ONLINE FIRST

ISSN: 0015-5659

e-ISSN: 1644-3284

Carrying angle among young adults of Saudi Arabia and its correlation with demographic characteristics: A cross sectional study

Authors: Jaya Shanker Tedla, Raghu Jetti, Batool Abdulelah Alkhamis, Ravi Shankar Reddy, Mastour Saeed Alshahrani, Devika Rani Sangadala, Vikram Sreenivasa Rao, Debjani Mukherjee, Ahlam Mohammed Alamri, Hind Khalid Ali AlQahtani

DOI: 10.5603/fm.101752

Article type: Original article

Submitted: 2024-07-26

Accepted: 2024-09-02

Published online: 2024-09-10

Carrying angle among young adults of Saudi Arabia and its correlation with demographic characteristics: a cross sectional study

Jaya Shanker Tedla[1], Raghu Jetti[1], Batool Abdulelah Alkhamis, Ravi Shankar Reddy[1], Mastour Saeed Alshahrani[1], Devika Rani Sangadala, Vikram Sreenivasa Rao[2], Debjani Mukherjee[1], Ahlam Mohammed Alamri[3], Hind Khalid Ali AlQahtani

[1]Program of Physical Therapy, Department of Medical Rehabilitation Sciences, College of Applied Medical Sciences, King Khalid University, 61421 Abha, Saudi Arabia
[2]College of Medicine, King Khalid University, 61421 Abha, Saudi Arabia
[3]Physiotherapy Department, Armed Forces Hospital Southern Region Rehabilitation Health Services, Khamis Mushait, Saudi Arabia

Address for correspondence: Jaya Shanker Tedla, Department of Medical Rehabilitation Sciences, College of Applied Medical Sciences, King Khalid University, S-058, Building Number M03, Al Fara, 61421 Abha, Saudi Arabia; e-mail: jtedla@kku.edu.sa

ABSTRACT

Background: The angle between the median axes of the forearm and arm is called the carrying angle (CA). Sex differences in CA and its relation to age, height, weight, and BMI are unclear. The aim of the present study was to measure the CA in male and female subjects in the Saudi population and correlate it with the above variables.

Materials and methods: A digital goniometer was used to measure CA in 181 males and 165 females. Information on age, height, weight, and BMI was also recorded.

Results: CA showed differences based on sex, though was independent of age, height, weight, and BMI. Hormonal factors may influence CA and could explain larger CA values in female subjects.

Conclusions: CA measurement in specific population groups contributes to the successful management of several pathological conditions of the elbow and aids in the design of elbow orthotics and prosthetics.

Keywords: carrying angle, elbow, goniometry, BMI

INTRODUCTION

Carrying angle (CA), or cubital angle, is the angle made by the median axes of the arm and forearm when the forearm is in full extension and supination, known as the anatomical position [23]. CA improves the upper extremity's mechanical advantage when carrying objects, hence its name [2]. The anatomical characteristics that produce CA in both sexes are the medial border of the trochlea, which projects 6 mm inferior to its lateral edge, and the obliquity of the superior articular surface of the coronoid process in relation to the shaft of ulna [31]. Normal CA is 5°–10° in males and 10°–15° in females. In both sexes, an angle of > 15° is considered a "cubitus valgus," and an angle < 5° is considered a "cubitus varus" [26]. CA disappears during forearm pronation, elbow flexion, and the general functional position of the hand [21].

In general, CA is larger in females than in males, making it one of the female secondary sex characteristics. While some researchers have not found significant sex differences, the majority of studies have reported sex differences in CA. The narrower shoulders and wider pelvis in females could be attributed for this sex difference, though one study reported that CA was not associated with pelvic width [17]. Shorter height and joint laxity in females might also be factors influencing CA [17, 18].

CA is influenced by various anthropometric features, such as height and hand dominance. It has been found to be larger in shorter persons, and smaller on the nondominant side compared to the dominant side in both res [17, 30]. However, some studies have reported no difference between sides [9, 18, 28]. The aforementioned factors also vary based on ethnic group. Earlier reports correlated CA with age, sex, height, weight, and handedness. CA has been evaluated in relation to sex and hand dominance in Indian population [9, 15, 18, 25, 28, 29] and was correlated with height, age, and forearm length in a Nepalese population [2, 30]. Comparison between children and adults [19] has shown that adults have larger CA than children and that CA increases with age in a Turkish population [35]. CA has also been studied during the fetal period and was found to be sexually dimorphic in the early intrauterine period during 10–35 weeks of

gestation [13]. It was found to be larger in females than in males in Indian and Turkish samples [6, 35]. Shorter people demonstrated larger CA than taller persons of the same age in an Indian population [17]. These parameters also correlated with CA in a Jordanian population [3]. CA was correlated with hip circumference in a Nigerian population [14, 22]. In a Greek population, obesity was shown to correlate with larger CA [23]. Dominant-side CA was larger than nondominant-side CA in Greek and Turkish populations [23, 35].

CA varies between different ethnic groups, and there is conflicting evidence on the impact of sex, handedness, age, height, weight, and forearm length on CA. However, there are no studies in the Saudi population exploring the relationship between CA and other variables. The current study was undertaken in order to evaluate CA and its relationship with other anthropometric parameters.

MATERIALS AND METHODS

The study protocol was approved by the institutional ethics committee (ECM# 2020-3206). A total of 346 volunteers (181 males and 165 females) were recruited after obtaining written informed consent. All included individuals were between 18 and 24 years of age and were college-attending young adults with normal elbow bony configuration. Individuals with congenital deformities, trauma, or fractures in the proximity of the elbow joint were excluded from the study.

The study was conducted in the Department of Medical Rehabilitation Sciences, College of Applied Medical Sciences, King Khalid University, Abha, Kingdom of Saudi Arabia. CA was measured using the Baseline Evaluation Instruments Digital Absolute + Axis™ goniometer (12-1027) with the individual standing in the anatomical position. Reference points were marked with an erasable whiteboard marker at the cubital crease for the fulcrum, bicipital groove for the stationary arm, and palmaris longus tendon at the wrist for the movable arm. The fulcrum was fixed at the midpoint of the cubital crease, the stationary arm was aligned with the median axis of the arm (i.e., in line with the bicipital groove and biceps brachii tendon), and the movable arm was aligned with the median axis of the forearm (i.e., along the palmaris longus tendon) [5]. The angle between the two arms was noted in degrees (Fig. 1), and the same procedure was repeated on the other side. Individual’s height was measured with a stadiometer and weight was recorded with a standard scale in kilograms. Body mass index (BMI) was calculated using the standard

formula (kg/m^2). Volunteers were asked for their age and sex, and this information was documented in a data entry sheet.

The data were analyzed with the IBM SPSS statistics software version 20. Descriptive statistics were applied to calculate mean values for CA, age, height, weight, and BMI. An independent sample *t*-test was used to assess differences in CA based on sex and handedness, and P values less than 0.05 were considered statistically significant. Pearson correlation coefficient was used to evaluate the correlation between CA and age, height, weight, and BMI.

RESULTS

Descriptive statistics for carrying angle, age, height, weight, and BMI in male subjects

Among the 181 male subjects, the mean values for CA for right and left sides were 7.98 ± 2.56 and 7.79 ± 2.46, respectively. The average age of the subjects was 21.1 ± 1.79 years. Mean height was 170.7 ± 6.19, mean weight was 71.6 ± 15.8, and mean BMI was 27.1 ± 36.7 (Table 1).

Descriptive statistics for carrying angle, age, height, weight, and BMI in female subjects

Among the 165 female subjects evaluated, the mean CA values for right and left sides were 13.2 ± 1.82 and 13.0 ± 1.72, respectively. Mean female subject age was 20.9 ± 2.12 years, mean height was 158.5 ± 5.31, mean weight was 56.4 ± 9.53, and mean BMI was 22.4 ± 3.38 (Table 1).

Carrying angle difference between sexes

An independent sample t-test was performed to assess the difference in CA between male and female subjects. There was a statistically significant difference between males and females in right CA ($P < 0.001$). Levene's test, with equal variances not assumed, showed F (324) = 13.8. Independent sample t-test showed a significant difference, t (324) = −21.96, P = 0.000 (Table 2). The difference between male and female subjects in left CA was also statistically significant ($P < 0.001$). Levene's test, with equal variances not assumed, showed F (322) = 18.3, and *t*-test showed a significant difference, t (322) = −23.0, P = 0.000 (Table 2).

Right and left carrying angle differences by sex

In both male and female subjects, there was no significant difference between right and left CA. Although mean right CA values were larger than left CA values in both sexes, the difference was not statistically significant (Table 3).

Correlation of carrying angle in male subjects with age, height, weight, and BMI

Pearson correlation coefficient was used to analyze the correlation between CA and age, height, weight, and BMI. However, we did not get any statistical significant correlation between any of the parameters (Table 4).

Correlation of carrying angle in female subjects with age, height, weight, and BMI

Right and left CA was positively correlated with subject height and weight, and left CA was negatively correlated with age and BMI. However, none of the positive or negative correlations had statistical significance (Table 4).

DISCUSSION

This is a unique study aimed at identifying clinical CA reference values among young adults in the Kingdom of Saudi Arabia. CA is larger in females and is considered one of the secondary sex characteristics. In the present study, mean CA was significantly larger in female subjects than in males. Similar observations have been made in Malaysian, Indian, Nepalese, and Greek populations [2, 20, 23, 27]. On the contrary, others have reported no sex difference in CA [29, 30]. The present study's findings are similar to those found in a Turkish population [1]. Similar results were also reported in a Jordanian population [3]. The reference values of the present study are compared with other published reports (Table 5).

Sex differences in CA have been reported even during the fetal period [13]. The sex difference observed in the present study correlated well with another radiographic study conducted in a Saudi population [4]. Several theories have been proposed to explain sex differences in CA. The well-known muscular theory and broader pelvis in females do not adequately explain the larger CA in females; it may be instead related to ligamentous laxity and genetic constitution in females [8]. The larger CA in females may also be attributed to the hormone estrogen that influences bony remodeling and stress. The inferior one-third of the

humeral shaft has a slight lateral deviation in females, which could also be one of the reasons for a larger CA [11].

In the present study, right CA values are larger than left CA values in both male and female subjects; however there is no statistical significant difference. In previous studies on Nepalese and Jordanian subjects, mean CA values for both sexes were significantly larger on the right side compared to the left side [2, 3]. However, other studies have reported larger CA on the left side than the right side [30]. The present study's findings are similar to those in a Turkish population, as no significant differences in CA were found between right and left limbs [1]. Similarly, no difference in right and left CA was found during the fetal period [13]. A larger CA on the right side could be related to its higher level of functional use.

In previous studies, CA has been positively correlated with age [11, 12, 14, 16, 32, 33], with values becoming stable at 15–16 years of age [3, 16]. However, in the present study, CA had a non-significant positive correlation with age in male subjects and a non-significant negative correlation in female subjects. In a study of Indian subjects, CA was not correlated with the age [28]. Another study in an Indian population found CA to have a significant positive correlation with age in females and a negative correlation with age in males [18]. CA was negatively correlated with age during the fetal period [13]. Skeletal maturation could be the reason for increased CA with age [33].

CA had a non-significant positive correlation with height in both sexes. In contrast to our findings, CA was found to have a significant negative correlation with age in Indian female subjects [28]. Left CA showed a significant positive correlation with height while right CA showed a negative correlation with height in Nepalese subjects [30]. CA did not correlate with height in 5- to 18-year-old Indian subjects [6]. Height also did not influence CA in another study on Indian subjects [25]. There was a negative correlation between height and CA in Turkish subjects and Indian female subjects [1, 18]. In shorter people, the medial aspect of the ulnar trochlear notch deviates from the medial ridge of the trochlea, causing a larger CA [28].

In the present study, weight was showed non-significant negative correlation with CA in males and non-significant positive correlation with CA in females. In a Jordanian population, weight did not have a significant influence on CA in either sex [3]. We found a negative correlation between CA and BMI, similar to a study on a Turkish population [1]. The

discrepancies in CA in various studies could be related to the methodologies used to measure sample size and subject ethnicity.

Knowledge of CA helps clinicians in the management of pathological conditions of the elbow [36]. An increased CA or cubitus valgus may lead to joint instability and pain during exercise and sports [20]. It is important to know the CA during orthopedic treatment, including elbow reconstruction and implantation surgeries, manual therapy, and elbow orthotic and prosthetic design [24, 34]. Cubitus valgus deformity may increase the risk of nontraumatic ulnar neuropathy [10].

CONCLUSIONS

From the results of the present study, it can be concluded that CA differs based on sex in the Saudi population, though is independent of age, height, weight, and BMI. While the present study included male and female subjects between 18 and 24 years of age, future studies should include larger age groups and sample sizes to draw further concrete correlations.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

All the collected and analyzed data and materials were available with the corresponding author.

Ethics statement

The study protocol was approved by the Institutional Ethics Committee (ECM# 2020-3206). All the subjects provided written informed consent for their participation.

Author contributions

JST and RJ had planned the study and obtained necessary permissions to carry out the work. BAA, RSR, MSS, DRS, VSR, AMA, DM and HKAA collected the data. BAA, RSR, JST, DM and RJ analyzed the data and contributed to the results section. JST, RJ, BAA, RSR, MSS, DRS, VSR, AMA, DM and HKAA reviewed the available literature. JST, RJ, BAA, RSR, MSS, DRS, VSR, AMA, DM and HKAA prepared the manuscript. JST, RJ, BAA, RSR, MSS, DRS, VSR, AMA, DM and HKAA drafted, refined, and proofread the manuscript for publication.

Funding

The Deanship of Research and Graduate Studies at King Khalid University funded this work through Large Research Project under grant number RGP2/216/45.

Acknowledgments

1. The authors extend their appreciation to the Deanship of Research and Graduate Studies at King Khalid University for funding this work through Large Research Project under grant number RGP2/216/45.
2. The authors declare that there is no usage of AI related tools.

Conflict of interest

All authors hereby declare that no potential competing interests

REFERENCES

1. Acikgöz A, Balci R, Göker P, et al. Evaluation of the elbow carrying angle in healthy individuals. Int J Morphol. 2018; 36(1): 135–139, doi: 10.4067/s0717-95022018000100135.
2. Adhikari RK, Yadav SK, Karn A. IJCRR a comparative study of carrying angle with respect to sex and dominant arm in eastern population of nepal. Int J Cur Res Rev. 2017; 9: 19–22.
3. Allouh M, Khasawneh R. Measurement of the carrying angle in Jordanians with respect to different body parameters = قياس زاوية الحمل لدى الأردنيين. Jordan Med J. 2014; 48(2): 93–101, doi: 10.12816/0024899.
4. Alsubael MO, Hegazy AM. Radiographic evaluation of the normal elbow carrying angle in adults. J Med Sci. 2010; 10(2): 40–44, doi: 10.3923/jms.2010.40.44.
5. Amis AA, Dowson D, Unsworth A, et al. An examination of the elbow articulation with particular reference to variation of the carrying angle. Eng Med. 2016; 6(3): 76–80, doi: 10.1243/emed_jour_1977_006_021_02.

6. Balasubramanian P, Madhuri V, Muliyil J. Carrying angle in children: a normative study. J Pediatr Orthop B. 2006; 15(1): 37–40, doi: 10.1097/01202412-200601000-00008, indexed in Pubmed: 16280718.
7. Bari W, Alam M, Omar S. Goniometry of elbow carrying angle: a comparative clinical study on sexual dimorphism in young males and females. Int J Res Med Sci. 2015: 3482–3484, doi: 10.18203/2320-6012.ijrms20151242.
8. Beals RK. The normal carrying angle of the elbow. A radiographic study of 422 patients. Clin Orthop Relat Res. 1976; 119: 194–196, doi: 10.1097/00003086-197609000-00029.
9. Bhat MA, Bhat TA, Ganie PA, et al. Comparative study of carrying angle between dominant and non dominanat limb in kashmiri population. Int J Contemp Med Res. 2019; 6(6): 2–4, doi: 10.21276/ijcmr.2019.6.6.2.
10. Chang CW, Wang YC, Chu CH. Increased carrying angle is a risk factor for nontraumatic ulnar neuropathy at the elbow. Clin Orthop Relat Res. 2008; 466(9): 2190–2195, doi: 10.1007/s11999-008-0308-2, indexed in Pubmed: 18506557.
11. Dey S, Mandal L, Kundu B, et al. Carrying angle of the elbow: It's changes from childhood to adulthood: Morphometric study in Eastern India. Indian J Basic Appl Med Res. 2013; 8: 823–30.
12. Emami MJ, Abdinejad F, Khodabkhshi S, et al. The normal carrying angle of the elbow in Shiraz. Med J Islam Repub Iran. 1998; 12: 37–39.
13. Erdoğan K, Malas MA. The investigation of the carrying angle of the elbow in fetal period. Surg Radiol Anat. 2020; 42(8): 911–918, doi: 10.1007/s00276-020-02438-2, indexed in Pubmed: 32086625.
14. Ezejindu DN, Chinweife KC, Ejimofor OC, et al. 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: 2250–3153.
15. Hg T, Uk M, Rajendra R. The correlative study of degrees of carrying angle with height of body in both the sexes of south Indian population Correlation between height and carrying angle in Male. Indian J Clin Anat Physiol. 2017; 4: 369–372.
16. Kaewpornsawan K, Kamegaya M, Udompunturak S, et al. The normal reference values of carrying angle from birth to adolescence. Siriraj Med J. 2018; 70: 284–288.

17. Khare GN, Goel SC, Saraf SK, et al. New observations on carrying angle. Indian J Med Sci. 1999; 53: 61–67.
18. Kothapalli J, Murudkar P, Seerla L. The carrying angle of elbow — a correlative and comparative study. Int J Curr Res Rev. 2013; 05: 71–6.
19. Kumari KL, Sekhar RC. A comparative study of carrying angle between chidren and adult in andhra population. J Dent Med Sci. 2016; 15(6): 33–36.
20. Lim V, Jacob NA, Ghani MFS, et al. An anthropometric study on the carrying angle of elbow among young adults of various ethinicities in Malaysia. Natl J Integr Res Med. 2014; 5: 20–23.
21. Norkin PKLC. Joint structure and function. 5th ed. A Davis Company, Philadelphia 2011.
22. Oladipo GS, Paul JN, Amasiatu VC, et al. An examination of carrying angle of students in Madonna University, Elele, Port Harcourt, Rivers State, Nigeria. J Appl Biotechnol Bioeng. 2019; 6: 95–9, doi: 10.15406/jabb.2019.06.00179.
23. Paraskevas G, Papadopoulos A, Papaziogas B, et al. Study of the carrying angle of the human elbow joint in full extension: a morphometric analysis. Surg Radiol Anat. 2004; 26(1): 19–23, doi: 10.1007/s00276-003-0185-z, indexed in Pubmed: 14648036.
24. Punia RS, Sharma R, Usmani JA. The carrying angle in an Indian population. J Anat Soc India. 1994; 43: 107–10.
25. Rajesh B, Reshma VR, Jaene RC, et al. An evaluation of the carrying angle of the elbow joint in adolescents. Int J Med Biomed Res. 2013; 2(3): 221–225, doi: 10.14194/ijmbr.2310.
26. Robert C, Manske M, David J. Orthopedic physical assessment. 7th ed. Missouri: Elsevier .
27. Ruparelia S, Patel S, Zalawadia A, et al. Study of carrying angle and its correlation with various parameters. NJIRM. 2010: 1.
28. Shah PA, Naqvi W. Carrying angle and its co-relation with different parameters height, length of forearm, and age. Int J Physiother. 2020; 7(5), doi: 10.15621/ijphy/2020/v7i5/782.
29. Sharma AK, Jabeen N, Magotra R, et al. study of carrying angle of elbow among young adults of Jammu & Kashmir. JK Sci. 2019; 21: 52–54.

30. Sharma K, Mansur DI, Khanal K, et al. Variation of carrying angle with age, sex, height and special reference to side. Kathmandu Univ Med J (KUMJ). 2013; 11(44): 315–318, doi: 10.3126/kumj.v11i4.12540, indexed in Pubmed: 24899327.
31. Standring S. Gray's Anatomy. 41st ed. Elsevier, London 2016.
32. Terra B, Silva B, Carvalho H, et al. Evolução etária do ângulo de carregamento do cotovelo: estudo clínico-radiográfico. Acta Ortop Bras. 2011; 19(2): 79–82, doi: 10.1590/s1413-78522011000200003.
33. Tükenmez M, Demirel H, Perçin S, et al. [Measurement of the carrying angle of the elbow in 2,000 children at ages six and fourteen years]. Acta Orthop Traumatol Turc. 2004; 38(4): 274–276, indexed in Pubmed: 15618770.
34. Van Roy P, Baeyens JP, Fauvart D, et al. Arthro-kinematics of the elbow: study of the carrying angle. Ergonomics. 2005; 48(11-14): 1645–1656, doi: 10.1080/00140130500101361, indexed in Pubmed: 16338730.
35. Yilmaz E, Karakurt L, Belhan O, et al. Variation of carrying angle with age, sex, and special reference to side. Orthopedics. 2005; 28(11): 1360–1363, doi: 10.3928/0147-7447-20051101-16, indexed in Pubmed: 16295195.
36. Zampagni ML, Casino D, Zaffagnini S, et al. Estimating the elbow carrying angle with an electrogoniometer: acquisition of data and reliability of measurements. Orthopedics. 2008; 31(4): 370, doi: 10.3928/01477447-20080401-39, indexed in Pubmed: 19292279.

Table 1. Mean ± SD values of carrying angle of right and left [degrees], age [years], height [cm], weight [kg] and BMI [kg/m^2].

Sex	**N**	**CA right**		**CA left**		**Age [years]**		**Height [cm]**		**Weight [kg]**		**BMI [kg/m^2]**	
Male	181	7.98 ± 2.56		7.79 ± 2.46		21.1 ± 1.79		170.7 ± 6.19		71.6 ± 15.8		27.1 ± 36.7	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
		2	17	2	18	18	24	154	190	44	130	18	24
Female	165	13.2 ± 1.82		13.0 ± 1.72		20.9 ± 2.12		158.5 ± 5.31		56.4 ± 9.53		22.4 ± 3.38	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
		6	17	6	17	18	24	142	174	36	93	15	32

N — Number; CA — carrying angle; cm — centimeters; kg — kilograms; m — meter; Min — Minimum; Max — maximum.

Table 2. Carrying angle difference between the male and female subjects.

CA	**Sex**	**N**	**Mean ± SD**	**F value**	**t value**	**difference**	**P value**
Right	Male	181	7.98 ± 2.56	13.85	–21.96	324.7	< 0.001
	Female	165	13.21 ± 1.82				
Left	Male	181	7.79 ± 2.46	18.33	–23.06	322.4	< 0.001
	Female	165	13.03 ± 1.72				

Independent sample t-test p value < 0.001. N — number; CA — carrying angle; SD — standard deviation.

Table 3. Mean values of right and left carrying angle in the male and female subjects.

Sex	**N**	**CA**	**Mean ± SD (degrees)**	**F value**	**t value**	**difference**	**P value**
Male	181	Right	7.98 ± 2.56	0.160	0.730	360	0.466
		Left	7.79 ± 2.46				
Female	165	Right	13.21 ± 1.82	1.07	0.901	328	0.368
		Left	13.03 ± 1.72				

Independent sample t-test p value > 0.005. n — number; CA — carrying angle; SD — standard deviation.

Table 4. Correlation values of carrying angle with age, height, weight and BMI

Sex	N	CA	Value	Age	Height	Weight	BMI
Male	181	Right	r	0.081	0.068	–0.033	–0.064
			p	0.277	0.363	0.655	0.389
		Left	r	0.070	0.001	–0.069	–0.062
			p	0.346	0.987	0.353	0.404
Female	165	Right	r	–0.044	0.075	0.039	–0.020
			p	0.575	0.340	0.618	0.801
		Left	r	–0.093	0.045	0.039	–0.057
			p	0.235	0.563	0.618	0.466

N — Number; CA — carrying angle; BMI — Body Mass Index; r — correlation value; p — level of significance, Pearson correlation coefficient.

Table 5. Carrying angle reference values in specific population groups.

Author	Ethnic group	Male right and left CA		Female right and left CA	
Kothapalli et al. [18]	India	12.09 ± 4.66	10.20 ± 4.53	13.54 ± 6.44	11.90 ± 5.61
HG Thejeswari et al. [15]	India	169.8 ± 4.4	163.6 ± 6.1	171.2± 3.4	164.9 ± 3.6
Sharma et al. [29]	India	13.09 ± 5.67	11.20 ± 5.54	16.54 ± 7.45	14.90 ± 6.61
Shah and Naqvi [13]	India	–		12.63 ± 2.48	12.25 ± 2.57
Rajesh et al. [25]	India	6.7 ± 1.0		13.3 ± 2.4	
Bhat et al. [9]	India	12.25 ± 1.49	10.50 ± 1.39	14.85 ± 2.12	13.7 ± 1.8
Sharma et al. [30]	Nepal	4.55 ± 3.37	7.03 ± 3.40	4.95 ± 3.78	7.80 ± 3.95
Kumari and Sekhar [19]	South India	14.2 + 3.01	12.4 ± 1.12	19.4 ± 2.91	17.5 ± 2.48
Erdogan and Malas [13]	Turkey	15.18 ± 5.67	13.18 ± 5.39	8.83 ± 5.49	7.60 ± 4.39
Balasubramaniam et al. [6]	India	10.75		12.88	
Allouh and Khasawneh [3]	Jordan	13.0 ± 0.15	10.8 ± 0.16	16.6 ± 0.14	14.5 ± 0.23
Paraskevas et al. [23]	Greek	10.97 ± 4.27		15.07 ± 4.95	
Lim et al. [20]	Malaysia	6.1722	8.0033	10.2982	11.700
Ruparelia et al. [27]	India	6.90 ± 1.25	6.78 ± 1.38	11.85 ±	----------

				2.27	
Adhikari et al. [2]	Nepal	11.72 ± 1.37	10.02 ± 1.5	13.7 ± 2.09	11.74 ± 2.03
Acikgoz et al. [1]	Turkey	9.77 ± 2.82	9.85 ± 2.95	13.94 ± 3.97	14.03 ± 4.08
Alsubael and Hegazy [4]	Saudi Arabia	9.29 ± 2.98		18.47 ± 4.12	
Dey et al. [11]	India	12.5 ± 0.57		15.26 ± 0.45	
Emami et al. [12]	Iran	6.40		7.20	
Terra et al. [31]	Brazil	11.20 ± 4.45		12.78 ± 5.35	
Present study	Saudi Arabia	7.98 ± 2.56	7.79 ± 2.46	13.2 ± 1.82	13.0 ± 1.72

Figure 1. Digital goniometer and carrying angle measurement method.