The Journal of Anatomical Sciences
Email: journalofanatomicalsciences@gmail.com
J. Anat Sci 16(1)

Submitted: December 28, 2024
Revised: January 28, 2025
Accepted: February 10, 2025

Morphometry and Significance of the Carrying Angle of Elbow among 18-25 years Old Yorubas in Southwest Nigeria

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ABSTRACT

The carrying angle (CA) is an important anthropometric parameter with a wide range of significance and applications in forensic medicine and clinical procedures that involve the upper extremities. This study was conducted to evaluate the CA among the Yoruba tribe in Nigeria and elucidate its significance. This study was conducted among 220 subjects comprising 100 males and 120 females between 18-25 years belonging to the Yoruba tribe in Southern Nigeria. The biodata of the subjects was obtained, and the CA was assessed as the angle formed between the longitudinal axes of the arm and forearm. Data obtained was presented as mean ± SD and comparison was conducted using t-test with $p < 0.05$ considered as statistically significant. Among the study population, the mean CA was 12.450 ± 3.180; the mean CA value among the males (11.340 ± 2.670) was significantly lower (p = 0.024) than that of the females (13.250 ± 3.110); and the mean left CA value (11.980 ± 3.020) was significantly lower (p = 0.024) than that of the right side (13.120 ± 2.630). The right CA was significantly higher than the left CA in females only (p = 0.045). The carrying angle showed significant ($p<0.05$) sex and bilateral differences among the study population thereby indicating its relevance as an important anthropometric parameter in forensic medicine and related clinical procedures among the study population.

Keywords: carrying angle, sexual dimorphism, Yoruba tribe, Nigeria

INTRODUCTION

Physical anthropometry generally entails the study of the physical dimensions and measurements of the human body or its component structures such as visceral tissues, vascular tissues, musculoskeletal tissues, joints, integuments, and many more [1,2,3,4]. The quantitative derivatives of anthropometric studies have diverse applications in forensic medicine, plastic and reconstructive surgery, clinical diagnosis of diseases, and treatment planning [5,6,7,8].

The elbow refers to the area of transition between the arm and the forearm which comprises the elbow joint, one of the most functionally active joints of the body. The elbow joint is a hinge type of synovial joint located 2-3 cm inferior to the level of the humeral epicondyles [9]. In an anatomical position whereby the elbow joint is fully extended, the forearm is supinated and the shoulder is externally rotated, the longitudinal axes of the upper arm and forearm form an angular intersection known as the Carrying Angle (CA) also known as the cubital angle

[10,11]. The projection of the medial ridge of the humeral trochlear about 6mm superior to its lateral edge and partly with the obliquity of the superior articular surface of the ulnar coronoid process causes the formation of the carrying angle in the anatomical position as earlier described [12].

However, during the full pronation of the forearm and flexion of the elbow joint, the longitudinal axes of the arm and forearm merge leading to the disappearance of the carrying angle [11,12]. Generally, the Carrying Angle is one of the most important anthropometric parameters of the upper extremities in humans which can be evaluated radiographically or percutaneously. Its value commonly ranges from 5º to 15º and is usually higher among females than males. The condition when the value is higher than 15º or lower than 5º is referred to as *Cubitus valgus* and *Cubitus varus* respectively [12,13]. Different factors have been reported to determine its variation including geographical location, age, gender, dominant side of the upper limbs, height, laxity of ligaments of elbow joint, fractures and traumatic injuries, congenital anomalies, genetic, inflammatory or rheumatic diseases [14,15].

Functionally, the carrying angle enhances free swinging of the forearm during walking and carriage of objects [13]. It has significant relevance during the evaluation of traumatic elbow injuries, management of elbow disorders, elbow reconstructive surgery, and the design of upper limb prosthesis and orthosis [16]. The carrying angle has been widely assessed in different populations in the Northern and Southern parts of Nigeria to elucidate its functional, morphological, and clinical relevance [16,17,18,19,20]. However, there remains a dearth of such studies among the Yoruba tribe in Southern Nigeria, which necessitated the current study aimed at evaluating the Carrying Angle among 18-25-year-old Yorubas in Ede, Osun State, Nigeria, to assess possible sexual dimorphism and bilateral differences among the study population.

MATERIALS AND METHODS

Study population

The study was conducted among 220 randomly selected participants (comprising 100 males and 120 females), aged between 18-25 years old in Ede, Osun State, Nigeria. This study involved only subjects whose paternal and maternal parents and grandparents belonged to the Yoruba tribe in Southwest Nigeria.

Inclusion and exclusion criteria

In addition, only individuals without any upper limb deformity, pathology, asymmetry, and history of arm, forearm, or elbow injury were included in this study. Non-compliant prospective subjects were excluded from this study.

Measurement of study parameters

The age and gender of all participating subjects were recorded before the measurement of the carrying angle. In this study, the measurement of the carrying angle was carried out with the aid of a manual goniometer. Measurement was conducted when the subject was in a standing anatomical position with the elbow in full extension, forearm supinated and shoulder externally rotated. The median longitudinal axis of the arm was defined by a line that connects the midpoint of the horizontal line between the lateral margin of the anterior axillary fold and the maximum width of the deltoid to the midpoint of the horizontal inter-epicondylar line [21,22]. The median longitudinal axis of the forearm was defined by connecting the midpoint of the inter-epicondylar horizontal line to the midpoint of the inter-styloid horizontal line. The Carrying Angle between the two longitudinal axes was measured for each side and recorded (Figure 1). The measurement procedure was repeated twice and the average value of the measurements was calculated to reduce the margin of error.

In addition, the average value of the right and left Carrying Angles was calculated for each subject.

Figure 1: Anthropometric evaluation of the Carrying angle

Ethical approval

This study was carried out following approval by the Research and Ethics Committee of the Faculty of Basic Medical Science, Redeemer's University, Ede, Nigeria with approval number RUN/FBMSERC/ANA/2022/29. The study followed the Helsinki Declaration for research involving human participants.

Statistical analysis

The data obtained was statistically analyzed using IBM-Statistical Package for Social Sciences (IBM-SPSS) version 22 (IBM Corp, Armonk, NY, USA). The data was analysed with an independent t-test for group comparisons between the genders, and sides. The results were evaluated in the 95% confidence interval and $p<0.05$ were considered statistically significant.

RESULTS

This study involved 220 subjects (100 males and 120 females) with an overall mean age of 20.77 ± 2.33 years, the mean age of the male subjects was 21.75 ± 1.15 years while that of the female subjects was 19.61 ± 1.25 years. For the entire study population, the results showed that the mean ± SD of the carrying angle was 12.450 ± 3.180 (Table 1). The mean ± SD of the carrying angle among male subjects (11.340 ± 2.670) was significantly lower ($p = 0.024$) than the value among the female subjects (13.250 ± 3.110) (Table 1). Furthermore, the right and left carrying angles among female subjects were significantly higher than the corresponding values among male subjects (Table 2). The mean right carrying angle (13.120 ± 2.630) was significantly higher ($p = 0.024$) than the left carrying angle (11.980 ± 3.020) among the study population (Table 2).

Table 1: The average Carrying Angle among subjects according to gender.

VARIABLES	GENDER		TOTAL CA (n = 220)
	MALE CA (n = 100)	FEMALE CA (n = 120)	
Mean (^{0})	11.34	13.25	12.45
SD (^{0})	2.67	3.11	3.18
Minimum (^{0})	4.00	5.00	4.00
Maximum (^{0})	20.00	25.00	25.00
p-value	*0.024		

CA=Carrying angle, SD=standard deviation, n=number of subjects, ***=** significant gender and side differences at $p<0.05$

Table 2: The right and left Carrying Angle among the subjects.

VARIABLES	RIGHT		LEFT		COMBINED	
	MALE CA (n = 100)	FEMALE CA (n = 120)	MALE CA (n = 100)	FEMALE CA (n = 120)	RIGHT CA (n = 220)	LEFT CA (n = 220)
Mean (^{0})	11.38	13.72	11.29	12.88	13.12	11.98
SD (^{0})	3.38	2.97	2.99	2.83	2.63	3.02
Minimum (^{0})	4.00	5.00	4.00	5.00	4.00	4.00
Maximum (^{0})	20.00	24.00	18.00	25.00	24.00	25.00
p-value	*0.033		*0.025		*0.024	

CA=Carrying angle, SD=standard deviation, n=number of subjects, ***=** significant gender and side differences at p<0.05

In addition, the findings among male subjects did not show any significant side difference (p = 0.125) however, the right Carrying Angle was significantly (p = 0.045) higher than the left Carrying Angle among the female subjects (Table 3). The comparison of the carrying angle between the study population and other populations is presented in Table 4.

Table 3: The CA among the male and female subjects.

VARIABLES	**MALE** (n = 100)		**FEMALE** (n = 120)	
	RIGHT CA	LEFT CA	RIGHT CA	LEFT CA
Mean (^{0})	11.38	11.29	13.72	12.88
SD (^{0})	3.38	2.99	2.97	2.83
Minimum (^{0})	4.00	4.00	5.00	5.00
Maximum (^{0})	20.00	18.00	24.00	25.00
p-value	0.125		*0.045	

CA=Carrying angle, SD=standard deviation, n=number of subjects, ***=** significant gender and side differences at p<0.05

Table 4: The carrying angle in different study populations

Author(s)	Country (Tribe/Region)	Age group	Side	Carrying Angle (^{0})	
				MALE	FEMALE
Acikgöz *et al.*[11]	**Turkey**	18-25 years	Combined	9.81 ± 2.82	13.99 ± 3.97
			Dominant upper limb	9.77 ± 2.82	13.94 ± 3.97
			Non-dominant upper limb	9.85 ± 2.95	14.03 ± 4.08
Rajesh *et al.* [21]	**India**	17-20 years	Combined	6.70 ± 1.00	13.60 ± 2.40
Bhat *et al.*[23]	**India** (Kashmiri)	18-30 years	Right	12.25 ± 1.49	14.85 ± 2.12
			Left	10.50 ± 1.39	13.70 ± 1.80
Kothapalli *et al.*[24]	**India** (Karnataka)	18-22 years	Right	12.09 ± 4.66	13.54 ± 6.44
			Left	10.20 ± 4.53	11.90 ± 5.61
Kazi *et al.*[25]	**India**	17-21 years	Combined	7.56 ± 1.67	10.66 ± 1.83
			Right	8.03 ± 1.72	11.05 ± 2.01
			Left	7.09 ± 1.73	10.26 ± 1.86

Adhikari *et al*. [26]	**Nepal**	16-24 years	Dominant upper limb	11.72 ± 1.37	13.70 ± 2.09
			Non-dominant upper limb	10.02 ± 1.50	11.74 ± 2.03
Yadav *et al*.[29]	**Nepal**	17-25 years	Combined	10.88 ± 2.22	13.05 ± 2.67
Chinweife *et al*.[18]	**Nigeria** (Igbo)	10-19 years	Right	12.30 ± 1.88	13.82 ± 1.65
			Left	10.99 ± 1.87	12.55 ± 1.76
Udoaka and Oghenemavwe [19]	**Nigeria** (Niger Delta)	-	Combined	11.30 ± 1.37	15.20 ± 0.97
Sani *et al*.[15]	**Nigeria** (Hausa)	18-28 years	Combined	10.24 ± 4.26	14.54 ± 3.90
Present Study	**Nigeria** (Yoruba)	18-25 years	Combined	11.34 ± 2.67	13.25 ± 3.11
			Right	11.38 ± 3.38	13.72 ± 2.83
			Left	11.29 ± 2.99	12.88 ± 2.97

DISCUSSION

The findings of the current study showed that the right Carrying Angle was significantly higher than the left Carrying Angle among the female subjects and the entire study population. These findings showed similarity to previous studies conducted among other proximate or distant study populations. According to a study conducted among the proximate Igbo tribes, the right Carrying Angle was significantly higher than the left Carrying Angle among both male and female subjects [18]. This was similarly reported among the distant Indian and Nepalese populations [23,24,25,26]. Essentially, various factors have been reported to influence the variability of the Carrying Angle which include an increase in age, racial difference, methods of measurement (radiographical or percutaneous), and stature of an individual [22,27,28]. These factors required significant consideration during clinical planning for the treatment of elbow pathologies (including reconstruction or arthroplasty) as well as during the design of elbow prostheses.

Furthermore, the Carrying Angle has been reported to exhibit significant side differences whereby the value for the right side, which is often the dominant upper limb in many populations, is usually higher compared to the left side [23,24]. This finding was similarly observed among the current study population. Conversely, the study conducted among the Turkish population reported contradicting results with the Carrying Angle of the dominant (right) upper limb reportedly lower than the value for the non-dominant (left) side in both males and females [11]. Essentially, the asymmetrical development of the right and left upper extremities has been reported to contribute to the contralateral variation of the Carrying Angle in an individual [29].

Moreover, the Carrying Angle has been reported to exhibit significant sexual dimorphism in different human populations [19]. Accordingly, the results of this study showed significant sexual dimorphism in the mean Carrying Angle values of the bilateral sides. This conformed the findings from previous studies among the Nigerian Hausas, Igbos, and other tribes from the Northern and Southern parts of Nigeria [16-19]. The results of their studies indicated prominent sexual dimorphism with the Carrying Angle values being significantly higher among the female subjects than the male counterpart. Additionally, studies carried out in Turkey, India, and Nepal observed this similar sexual dimorphism in their populations [11,21,23,26]. These findings about Carrying Angle further provide credence to its role in differentiating one sex from the other [30]. Essentially, the higher Carrying Angle values among the females have been described as one of the secondary sexual characteristics in females

that are not directly associated with reproduction [31,32]. The different body proportions and morphological features of the females such as smaller shoulders and wider hips have been reported to contribute to the higher Carrying Angle than in males [33]. Furthermore, the higher Carrying Angle value has been associated with ligamentous laxity and could act as a risk factor for non-traumatic ulnar nerve neuropathy [17,34,35].

Furthermore, the Carrying Angle is an important anthropometric parameter with diverse applications in different clinical procedures that involve the upper extremities. This includes its application in the evaluation of traumatic elbow injuries or disorders especially those that may require reconstruction or arthroplasty [12,22]. In essence, adequate information about the Carrying Angle is needed during the pre-operative surgical planning for trauma or deformities of the elbow joint. It is also of clinical relevance during epicondylar disease therapy, the design of elbow prostheses, and elbow replacement implants [22]. Aside from from its comparison based on sex and bilateral sides, the relationship of Carrying Angle with other anthropometric parameters (including body mass index, arm length, forearm length, inter-epicondylar distance, trans-trochanteric diameter) has also been investigated by different previous studies with contrasting outcomes [20,22,36]. In essence, the findings of this study would provide useful information during the aforementioned clinical procedures among the study population.

CONCLUSION

This study provided the reference value for the Carrying Angle among the study population which will be of significant relevance during clinical procedures involving the elbow joint. It further described the existence of sex-based and bilateral dimorphism among the study population.

REFERENCES

1. Oludiran OO, Omotoso DR, Sakpa CL. Nasofacial indices among children in southern Nigeria. Afr J Biomed Res. 2012;15(2):141-3.
2. Omotoso DR, Okwuonu UC, Yawson EO, Awoniran PO. Morphometry and significance of collodiaphyseal angle among Bini tribe in Southern Nigeria. J Forensic Sci Med. 2024; 10:20-23.
3. Kumar A, Sharma L, Archana, Kaushik G, Saini N, Soni RK, *et al*. Estimation of sex by applying discriminant function analysis on osteometric parametrics of clavicle in population of Haryana. J Forensic Sci Med. 2023; 9:106-11.
4. Omotoso DR, Adagbonyin O, Bienonwu E, Uwagbor V. Anthropometric evaluation of nasal height, nasal breadth and nasal index among Bini children in Southern Nigeria. Int J Anat Res. 2019;7(3):6896-900.
5. Omotoso DR, Ojeikere V. Radiographical assessment of the subpubic angle among adult Bini tribe in Nigeria and overview of its significance. J Datta Meghe Inst Med Sci Univ 2024; 19:325-9.
6. Yadav S, Nayak VC, Palimar V, Gupta C, Chetal JR. An estimation of stature and sex using various anthropometric parameters in South Indian population. J Forensic Sci Med. 2023; 9:130-6.
7. Omotoso DR, Baxter-Grillo D, Adagbonyin O, Bienonwu E. Comparative assessment of cephalic index among Bini and Igbo tribes in Benin City, Nigeria. Int J Anat Res. 2019;7(2):6685-9.
8. Omotoso DR, Ita-Okon B. Comparative study of nasal morphometry among the Ibibio and Bini Tribes in Southern Nigeria. J Morphol Sci. 2023; 40:220-4.
9. Moore KL, Dalley AF, Agur AMR. Clinically Oriented Anatomy. Eighth Edition, Philadelphia, Wolters Kluwer. 2018;644-5.
10. Verma V, Singh A, Ksuhwaha NS, Sharma Y, Singh A. Correlation between

morphometric measurements and carrying angle of human elbow. Cureus. 2022; 14(7): e27331.
11. Acikgöz AK, Balci RS, Göker P, Bozkir MG. Evaluation of the Elbow Carrying Angle in Healthy Individuals. Int J Morphol. 2018;36(1):135-9.
12. Shah PA, Naqvi WM. Carrying angle and its co-relation with different parameters height, length of forearm, and age. Int J of Physiother 2020;7(5):211-5.
13. Lim V, Jacob NA, Ghani MF, Wang DC, Devi AK. An anthropometric study on the carrying angle of elbow among young adults of various ethnicities in Malaysia. Nat J Integr Res Med. 2014;5(6):20-3.
14. Terra BB, Silva BCM, Bella H, Carvalho F, Dobashi ET, Pinto JA, *et al*. Evolution of the carrying angle of the elbow: A clinical and radiographic study. Acta Orthoped Brasil. 2011;19(2):79-82.
15. Daneshmandi H, Shahrokhi H, Pegah R, Nazary SH. The study of predictor's anthropometric parameters of upper limb with elbow carrying angle in athlethes. J Rom Sports Med Soc. 2014;10 (4):2447-51.
16. Sani A, Modibbo MH, Tela IA, Bilkisu UK. Determination of carrying angle among Hausa ethnic population of Zamfara State, Nigeria. Dutse J Pure Appl Sci. 2020;6(4):221-7.
17. Oladipo GS, Paul JN, Amasiatu VC, Alabi AS, Amadi PN. An examination of carrying angle of students in Madonna University, Elele, Port Harcourt, Rivers State, Nigeria. J Appl Biotechnol Bioeng 2019;6(2):95-9.
18. Chinweife KC, Ejimofor OC, EZjindu DN. Correlation of carrying angle of the elbow in full extension and hip-circumference in adolescents of Nnewi people in Anambra State. Int J Sci Res Publ. 2014;4(10):1-8.
19. Udoaka AI, Oghenemavwe L. A radiographic study of the carrying angle in the people of Niger Delta region in southern Nigeria. Afr J Med Phy Biomed Eng Sci. 2009; 1:18-20.
20. Anibor E, Ojigho E, Ogbatorho T. Correlation between body mass index and carrying angle among adolescents in Abraka, Nigeria. I J Foren Med Invest. 2016;2(1):13-6.
21. Rajesh B, Reshma VR, Jaene RC, Somasekhar IT, Vaithilingam A. An evaluation of the carrying angle of the elbow joint in adolescents. Int J Med Biomed Res. 2013;2(3):221-5.
22. Manandhar B, Shrestha I, Shrestha R. Dominance of carrying angle in right-hand among Dental students of a Teaching Hospital: A descriptive cross-sectional study. J Nepal Med Assoc. 2022;60(247):282-5.
23. Bhat MA, Bhat TA, Ganie PA, Mir WA. Comparative study of carrying angle between dominant and non-dominant limb in Kashmiri population. Int J Comtemp Med Res. 2019;6(6): F1-3.
24. Kothapalli J, Murudkar PH, Seerla LD. The carrying angle of elbow - A correlative and comparative study. Int J Curr Res Rev. 2013;5(7):71-6.
25. Kazi S, Keche H, Joshi PK, Wanjari AN. The comparison and evaluation of carrying angle of elbow with anthropometric measurements in both sexes. Int J Anat Res. 2017;5(4.3):4686-90.
26. Adhikari RK, Yadav S, Kam A. A comparative study of carrying angle with respect to sex and dominant arm in eastern population of Nepal. I J Curr Res Rev. 2017;9(7):19-22.
27. Kaewpornsawan K, Kamegaya M, Udompunturak S, Eamsophana P, Ariyawatkul T. The normal reference values of carrying angle from birth to adolescence. Siriraj Med J. 2018;70(4):284-8.
28. Jan SS, Shah BA, Shahdad S, Saleem SM. Morphometric measurements of carrying angle of elbows and its association with gender and height among Kashmiri population: A cross-sectional study. J Medic Sci Clin Res. 2018;6(9):1092-8.

29. Yadav SK, Malla BK, Srivastava AK, Verma A, Kumar A. An anthropometric study of carrying angle and other parameters in young adults of Kathmandu, Nepal. Revista Română de Anatomie funcţională şi clinică, macro- şi microscopică şi de Antropologie 2018;17(2):99-105.
30. Alsubael MO, Hegazy AAM. Radiographic evaluation of the normal elbow carrying angle in adults. J Med Sci. 2010; 10:40-4.
31. Atkinson WB, Elftman H. The carrying angle of the human arm as a secondary sex character. Anatom Rec. 1945;91(1):49-52.
32. Richards JE, Hawley RS. Sex Determination: How Genes determine a developmental choice. The Human Genome, Third Edition, 2011:273-98.
33. Khan MS, Singh RB. Variation in carrying angle - A normative study. Ind J Orthopead Surg. 2023;9(4):237-42.
34. Chang C-W, Wang Y-C, Chu C-H. Increased carrying angle is a risk factor for nontraumatic ulnar neuropathy at the elbow. Clin Orthop Relat Res. 2008;466(9):2190.
35. Pandeya A, Timalsina B, Khadka B, Chaudhary D, Sah SK. Carrying angle and its variations with anthropometric parameters among the medical students of Rupandehi district, Nepal. Saudi J Med Pharmaceut Sci. 2017;3(10A):1043-46.
36. Kushwaha NS, Verma V, Singh A, Sharma Y, Singh A. A study of factors associated with carrying angle of the human elbow in pediatric age group. Cureus 2022;14(5):e25478.