the demography of the studied population.

Surprisingly, there was no association between diameter and BMI in the female participants, whereas 80% of the mildly obese participants were females. Päivänsalo *et al*. reported association of BMI with the aorti diameter in females while blood pressure had no association in same groups.[5] However, with the observation from our study, the absence or presence of an association between BMI and diameter in females or males, respectively, itself is a form of sexual dimorphism even though it was concealed in the descriptive statistical analysis of arterial diameters between the two sexes. Our study findings seem to have sexual dimorphism in terms of associations between carotid artery diameter and other biophysical or clinical parameters, even though such dimorphism was not observed in the actual diameters in the two groups. This may be explained by the different ways males and females react to the same stimuli as a result of the difference in their body morphology or biological composition.[3] Rockman *et al.* in their multiracial study had demonstrated that while African-American men had the lowest prevalence of severe CAS among other races, African-American females did not have the lowest prevalence among women of other races. More so, African-American men were more likely to develop CAS in comparison to African-American women than Caucasian men to their women even though the men of the former group appeared to be more protected from CAS than their women with an unadjusted odds ratio of 0.55 to 0.7 compared to the latter group.

In the males, on both sides, there was no association between carotid artery diameter with either pulse or blood pressure. However, in the females, we noted an negative association between pulse and left ECA only ($r = -0.347$) and a positive correlation between blood pressure (using MAP) and right ECA ($r = 0.453$) and left ECA ($r = 0.335$). Blood pressure associations with arterial diameter were reported for both sexes by Päivänsalo *et al.*[5] One would expect the arterial pressure-diameter association to be linear in healthy young adults as in hypertensive patients.[12] Again, we are seeing dimorphism between sexes, however, in the opposite direction as seen in the BMI. Since there is no constant pattern in the dimorphism or the associations, we could assume that it is an occurrence by chance or from unknown reasons. Whatever it is, it appears sexual difference does exist in a way, although its statistical significance could depend on the sample size of the population studied or core genetic factors not considered in this study as noted by Sandberg and Ji.[3]

Conclusion

From our observation, sexual dimorphism may be concealed in a data in its pure form. However, correlation of the measured value to other relevant parameters to establish their association may reveal hidden characteristics of the data. There are publications where a significant difference between sexes for carotid artery diameter has been established; however, there is a dearth in literature from our search to show that a concealed sexual dimorphism may be revealed, if the data are subjected to further analysis with other measurable parameters. We propose that establishment or disregard of the existence of sexual dimorphism in clinical data should include consideration of both descriptive and correlative analysis of the data.

Acknowledgment

The authors appreciate Dr Enefia Kiridi of the Niger Delta University, Amassoma and Dr Opumunu Ibegu of the Diete Koki Memorial Hospital, Opolo, for their assistance and support during the period of data acquisition.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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