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Volumetric assessment of Posterior cranial fossa in a West African population

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ABSTRACT

Background and Objectives: Posterior fossa pathologies can have potentially devastating outcomes. The volumetric capacity of this fossa, known to have ethnoregional variations, can thus be critical in determining outcomes and intervention measures and approaches to pathologies involving this region. This study aimed to evaluate the normal posterior fossa volumes within the West-African subpopulation. Methods: This was a descriptive study of all patients presenting for a cranial imaging study at the study location within a two-year period using a 1.5T MRI of this cranial region. Obtained data included the transverse and anteroposterior diameters, and the height of this fossa and the obtained data was analyzed. P values < 0.05 was statistically significant. Results: A total of 315 patients were recruited (165 males and 150 females). The average posterior fossa transverse diameter, anteroposterior diameter and height were 108.19 mm, 71.58 mm and 35.53 mm respectively for males, and 105.7 mm, 66.48 mm, and 34.24 mm for females respectively. The average posterior fossa volume for males (292.36 cm^3) was significantly higher than for females (252.90 cm^3) (p= 0.0038). The highest average posterior fossa volume was between 16-30 years for males and above 75 years for females. Conclusion: Posterior cranial fossa volumes for the West African population is significantly higher than those obtained for other regions. In addition to being beneficial in some posterior fossa space occupying lesions, this larger volume can explain the relative rarity and sexual preferences of some posterior fossa congenital abnormalities like Chiari-1 malformation amongst the West African population

1. Introduction

The base of the cranial cavity has remained a conundrum to many neurosurgeons. This important part of the cranial cavity plays host to important structures of the central nervous system, and varieties of pathologies can arise from such structures within this cavity. The cranial base can anatomically be divided into three fossae.

The posterior cranial fossa or infratentorial fossa, the broadest and deepest of the three fossae,[1–3] is the cavity located between the foramen magnum and the tentorium cerebelli. It is bounded posteriorly by the squamous part of the occipital bone, anteriorly by the clivus, dorsum sellar and posterior aspect of the body of the sphenoid bone, and antero-laterally by petrous and mastoid parts of the temporal bone and the lateral parts of the occipital bone.[4] It contains the cerebellum, pons and medulla, foramina for cranial nerves VII to XII, fourth ventricular apparatus, and parts of the posterior circulation. Furthermore, 10 of the cranial nerves, except cranial nerves I and II traverse the posterior cranial fossa.[5] The dural venous sinuses – transverse, sigmoid and occipital sinuses traverse this fossa.[1] The posterior cranial fossa is unique because of three main characteristics. Firstly, it is bounded by relatively tight unyielding structures – tentorium cerebelli superiorly, the bony clivus and petrous anteriorly, and the suboccipital bone postero-inferiorly. Secondly, it consists of very vital structures including the brainstem and its cardiorespiratory centre and cranial nerve nuclei, the fourth ventricular apparatus and the posterior circulation. Thirdly and because of the first, these important structures are compactly organized within this constrained cavity.

Anatomically within the tight unyielding compact structure of the posterior fossa, two potential exit points exists. Superiorly, the infratentorial or posterior fossa communicates with the supratentorial compartment via the tentorial incisura. Inferiorly, the posterior fossa communicates with the spinal canal via the foramen magnum. The average volume of the posterior fossa in normal adults within the

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Abbreviations

PCFV	Posterior cranial fossa volume
APD	Anteroposterior diameter
TD	Transverse diameter
HGT	Height
SD	Standard deviation

western population in several literature has been defined as about 200 cm^3 in males and somewhat lesser at 178 cm^3 in females.[6–8] The soft tissues of the posterior fossa (cerebellum, brainstem, nerves) have been demonstrated to make up 80% of the posterior fossa volume, with the blood component and CSF making up 10% each.[9,10] Thus, the soft tissues, CSF and blood components will correspondingly make up 160 cm^3, 20 cm^3, and 20 cm^3 respectively of the volume of this fossa. A space-occupying lesion of the posterior cranial fossa that is up to 20 cm^3 will therefore displace its corresponding volume of CSF. Any further increase in volume of such lesion will lead to a rise in the pressure of the posterior fossa, which will induce herniation of the brainstem and/or cerebellum inferiorly via the foramen magnum, or of the cerebellum superiorly via the incisura.

Space-occupying lesions of the posterior cranial fossa such as cerebellar haematomas or infarcts and tumours, arachnoid/epidermoid cysts, fourth ventricular and brainstem tumours are thus, notoriously life threatening because they can cause rapid rise in intracranial pressure in this compact compartment of the brain, as well as cause compression of vital structures such as the brain stem and obstruct fourth ventricular outflow. Jugular foramen syndrome or Vernet's syndrome, a disorder characterized by compression and paralysis of cranial nerves IX to XI as they traverse the jugular foramen,[11] can be caused by several pathologies which also induce overcrowding of the posterior cranial fossa. Some of these pathologies include neoplastic lesions such as schwannomas, meningiomas, paragangliomas, metastases, bony neoplasms (aneurysmal bone cyst, chordomas), and vascular conditions such as extracranial ICA or vertebral artery aneurysms and jugular diverticulum.[12–16] Osseous abnormalities such a Paget's disease, craniosynostosis and basilar invagination can also cause reduced posterior fossa volume.

Most congenital malformations of the cranium are related to maldevelopment of the posterior cranial fossa and craniocervical junction. Additionally, because of its compact nature and its vital contents including the cardiorespiratory centres and fourth ventricular apparatus, pathologies involving this area can be immediately life threatening. Such pathologies can range from bony abnormalities, congenital/developmental, ventricular, as well as those involving the soft tissues and nerves.

Chiari I malformation has traditionally been defined as a disorder characterized by at least $\geq$3 mm herniation of both cerebellar tonsils (or 5 mm if one tonsil) below the level of the foramen magnum on radiology.[17,18] This definition has however been seen as too restrictive in defining Chiari I malformation because some patients who do not meet the $\geq$ 3–5 mm criteria present with features and complications attributable to Chiari 1 malformation.[19] The most consistent feature noted in patients with Chiari I malformation is overcrowding of the hindbrain induced by hypoplasia of the occipital bone of the posterior fossa.[20–26] Chiari I malformation is complicated by CSF flow disorders with about 50–75% of patients developing syringomyelia.[17,27] Females are generally associated with physiological overcrowding of the posterior fossa when compared with males,[6] a finding which might be attributed to their comparatively smaller posterior fossa volume. This might further explain why females have greater incidence of Chiari I malformation when compared to males.[28–32]

Most studies done on volumetric assessment of the posterior fossa was done within the western population and there exist a paucity of data on that within the African population, even though literature has demonstrated sharp regional and racial variations in the cranial morphology.[33–35] Furthermore, some disorders such as Chiari I malformation associated with maldevelopment of the posterior cranial fossa have been shown to be commoner amongst the western white population.[36] Such variation in incidence might be explained by possible volumetric differences in the anatomy of the posterior fossa within such groups. Such volumetric differences might also explain why some posterior fossa lesions with smaller volumes manifest earlier than some with larger volumes within the same geography. Knowledge of the posterior fossa volume additionally aids in pre-operative planning of posterior fossa surgeries. Moreover, in the presence of morphologic variations of posterior fossa amongst regions, knowledge of the normal posterior fossa volume for a given subpopulation or subregion will assist in timing of evacuation of posterior fossa haematoma, rather than utilizing a standard volume cut-off of a given population on another population with different morphology and possibly volume. Thus, utilizing a volume cut-off of 20 cm^3 for evacuation of an intracerebellar haematoma might be sufficient for a given subpopulation whose normal posterior fossa volume is 200 cm^3. But such cut-off timing might not be sufficient for another population whose normal volume is 150 cm^3. Initiating an intervention at 20 cm^3 for such a population will consequently be belated.

The objective of this study was to evaluate the normal posterior fossa volumes within our African subregion.

2. Methods

This was a descriptive study of all patients presenting for a cranial imaging study at the study location within a two-year period, July 2020 to June 2022, after due ethical approval and patient consent. Inclusion criteria included patients of all ages with no presence of a radiological abnormality of the posterior fossa. Patients with posterior fossa abnormality were excluded. Measurements were obtained using a 1.5T MRI of the cranial region from T1W sagittal, coronal and axial views. Obtained data included.

- Measurement of the antero-posterior distance (APD) of the posterior fossa (optimally viewed on sagittal section) – a line drawn from the dorsum sellar to the posterior internal occipital protuberance.
- Measurement of the transverse diameter (TD) (optimally viewed on axial section) – lateral distance between the points most remote from each other in the cerebellar hemisphere.
- Height of the posterior cranial fossa (hgt) (optimally viewed from sagittal section) – perpendicular distance from the midpoint of the foramen magnum to the superior edge of the tentorium cerebelli.[37] In this study, half of the height (taken as HGT) is measured by a line drawn from the middle of McRae line inferiorly) to the middle of Twinning line superiorly. McRae line is a line running from the opisthion to the basion. Twinning line is a line joining the tuberculum sellar and the torcula.[38,39]
- Volume of the posterior fossa (PCFV) was measured using the formula for the volume of an ellipsoid: $4/3 \times \pi \times abc$, where a = half the distance of the TD, b = half the distance of the APD, and c = half the hgt (i.e. HGT).[40]
- Since half the height is being measured as above, the PCFV will thus be $4/3 \times 22/7 \times (TD/2) \times (APD/2) \times (HGT)$
- Thus, the PCFV will be **1.048 × APD × TD × HGT.**

The data obtained was entered into spread sheets, collated, and expressed as frequency tables and graphs. Statistical analysis was performed using GraphPad Prism software (GraphPad Prism 9.4.1.681 for Windows, GraphPad Software, San Diego, California USA, www.graphpad.com). Descriptive statistics were used to calculate means and standard deviation, and sample *t*-test and two-way ANOVA were used for group comparisons of means. p value < 0.05 was regarded as statistically significant.

3. Results

A total of 315 patients were recruited into the study Table 1). Males accounted for 52.4% (165) and females accounted for 47.6% (150), giving a male to female ratio of 1.1:1.

The average posterior cranial volumes as well as the average heights, anteroposterior and transverse diameters by age and sex are displayed in Table 2. The highest average posterior fossa volume was between 16 and 30 years for males and above 75 years for females, while the lowest was above 75 years for males and below 15 years for females (Table 2).

The average heights for the males remained higher than for females throughout all age groups (Fig. 4). The average APD and TD showed similar trend of male predominance over females across all age groups from 0 to 75 years. However above 75 years, the TD and APD showed a female predominance. Generally, there was a progressive increase in the TD and APD in the male sex from 0 to 60 years, after which these parameters began to decline, until they fell below those for the females from 75 years of age (Figs. 2 and 3). The posterior cranial volume measurements showed similar trend, with male predominance form 0–75 years, after which the female sex predominated (Fig. 1).

Comparative analysis done between the two sexes showed that on the average, the male sex had a statistically significantly higher APD than females ($p = 0.0142$). Males had an average APD of 71.58 ± 3.654 compared to females (66.48 ± 2.103) (Table 3). Similarly, the average posterior cranial fossa volume for the males (292.4 ± 11.53) was significantly higher than that obtained for females (252.9 ± 23.11). This was highly significant ($p = 0.0038$). There was no significant difference in the height and transverse diameters obtained between males and females (Table 3).

4. Discussion

Posterior cranial fossa parameters are extremely useful in understanding pathologies that might be found in this region, as well as possible interventions that could be applied. Overcrowding of the posterior cranial fossa as exemplified in conditions like Chiari I malformation, as well as other conditions which are associated with volume compromise of this region (for instance, basilar invagination, tumours, haematoma) can be approached with appropriate knowledge of these parameters. There is paucity of data on posterior fossa volume within the African continent. Thus, most of the comparisons have been made with those obtained from the western population. This study was a unique one, comparing the posterior fossa parameters for West African subpopulation. As observed with most other studies, the PCFV for males were generally larger than for females.[38,40] The mean PCF height obtained for males in this study was 35.53 mm (±1.817) and 34.24 mm (±2.099) for females (Table 3). These results were similar to those obtained by Kanodia et al (35.5 mm for males, 34.6 mm for females) and Rath et al in southeast Asia,[38,39] but much higher than those obtained from studies in eastern Europe.[41,42] The APD distance obtained in this study was also similar to those seen with the Asian population.[38,39] In contrast, the average posterior fossa volume obtained in this study for both males (292.4 ± 11.53 cm^3) and females (252.9 ± 23.11 cm^3) were much higher than those obtained in studies done within the Asian population, as well as the western and European populations. In southeast Asia, Kanodia reported a volume of 162.88 cm3 for males and 148.99 cm3 for females,[39] Iqbal reported a volume of 159.66 cm^3 for males and 154.50 cm^3 for females, while Rath reported 134.5 cm^3 and 113.7 cm3 for males and females respectively.[38,40] Trigylidas et al and Prassoupoulos et al obtained similarly lower values in their studies on western population.[42,43] Posterior fossa abnormalities such as Chiari I malformation generally have been noted to have lower incidence amongst African population compared to the western and Asian populations.[36] Studies have correspondingly shown whites, females and patients with high BMI to have a higher prevalence of posterior fossa abnormalities like Chiari 1 malformation.[36,44,45] This large posterior cranial volume size amongst this African subpopulation might play a crucial role in explaining this observation. Moreover, the PCFV was noted to be generally larger in males compared to females. This might also explain the lower incidence of congenital posterior cranial fossa abnormalities in males when compared to females.[45] Furthermore, this study demonstrated that the APD was the only parameter of the three parameters that determine the posterior cranial fossa volume (APD, HGT and TD) that was significantly different between the male and female sexes (Table 3). The significantly different APD between males and females in this study contributed to the significant difference in the posterior cranial fossa volume observed in this study between males and females.

Another implication of this larger PCFV seen with the black West African subpopulation is that this population subset would more likely be tolerant to increases in posterior fossa volume by certain pathologies when compared to other populations. For instance, assuming it would take a displacement of 10% of PCFV by a posterior fossa space occupying lesion for intracranial pressure to rise to precarious levels (assuming the brain, CSF and blood make up 80%, 10% and 10% respectively of the cranial cavity), it implies that an individual from such subpopulation can tolerate up to a diameter of 3.82 cm for males or 3.64 cm for females of a space occupying lesion before the overt effects of herniation from the raised ICP can emerge or before an initiated emergent intervention might be considered belated. This is as opposed to a cut-off level of 3 cm for other populations of the world. Note that the volume of a sphere is $V = \frac{4}{3}\pi r^3$, where r is the radius of the SOL. Thus, the diameter would be 2r.

Furthermore, knowledge of such variations for our subpopulation can be beneficial in neurosurgical planning for surgeries involving posterior fossa decompression. Historically, the size of a suboccipital craniectomy for approach to posterior fossa pathologies was made such that it is not too small to defeat the purpose of decompression or access to the pathology, or too wide such that it results in cerebellar and potentially brainstem sagging with its associated complications. Such larger posterior fossa volumes for our subpopulation can imply attempts at wider craniectomies without potential risk of the cerebellar ptosis or limitation in access or corridor to pathologies within the posterior fossa during surgeries.

This study had a limitation. Though these scans were done on patients with structurally normal posterior cranial fossa, they were not entirely healthy patients as some had cranial imaging for other indications which included metastatic screening, and other neurologic indications such as seizures, primary headaches, or migraines.

Table 1
Frequency by age and sex.

Age	Male	Female
0–15 yrs	6	18
16–30 yrs	18	24
31–45 yrs	33	27
46–60 yrs	27	30
61–75 yrs	54	36
>75 yrs	27	15
Total	**165**	**150**

5. Conclusion

Normal average posterior cranial fossa volume obtained in this study for West African males and females are 292.4 cm^3 and 252.9 cm^3 respectively. This is larger than the average volume noted for Caucasians, Asians and Europeans (<200 cm^3). Furthermore, this could likely explain the rarity of posterior fossa cranial abnormalities seen with the

Table 2
Average PCFV parameters by age and sex. PCFV – posterior cranial fossa volume; APD-anteroposterior diameter; TD-transverse diameter; HGT-height.

	HGT (mm)		APD (mm)		TD (mm)		PCFV (cm^3)	
Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
0–15 yrs	32.25	30.22	76.2	65.78	105.4	105.53	293.28	219.69
16–30 yrs	35.32	35.27	75.73	66.03	110.81	106.96	311.71	263.14
31–45 yrs	36.99	35.14	67.71	67.71	110.37	102.30	289.76	255.77
46–60 yrs	35.01	34.96	71.68	64.94	112.65	106.67	296.26	254.21
61–75 yrs	36.78	33.80	69.65	64.34	105.26	104.30	285.78	237.02
>75 yrs	36.85	36.05	68.50	70.08	104.65	108.45	277.39	287.56
TOTAL AVERAGE	35.53	34.24	71.58	66.48	108.19	105.70	292.36	252.90

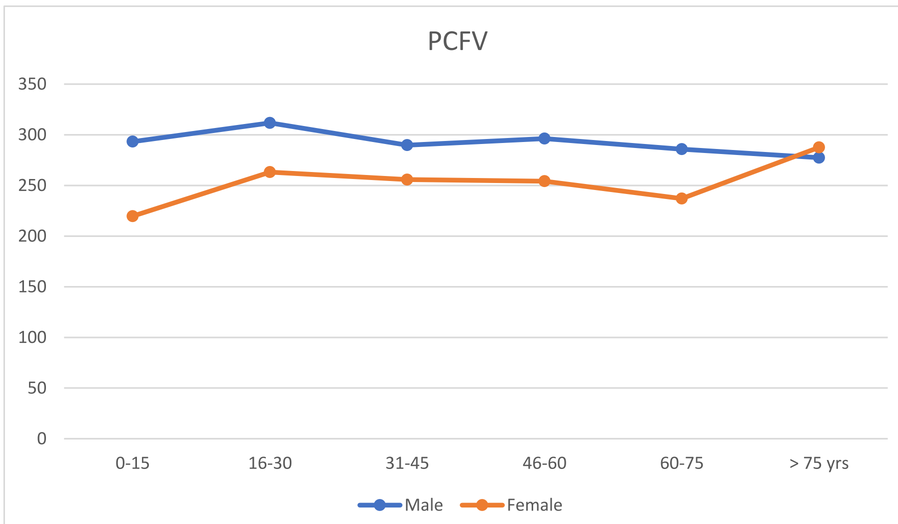

Fig. 1. posterior cranial fossa volume for both sexes across different age groups. The average posterior cranial fossa volume was higher for males than females across all age groups until 75 years, where the average volume in females became higher. PCFV – posterior cranial fossa volume.

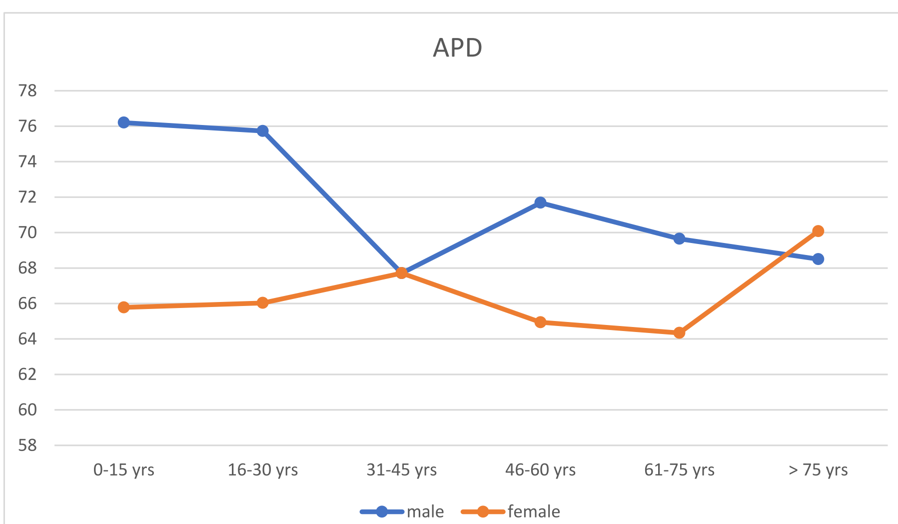

Fig. 2. age group comparisons of the average anteroposterior diameter of the posterior cranial fossa, compared between males and females. The average anteroposterior diameter remained higher for males except at 31–45 years and above 75 years. Between 31 and 45 years, the diameter was approximately equal for males and females, and above 75 years, females had greater diameter than males. These differences between the sexes were statistically significant ($p = 0.0142$). APD – anteroposterior diameter.

African subpopulation. This relatively larger volume could potentially be beneficial in posterior fossa space occupying lesions, as it gives more time before the effects of herniation or raised posterior cranial fossa pressure become overt. Additionally, such knowledge can be advantageous in planning of posterior fossa surgeries and in surgical approach to posterior fossa pathologies within this subpopulation.

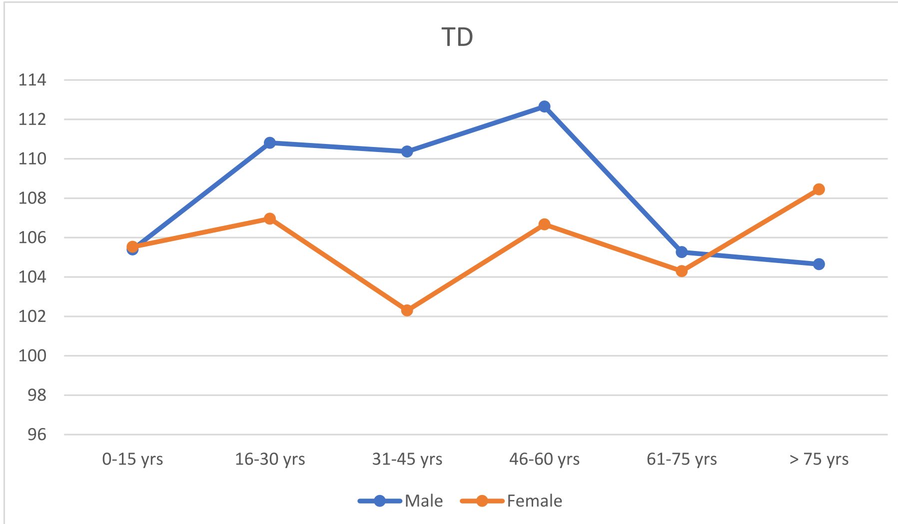

Fig. 3. age group comparisons of the average transverse diameter of the posterior cranial fossa between both sexes. Below 15 years, both sexes had equal transverse diameter. Between 15 years and 75 years, males had greater transverse diameter than females. However, above 75 years, females had greater diameter when compared to males. TD-transverse diameter.

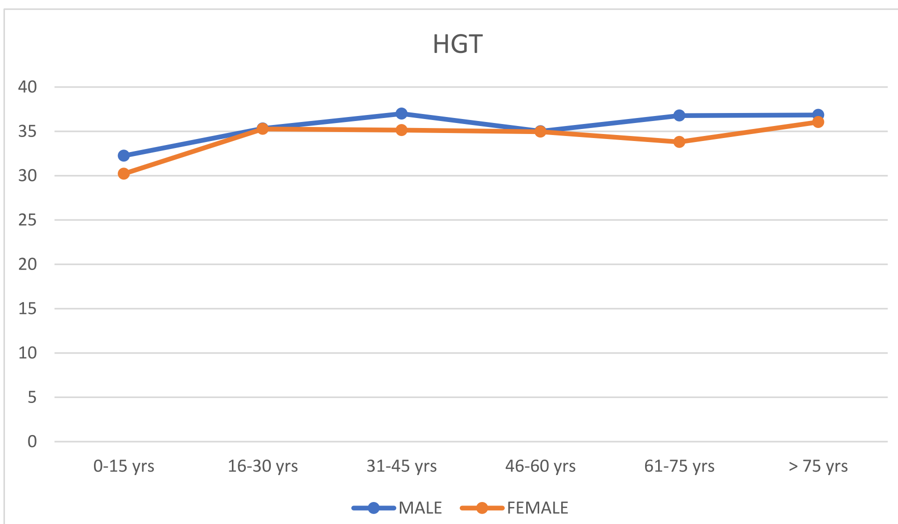

Fig. 4. age group comparisons of the average height of the posterior crania fossa between both sexes. The average height was roughly equal across all age groups in both sexes, with males having an insignificantly greater height at 31–45 years and 61–75 years groups. HGT – height.

Table 3
Posterior cranial fossa volume indices in both sexes. APD -anteroposterior diameter; TD-transverse diameter; PCFV-posterior cranial fossa volume; SD−standard deviation.

	Mean ± SD		*p* value
	Male	Female	
Height (mm)	35.53 ± 1.817	34.24 ± 2.099	0.2804
APD (mm)	71.58 ± 3.654	66.48 ± 2.103	0.0142
TD (mm)	108.2 ± 3.476	105.7 ± 2.174	0.1679
PCFV (cm^3)	292.4 ± 11.53	252.9 ± 23.11	0.0038

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CRediT authorship contribution statement

Donald E. Ogolo: Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **E.C. Ajare:** Validation, Writing – review & editing. **C.A. Ndubuisi:** Writing – review & editing. **Okwunodulu Okwuoma:** Writing – review & editing. **Sunday Nnama:** Resources. **S.C. Ohaegbulam:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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