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Original Article

Percutaneous clavicular length among Nigerian students of Delta State University: Clinical and forensic implications

[1]Ominde, B.S.; [1]Enaohwo, M.T.; [1]Omohwo, O.G.; [1]Jeremiah, O.; [1]Omoro, O.F.; [1]Igbigbi, P.S.

Abstract

BACKGROUND AND AIM: Evaluating the clavicle's length in forensic investigations can aid in sex determination and estimation of stature. It is also useful in ensuring successful surgical reduction of clavicular fractures. This study's goal was to determine the percutaneous length of the clavicle and elucidate their clinical and forensic applications.
MATERIALS AND METHODS: Four hundred students from a university in Delta State Nigeria were recruited after seeking ethical approval. We sought informed consent from the participants before the measurements of percutaneous clavicular length and height were taken. Using the statistical package for social sciences, the comparison of mean variables based on side, sex and age-groups was done. We employed linear regression analysis to derive equations that incorporated the percutaneous clavicular lengths to aid in estimating stature.
RESULTS: Males had longer clavicles than females (P<0.05). The clavicles demonstrated positive correlation with stature (P<0.05). The left percutaneous clavicular length was a better predictor of height than the right (P<0.05).
CONCLUSION: The study provides clavicular length data useful to orthopaedic surgeons and forensic experts in Delta State, Nigeria.

Keywords:
Stature; clavicle; length; height

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[1]*Department of Human Anatomy and Cell Biology, Delta State University, P.M.B. 1, Abraka, Nigeria.*

Address for Correspondence:
Ominde, B.S.
Department of Human Anatomy and Cell Biology, Delta State University, P.M.B. 1, Abraka, Nigeria.
berylominde@gmail.com

INTRODUCTION

The horizontal lying bone of the shoulder girdle is called the clavicle. This collar bone acts as a strut and facilitates the arm movements necessary for daily activities. It transfers upper limb's load to the axial skeleton (Sudikshiya *et al*., 2020). Usually, it's the first bone to ossify, beginning around the 5th to 6th weeks of gestation, and the last to achieve complete ossification at ages 22-30 years (Uduoka and Nwokediuko, 2013). The clavicle attains 80% of the adult length by ages 12 and 9 years in males and females respectively (Khade *et al*., 2021). Its growth is influenced by genetics, mechanical stresses and hormonal changes that occur during childhood and adolescence (Marjolein *et al*., 2001). The clavicle's size and dimensions in adults vary based on factors namely; race, physical activity, gender, nutrition, geographic location, age, ethnicity and socioeconomic status (Ominde *et al*., 2015; Ukoha *et al*., 2019, Sudikshya *et al*., 2020, Khade *et al*., 2021).

The clavicle is valuable in forensic investigations due to its durability, ease of measurement and ease of removal during autopsies (Pongpon *et al*., 2021). Its length is useful in establishing the biological profiles of unknown persons from fragmented or decomposed skeletal remains (Sehrawat and Pathak, 2016; Varsha *et al*., 2020). Precise clavicular length (CL) can help in predicting an individual's stature and sex especially in the absence of soft tissues that makes traditional methods like DNA analysis and fingerprinting impossible (Doshi and Reddy, 2017, Pongpon *et al*., 2021; Panuganti *et al*., 2022). This is common in mass disasters, such as explosions or earthquakes, where only mutilated skeletal remains are recovered (Prakash *et al*., 2024).

The clavicle is highly susceptible to fractures and its involvement encompasses 3% to 10% of all fractures (Qui *et al*., 2016). Effective surgical management of clavicular fractures requires the understanding of its morphometry to achieve optimal outcomes and minimise complications (Ominde *et al*., 2015). The precise design and choice of fixation devices such as clavicular plates and nails rely on population-specific data concerning the clavicular morphometry (Ominde

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et al., 2015, Qui *et al*., 2016). It is important for surgeons to be cognizant of the variations in clavicle's length and morphology across different populations (Ominde *et al*., 2015; Qui *et al*., 2016; Beck *et al*., 2021).

There is scarcity of data concerning the use of the clavicle's percutaneous length to estimate the stature of residents in Delta State, Nigeria. Our intention was therefore to determine the percutaneous clavicular length among Nigerian students of Delta State University and establish regression models that incorporate the clavicle's length to aid in height estimation.

MATERIALS AND METHODS

Study Area

The Faculty of Basic Medical Sciences of Delta State University, served as the study site for this cross-sectional, observational research project.

Ethical Approval

The Faculty of Basic Medical Sciences' ethical committee provided approval for this study (RBC/FBM/DELSU/24/350).

Selection of study participants

Four hundred (400) participants were recruited by simple random sampling technique and these included 200 female and 200 male undergraduate students, aged 18 to 25 years, who willingly provided verbal informed consent.

Sample size calculation

The population of students in the Faculty of Basic Medical Sciences was less than 10000. Therefore, to estimate the sample size for this study, the formula; nf=n*(1+ [n/N]) by Araoye (2004) was employed. The nf was regarded as the sample size desired when the total population is lower than 10000, while n was the size of the sample when the population is more than 10000. The N was considered the estimate of the size of the population. If n were to be 300 and the estimated population size being 4000, then the nf was calculated by substituting the values as follows;

nf= 300*(1+[300/4000])
nf= 300*(1+0.075)
nf= 300*1.075
nf= 322.5
nf= 323

Inclusion Criteria

Lower age limit of 18 years was selected because the clavicle's sexual dimorphism is obvious only after puberty (Panuganti *et al*., 2022). Furthermore, by 18 years of age, many individuals have attained their adult height (Khade *et al*., 2021).

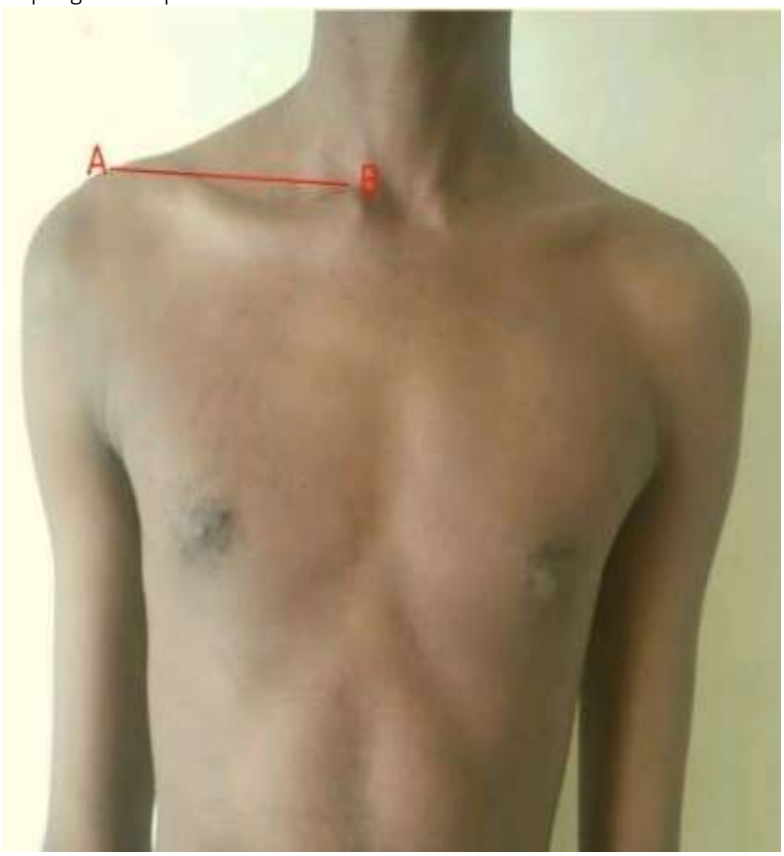

Figure 1. The percutaneous length of the right clavicle (A to B)

Figure 2. Measurement of stature.

Exclusion Criteria

Excluded subjects had history of lower limb or clavicular surgery, upper limb and pectoral girdle fractures, or had congenital deformities of the vertebral column such as kyphosis and scoliosis.

The maximum percutaneous lengths of the clavicles were measured bilaterally by a digital sliding vernier caliper (Shahe, China) with a 0.05 precision. This was determined using palpable clavicular landmarks namely; the innermost point on the sterno-clavicular joint and the outermost end on the acromioclavicular joint (Khade *et al*., 2021) (Figure 1). The height was measured using a stadiometer (Health Medical Equipment, England), from the vertex of the skull to the plantar aspect of the feet, with the participant in standing position and barefooted (Ukoha *et al*., 2019) (Figure 2). One investigator took all the measurements to minimize the interobserver errors. This investigator was trained to take the measurements thrice and record the average in centimeters

All the values were analyzed using the Statistical Package for Social Sciences (SPSS) Version 27.0 (SPSS Inc. Chicago, IL, USA). Gender and side variances in CLs were compared using the independent t–test and paired t-test respectively. Correlation between CL and stature was investigated using the Pearson's correlation test. Regression formulae incorporating the percutaneous lengths of the bilateral clavicles were derived to estimate stature. A high standard error of estimate (SEE) symbolized a lower accuracy of the variable in approximating stature. The P value was considered significant at 5%.

RESULTS

Eight hundred clavicles of 400 undergraduate students of equal gender composition (200 males and 200 females) were measured. These subjects' mean age was 20.51±1.83 years (range; 18 to 25 years); slightly higher in males (20.88±1.81 years) than females (20.14±1.78 years). (Table 1).

The participants' mean height was 170.02 ± 8.61 cm while the average CL was 15.81± 1.32cm (Table 2). The male subjects were taller and had longer clavicles than females ($p<0.05$) (Table 3). The mean CL on the left was higher compared to the right ($p<0.05$) (Table 4).

Age correlated positively with right and left CLs, although with a weak strength (r=258, 266, $p<0.05$) (Table 5). Stature correlated positively with both CLs, exhibiting a slightly higher strength (r=0.644) with the left than the right (r=0.603) clavicle (Table 6).

Linear regression models that used the left clavicle's length was more precise (SEE=6.60) than the right (SEE=6.88) (Table 6). However, only some variability in stature could perhaps be explained by the left (42%) and right (36%) CLs. A considerable portion of the variability was due to factors not included in the models. The model incorporating both CLs was akin to the left clavicular model (SEE=6.60) (Table 6). Table 7 displays the variant CLs and mean stature in diverse populations.

Table 1. Mean age of participants

Gender	Age Range	Mean± SD (years)
Males	18-25years	20.88±1.81
Females	18-25years	20.14±1.78
Total Population	18-25years	20.51±1.83

Table 2. Descriptive statistics of the parameters measured

	Minimum	Maximum	Mean ± SD
Height (cm)	149.0	193.0	170.02 ± 8.61
CL	12.59	19.42	15.81±1.32
Right CL (cm)	12.08	19.02	15.67 ± 1.36
Left CL (cm)	12.82	19.82	15.96± 1.32

CL- clavicular length

Table 3. Sex comparison of parameters in the studied population.

Variables (cm)	Sex	Mean±SD(cm)	t	P-value
Height	Males	175.14±7.69	14.77	0.001*
	Females	164.91±6.07		
Right CL	Males	16.51±11.71	15.61	0.001*
	Females	14.83±9.71		
Left CL	Males	16.84±10.74	17.63	0.001*
	Females	15.08±9.10		

CL- clavicular length, *P considered significant at<0.05

Table 4. Side comparison of the clavicular length in the study population

Gender	Mean ±Std Deviation (cm)		P value
	Right CL	Left CL	
Males	16.51±1.17	16.84±1.07	0.001*
Female	14.83±0.97	15.08±0.90	0.001*
Total	15.67±1.36	15.96±1.32	0.001*

CL- clavicular length, *P significant <0.05

Table 5. Correlation between clavicular length and age

		Age	Right CL	Left CL
Age	r	1	0.258**	0.266**
	P-		0.001	0.001

CL- clavicular length, **Correlation is significant at the 0.01 level, r- Pearson's correlation coefficient

Table 6. Linear regression analysis for height estimation using clavicular lengths

Variable (cm)	Predictive equations	R	R^2	SEE	P-value
Right CL	Stature = 110.34 + 3.808 * Right CL	0.60	0.36	6.88	0.001*
Left CL	Stature = 103.33 + 4.171 * Left CL	0.64	0.42	6.60	0.001*
Right CL and Left CL	Stature = 102.86 + 0.630 * Right CL + 3.59 * Left CL	0.65	0.42	6.60	0.001*

R-regression coefficient, R^2-Coefficient of determination, SEE-Standard error of estimate, * P value is statistically significant, H-Height, CL= clavicular length

Table 7. Comparison of the height and clavicular lengths in different population groups

Author	Country	N	Specimen	Gender	Height (cm)	Clavicular length (cm)	
						Right	Left
Trangadia and Gupta (2020)	India (Gujarat)	400	Post-mortem	M	169.2	14.37	14.23
				F	156.7	13.09	12.95
Khade *et al.* (2021)	India	489	Live subjects	M	172.68	15.85	15.70
				F	161.32	14.17	14.04
Pongpon *et al.* (2021)	Thailand	137	Radiographs	M	169.0	15.2	15.45
				F	159.6	13.71	13.94
Prakash *et al.* (2024)	India (Tamilnadu)	200	Post-mortem	M	165.3	14.74	15.24
				F	158.6	13.99	14.28
Current Study	Nigeria (Delta state)	400	Live subjects	M	175.14	16.51	16.84
				F	164.91	14.83	15.08

M-males, F- Females

DISCUSSION

Participants in the present study were taller than Nigerians evaluated in Anambra State (Ukoha *et al.*, 2019) and shorter than Indian and Thai populations (Varsha *et al.*, 2020; Trangadia and Gupta 2020, Khade *et al.*, 2021, Pongpon *et al.*, 2021, Prakash *et al.*, 2024). The mean CL was greater than reports of several previous studies (Uduoka and Nwokedioko, 2013, Ominde *et al.*, 2015, Varsha *et al.*, 2020; Trangadia and Gupta 2020, Khade *et al.*, 2021, Prakash *et al.*, 2024) (Table 9). Genetic, racial, geographical, ethnic and environmental influences like nutrition and physical activity could explain these population disparities (Ominde *et al.*, 2015; Ukoha *et al.*, 2019, Sudikshya *et al.*, 2020, Khade *et al.*, 2021). The source of clavicular specimen used either radiographs, dry bones, autopsy or living subjects could contribute to the morphometric variations (Sudikshya *et al.*, 2020). Surgical reduction of clavicular fractures and the subsequent shortening and displacement caused by the muscles attaching onto it, requires the knowledge of the normal length of the collarbone in a specific population (Sudikshya *et al.*, 2020). This awareness also informs the design and choice of the clavicular plates for fracture fixation and stabilization (Ominde *et al.*, 2015; Panuganti *et al.*, 2022).

Consistent with several reports, males were taller and had longer bilateral clavicles than females (Udoaka and Nwokediuko 2013, Ukoha *et al.*, 2019, Sudikshya *et al.*, 2020, Pongpon *et al.*, 2021; Panuganti *et al.*, 2022, Prakash *et al.*, 2024). This is because males have larger skeletal size, body build, and body mass than females due to their prolonged growth spurt characterized by a testosterone surge during puberty which leads to more pronounced shoulder broadening (Ukoha *et al.*, 2019, Khade *et al.*, 2021, Ominde *et al.*, 2024). Awareness of the significant sex variances in the CL is important in aiding forensic experts to accurately predict the sex of unknown skeletal remains. Additionally, it gives orthopedic surgeons the ability to provide individualized care by selecting implants that are specifically designed for a given sex group, thus improving surgical outcomes and minimize complications (Panuganti *et al.*, 2022).

Corresponding with several scholars, the left clavicle's length was greater than the right in both sex groups (Panuganti *et al.*, 2022, Pongpon *et al.*, 2021, Rani *et al.*, 2020, Prakash *et al.*, 2024). However, Varsha *et al.* (2020), Trangadia and Gupta (2020), and Khade *et al.* (2020) reported longer lengths on the right. The predominance of right handedness makes the right clavicle shorter owing to its greater curvature (Udoaka and Nwokediuko 2013, Sudikshya *et al.*, 2020, Ominde *et al.*, 2024). It is also more robust due to more developed muscles and ligaments attaching to it (Khade *et al.*, 2021). Bilateral asymmetry has likewise been ascribed to genetic factors, sex and growth hormones, lifestyle activities, nutrition, mechanical loading and occupational stress

(Ominde *et al*., 2015; Sudikshya *et al*., 2020, Khade *et al*., 2021). Additionally, the development of the brain, cerebral dominance and cerebral blood flow plays a role (Sudikshya *et al*., 2020). Consideration of clavicular asymmetry is paramount in the manufacture of clavicular appliances besides surgery (Ominde *et al*., 2015). In forensics, reconstructing a person's lifestyle and behaviors from skeletal relics might be aided by clavicular asymmetry, which may provide important information about a person's habits, and occupation.

Age had a positive association with CL, although weak, implying that the changes could be caused by hormonal, nutritional, and biomechanical influences rather than age. Most skeletal alterations caused by aging are obvious during puberty when growth is accelerated (Marjolein *et al*., 2001, Sudikshya *et al*., 2020, Khade *et al*., 2021). The present study used participants aged 18-25 years with the clavicles approaching complete growth.

Congruent with several reports, stature correlated positively with the CL (Ukoha *et al*., 2019, Trangadia and Gupta, 2020, Varsha *et al*., 2020, Khade *et al*., 2021, Prakash *et al*., 2021). This implies that taller people have longer clavicles for proper support of their wider shoulders and enhanced mobility of their longer arms. Therefore, an unknown subject's stature may possibly be estimated using the CL. Consistent with Trangadia and Gupta (2020), the left clavicle's length was a better predictor of stature than the right owing to the stronger correlation strength and lower standard error of estimate demonstrated by the regression model of the left clavicle. Ukoha *et al*. (2019) found high SEE in females and excluded the clavicle from estimating females' stature. Regression formula incorporating the bilateral CLs suggested similar accuracy of stature prediction as the left clavicular univariate model. Pongpon *et al*. (2021) observed higher accuracy of stature estimation using the multivariate regression equation incorporating bilateral CLs than univariate model involving one clavicle. They however noted that the multivariate equation may perhaps not be applicable in forensic cases where both clavicles cannot be recovered. The equations generated in our study were based on the mean CL in the total population studied, thus applicable even when the sex of an individual is unknown.

Conclusion: The results guide orthopaedic surgeons to accurately choose the appropriate clavicular implant for fracture reduction. In forensic investigations, the recovery of an intact left clavicle may provide better estimates for an individual's height than the right clavicle.

Strength of the Study: The use of percutaneous CL is a simple and reliable method because of the palpable subcutaneous landmarks used to define this variable.

Limitations of study: The study population was restricted to university students and this limited the sample size used.

Recommendations: A larger sample size can be used to ascertain the accuracy of the regression models. Other percutaneous metric variables of the shoulder girdle can be combined with the CL to increase the accuracy of estimating stature. Additionally, the percentage accuracy of using the percutaneous CL in sex determination can be investigated.

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Conflict of Interest: We declare no conflict of interest.

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