Photogrammetric Assessment of Upper Body Posture Using Postural Angles: A Literature Review

Deepika Singla, MPT Sports, Zubia Veqar, PhD, and Mohammed Ejaz Hussain, PhD

ABSTRACT

Objective: The purpose of this paper was to review the literature regarding the measurement properties of various angles used for postural assessment of the head, neck, shoulder, and thorax and to discuss the utility of these measures.

Methods: The inclusion criteria for this literature review were use of postural angles to assess posture, measurement of upper body posture, and research studies conducted in last 3 decades that had free full-text available online entirely in the English language. The exclusion criteria were review articles; studies involving subjects having obesity, visual problems, any history of surgery, respiratory, cardiovascular, neurologic, or congenital pathology or disease; and research studies in which postural angles were measured with respect to vertical only. The following databases were searched: PubMed Central, PubMed, ResearchGate, Springer Link, ScienceDirect, Google Scholar and Scielo through February 20, 2016.

Results: A total of 21 studies that were found to be best suited to explain the craniovertebral (CV) angle, sagittal head tilt, sagittal shoulder-C7 angle, coronal head tilt, coronal shoulder angle, and thoracic kyphosis angle were included in this review. Craniovertebral angle, sagittal head tilt, sagittal shoulder-C7 angle, coronal head tilt, and coronal shoulder angle possess moderate to high intrarater reliability. Craniovertebral angle, sagittal head tilt, sagittal shoulder-C7 angle and thoracic kyphosis angle possess high interrater reliability (except for sagittal head tilt when measured using the goniometer). Craniovertebral angle, sagittal head tilt, and sagittal shoulder-C7 angle have been proved to be valid measures of posture when compared with similar angles measured on radiographs. None of the studies reported intrarater reliability of thoracic kyphosis angle, interrater reliability of coronal head tilt and coronal shoulder angle, and validity of coronal angles and thoracic kyphosis angle.

Conclusions: We found several reliable methods to measure the postures of the head, neck, shoulder, and thoracic regions by measuring the CV angle, sagittal head tilt, sagittal shoulder-C7 angle, and thoracic kyphosis angle, respectively. Standardization of methods for angular measurement is recommended so that there is uniformity among studies regarding camera height, participant-camera distance, and type of software to generate normative data for postural angles. (J Chiropr Med 2017;16:131-138)

Key Indexing Terms: *Head; Posture; Shoulder; Kyphosis; Photogrammetry*

INTRODUCTION

Postural angles are variables that can be measured to quantify posture. These are different from linear measurements, which express postural deviations as distances between 2 bony landmarks.[1] Comparisons between 2 different values of a particular angle have yielded significant information regarding posture in many studies,[2-5] as normative values for postural angles of the sagittal plane do not exist in the literature.[6] Quantitative data obtained with postural angles can be used to evaluate and monitor the changes that occur during the rehabilitation process by comparing the previous and present values of an angle.

Measurement of various postural angles by using goniometry, photography, photogrammetry, and radiography has been reported in the literature. Photogrammetry is the most widely used method for noninvasive measurement of postural measures, as it eliminates the risk of exposure to harmful radiation encountered with the radiographic method,[7] and it does not require printing of photographs. Photogrammetry quantifies postural assessment by measuring linear distances and angles (formed between lines produced through body markers and horizontal or vertical lines) on digital photographs by using software specifically designed for this purpose.[7,8] Goniometry, which uses a

Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia, Okhla, New Delhi, India.

Corresponding author: Deepika Singla, MPT Sports, Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia, Jamia Nagar, Okhla, New Delhi-110025. Tel.: +91 8802201116, +91 8586976427. (e-mail: *dpkasingla@gmail.com*).

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handheld goniometer, has a disadvantage when used to record values for postural angles, since it becomes difficult to read the goniometer while the goniometer's arm is held by the therapist in a horizontal manner.[1]

There are a number of different postural angles routinely used by the authors in a clinical setting for patients presenting with biomechanical faults. The objective of this study was to review the measurement properties of various angles used for postural assessment of the head, neck, shoulder, and thorax and to discuss the utility of these measures.

Methods

A literature review was performed using the following keywords: head, posture, shoulder, kyphosis, and photogrammetry; PubMed Central, PubMed, ResearchGate, Springer Link, ScienceDirect, Google Scholar, and Scielo, in addition to other sources, were searched through February 20, 2016. The keywords were used individually and in various combinations to search for papers. No additional terms were used while searching. Because of their prior clinical experience, the authors were particularly interested in studies using angles that they knew by the terms *craniovertebral (CV) angle*, *sagittal head tilt*, *sagittal shoulder- C7 angle*, *coronal head tilt*, *coronal shoulder angle*, and *thoracic kyphosis angle*.

Studies were included if they used postural angles to assess posture or otherwise measured upper body posture, if they were conducted in last 3 decades, and if they were full-text articles that were available for free online entirely in the English language. Review articles were excluded, as were studies in which postural angles were measured with respect to vertical only. Studies were excluded if they involved subjects with respiratory, cardiovascular, neurological, or congenital pathology or disease, obesity, visual problems, or a history of surgery.

In judging the reliability of postural angle measurements in studies that used the intraclass correlation coefficient (ICC), if the ICC value of a particular angle was >0.75, then the reliability of that angle was considered very good, indicating high agreement between the 2 values of that angle recorded by the same or different raters. Intraclass correlation coefficient values ranging from 0.40 to 0.75 indicated moderate agreement, and ICC values <0.40 depicted poor intrarater and interrater agreement.[2,7,8]

Results

A formal record of studies obtained, accepted, and rejected after database searching was not kept. A total of 21 papers were selected by using the keywords and the inclusion and exclusion criteria. Table 1[9-21] summarizes the various studies that were included in this review and in which postural angles were measured. The various postural angles that can be measured for the upper body are listed below:

1. *Craniovertebral angle*[10,14,19,20]: Where a line drawn from the tragus of the ear to the C7 vertebra intersects a horizontal line, the CV angle is formed (Fig 1). It is used to measure the value of forward head posture, and the greater the value of this angle, the more forward the head is positioned on the neck. A vast variety of names exist for this angle, such as sagittal C7-tragus angle,[3] sagittal plane head alignment,[9] neck inclination angle,[1] cervical angle [2,8,12] head protrusion angle,[6,15] head position,[11] forward head posture,[13] forward head position,[16] and head anteriorization in relation to cervical vertebra 7.[17,18]
2. *Sagittal head tilt*[3]: This angle, which is formed between a line from the canthus of the eye and the tragus of the ear and the horizontal, is a measure of the posture of the upper cervical spine (Fig 2). The lesser the value of this angle, more forward the head is positioned on the neck. Different authors have given this other names, such as cranial rotation angle,[1] sagittal head angle,[2,8] gaze angle,[19] craniohorizontal angle,[14,20] and head alignment from the Frankfurt plane.[9]
3. *Sagittal shoulder-C7 angle*[3]: Where a horizontal line passing through the lateral shoulder meets the line drawn from C7 to the lateral shoulder, the point of intersection forms the sagittal shoulder-C7 angle (Fig 3). It indicates the degree of roundedness of the shoulders. A protracted shoulder would yield a lesser value of this angle. Alternative names for this angle are protraction/retraction angle,[2] sagittal plane shoulder alignment,[9] sagittal shoulder posture,[14] shoulder angle,[8] shoulder protrusion,[18] and forward shoulder posture.[13]
4. *Coronal head tilt*[3]: This angle, formed between the line joining inferior margins of ears and a horizontal line, is a measure of lateral flexion of head (Fig 4). Its normal value should be 180 degrees.[3] An alternative name for this angle is anterior head alignment.[9,14]
5. *Coronal shoulder angle*[3]: Also known as the anterior shoulder alignment,[9] this is defined as the angle between a horizontal line and a line joining the coracoid processes (Fig 5). It is used to determine whether the left and the right shoulders are level or not. Its normal value should be 180 degrees.[3]
6. *Thoracic kyphosis angle*[11]: The point where lines (perpendicular to the skin surface) produced through T12 and C7 markers intersect each other forms the thoracic flexion angle (Fig 6). The lesser the value, the less is the kyphosis. This angle has also been termed degree of thoracic kyphosis by Rodrigues et al.[4] and thoracic angle by Porto et al.[21]

These angles have been measured differently by various researchers in the past, and some considered the acute angle values,[1-4,6,8-21] whereas others took the obtuse angle values

Table 1. *Summary of Data Obtained From 21 Studies Included in This Review*

Author(s) (Year)	Angles Measured	Sample Size and Age	Method Used to Measure Angles	Position of Participants	Reference Value of Angles in Degrees	ICC Value (to Ascertain Reliability of Angles)	SEM Value
Raine & Twomey (1994)[9]	a)–e)	39 (17-48 yr)	Photographic	Standing	Mean ± SD: a) 51.3 ± 4.5 b) 175.6 ± 5.3 c) 47.6 ± 10.4 d) 180.1 ± 2.0 e) 181.5 ± 1.6	0.71-0.99 (intrarater)	—
Raine & Twomey (1997)[3]	a)–e)	160 (17-83 yr)	Photographic	Standing	Range: a) 117-152 b) 157-189 c) 25-92 d) 171-186 e) 173-186	0.71-0.99 (intrarater)	—
Rodrigues et al. (2009)[4]	f)	12 (65-74 yr)	Photogrammetric	Standing	—	—	—
Singla & Veqar (2015)[5]	a), b)	15 (18-25 yr) 15 (18-25 yr)	Photogrammetric	Standing	Mean ± SD: a) 129.65 ± 3.56 b) 165.15 ± 4.49	—	—
Lau et al. (2010)[10]	a)	30 (>18 yr)	EHPI	Standing	—	0.99 (intrarater) 0.99 (interrater)	—
Christie et al. (1995)[11]	a), f)	39 (18-46 yr) 20 (18-46 yr)	Photographic	Standing and sitting	—	—	—
Harrison et al. (1996)[1]	a), b)	41 (20-45 yr) 10 (23-43 yr)	Goniometry	Standing	Mean ± SD: a) 18.8 ± 4.2 b) 49.3 ± 7.0	a) = 0.74 b) = 0.81 (intrarater) a) = 0.68 b) = 0.34 (interrater)	—
Iunes et al. (2009)[6]	a)	21 (24.19 ± .3 yr)	Visual, photographic	Standing	Range: a) 51.50-60.56	—	—
Falla et al. (2007) [12]	a)	58 (37.9 yr) 10 (35 yr)	Photogrammetric	Sitting (in front of computer)	—	—	—
Niekerk et al. (2008) [2]	a)–c)	39 (15-16 yr)	PPAM, LODOX	Sitting	Range: a) 21.90-62.90 b) 0-34.70 c) 65.30-178.70	a) = 0.86-0.96 b) = 0.82-0.96 c) = 0.74-0.93 (intrarater)	a) = 8.06^0 b) =3.5^0 c) =11.09^0
Lewis et al. (2005) [13]	a), c)	60 (18-75 yr) 60 (18-75 yr)	Photographic	Standing	—	a) = 0.89-0.99 c) = 0.99-1 (intraphotograph, intrarater reliability) a) = 0.76-0.98 c) = 0.78-0.99 (interphotograph, intrarater reliability)	a) = 0.5^0 c) = 0.5^0 a) = 1.1^0 c) = 1.4^0

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Table 1. (*continued*)

Author(s) (Year)	Angles Measured	Sample Size and Age	Method Used to Measure Angles	Position of Participants	Reference Value of Angles in Degrees	ICC Value (to Ascertain Reliability of Angles)	SEM Value
						0.97-0.99 (intrarater reliability for accuracy of technique)	—
Chansirinukor et al. (2001)[14]	a), b), d)	13 (13-16 yr)	Photographic	Standing (with backpack)	Mean ± SD: a) 56.7 ± 3.5 b) 16.3 ± 5.0 d) 0.8 ± 2.9	0.73-1 (intrarater)	0.44^0-1.42^0
Iunes et al. (2008)[15]	a)	20 (23.5 ± 2.86 yr) 20 (22.55 ± 2.68 yr)	Photogrammetric	Standing (with and without heels)	Mean: a) 50.82	—	—
Greenfield et al. (1995)[16]	a)	30 (39 ± 13.7 yr) 30 (39 ± 13.9 yr)	Photographic	Standing	Mean ± SD: a) 52 ± 4.7	—	—
Weber et al. (2012)[7]	a)	80 (23.8 ± 3.65 yr)	Photogrammetric, radiographic	Standing	—	0.978 (intrarater)	—
Ruivo et al. (2014)[8]	a)–c)	275 (15-17 yr)	Photogrammetric	Standing	Mean ± SD: a) 47.96 ± 4.79 b) 17.6 ± 5.7 c) 50.95 ± 8.18	0.87-0.96 (interrater) 0.66-0.83 (intrarater)	1.64-2.35 2.72-4.03
Guedes & Joao (2014)[17]	a)	36 (12-16 yr) 38 (12-16 yr)	Photogrammetric	Standing	Range: a) 40.40-63.40	>0.90 (intrarater)	—
Coelho et al. (2014)[18]	a), c)	21 (5-14 yr) 39 (5-14 yr)	Photogrammetric	Standing	Range: a) 42.89-44.50 c) 152.40-156.80	>0.97 (interrater)	—
Helmy et al (2015)[19]	a), b)	22 (14.45 ± 2.5 yr)	Photogrammetric	Standing	Range: a) 48.4-51.8 b) 10.3-12.6	a) = 0.97-0.98 b) = 0.991-0.995 (intrarater) a) = 0.99 (interrater)	a) = 1-1.30 b) = 0.61-0.99 a) = 0.72-0.83
Hazar et al. (2015)[20]	a), b)	30 (16.4 ± 0.4 yr)	Photogrammetric	Standing	Mean: a) 48.4 Range: b) 20.8-21.2	a) = 0.984 b) = 0.989 (intrarater) a) = 0.983 b) = 0.990 (interrater)	—
Porto et al. (2013)[21]	f)	29 (17-35 yr)	Photogrammetric	Standing	—	0.81-0.96 (interrater)	—

ICC, intraclass correlation coefficient; *SEM*, standard error of measurement; *EHPI,* electronic head posture instrument; *PPAM,* photographic posture analysis method; *LODOX,* low-dose radiograph system.
Angles are defined as a) craniovertebral angle, b) sagittal head tilt, c) sagittal shoulder-C7 angle, d) coronal head tilt, e) coronal shoulder angle, and f) thoracic kyphosis angle.

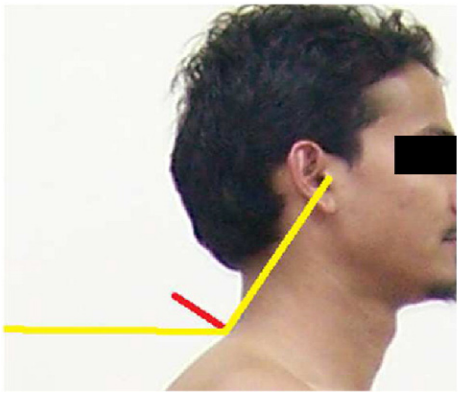

Fig 1. *Craniovertebral angle.*

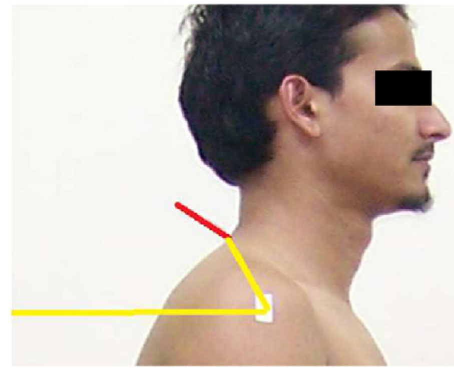

Fig 3. *Sagittal shoulder-C7 angle.*

into account.[2,3,5,9,18] All the above-mentioned angles, except the thoracic kyphosis angle, have been found to have moderate to high intrarater reliability, with standard error of measurement (SEM) values being reported for only the CV angle, sagittal head tilt, sagittal shoulder-C7 angle, and coronal head tilt, indicating low variability of measurements (Table 1). Inter-rater reliability was found to be reported for only 4 of these angles, namely, the CV angle, sagittal head tilt, sagittal shoulder-C7 angle, and thoracic kyphosis angle, with all of them having high interrater reliability (except for sagittal head tilt when measured by using the goniometer) and low variability as depicted by SEM values. No studies were found to have reported SEM values for the thoracic kyphosis angle. Two studies concluded that measurement of the CV angle, sagittal head tilt, and sagittal shoulder-C7 angle by using photographs was valid, showing moderate to strong correlations with similar angles measured on radiographs.[2,7]

Discussion

This review aimed to verify the measurement properties and the utility of certain angles used for the assessment of posture of the head, neck, shoulder, and thoracic regions. To our knowledge, this review is first of its kind to highlight the quality and usage of postural angles for the assessment of upper body posture.

Several examples from the literature may help illustrate how these various postural angles can be used. Lau et al.[10] used the Electronic Head Posture Instrument (EHPI) to calculate CV angles and to correlate the CV angle values with anterior head translation (AHT) values obtained from radiographs (Fig 1). The authors stated that EHPI has excellent intrarater and interrater reliability (both with ICCs = 0.99). Craniovertebral angle values showed good inverse correlation with AHT values, suggesting that CV angle is a reliable measure of head and neck posture.[10] Craniovertebral angle and the sagittal head tilt (Fig 2) were measured using the goniometer by Harrison et al.,[1] who had used the former as a surrogate of neck inclination and the latter as a surrogate of cranial rotation. Interrater reliability, which was determined by using ICC, was found out to be 0.68 (moderate) and 0.34 (poor) for the CV angle and the sagittal head tilt, respectively, and intrarater reliability was found to be excellent for both the angles. Because the investigators had difficulty keeping the stationary bar of the goniometer parallel to the horizontal, they recommended development of some reliable method for estimating the postural angles.

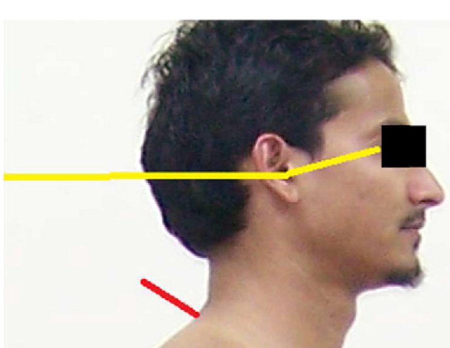

Fig 2. *Sagittal head tilt.*

Fig 4. *Coronal head tilt.*

Fig 5. *Coronal shoulder angle.*

Raine and Twomey[3] used photographic and digitization procedures to measure various postural angles. They photographed 160 asymptomatic individuals from the side and from the front in the standing position. White adhesive dots marked several anatomic locations (mastoid process, coracoid processes, head of the humerus, a point just inferior to the sternal notch, and the spinous processes of vertebrae C7, T6, and T12). The photographs were then digitized so as to obtain *x* and *y* coordinates, and the coordinates were used to measure the coronal head tilt, coronal shoulder angle, sagittal head tilt, sagittal C7-tragus angle, and the sagittal shoulder-C7 angle. Reliability ranged from good to excellent (ICCs of 0.71, 0.89, 0.82, 0.88, and 0.91, respectively). The above-mentioned study required the subjects to be in the standing position. However, similar and various other measurements have been done using photographic method and digitization procedures, with the subjects in the sitting position or standing with a backpack.[2,12,14]

Chansirinukor et al.[14] had conducted a pilot study to determine the effect of backpacks on the cervical and shoulder postures of adolescents. Five photographs per view were obtained; for the first photograph, subjects stood without carrying backpacks; for the second photograph, they stood with their own backpacks carried over both the shoulders; for the third photograph, backpacks were carried only over the right shoulder; for the fourth photograph, a backpack holding the equivalent of 15% of body weight was carried over both the shoulders; and for the last photograph, subjects were asked to walk for 5 minutes at their normal speed while carrying their own backpacks over both shoulders. The ICC values for intrarater reliability of the postural angles that were measured demonstrated moderate to excellent results (0.73-1.00) and SEM values (0.44-1.42 degrees) indicated that the measurements had low variability. All angles (craniohorizontal angle, craniovertebral angle, and anterior head alignment) were least affected when a backpack was carried over both the shoulders. The results revealed an increased forward position of the head while carrying the backpack over one shoulder compared with carrying it over both shoulders. The authors also recommended that adolescents carry backpacks weighing <15% of their body weight so that a normal posture can be maintained while carrying the backpack.

Iunes et al.[15] had conducted a photogrammetric analysis of posture among 40 women. They had divided the subjects into 2 groups, with each group comprising 20 subjects. Group 1 consisted of women who used to wear high-heeled shoes on a daily basis, and group 2 was composed of women who used to wear high-heeled shoes occasionally. Photographs were obtained in the anterior frontal and right sagittal planes. The subjects first stood barefoot and then wore one type of high-heeled shoes (6.5-cm platform heel sandals or 8-cm heeled stilettos). The results showed that the head protrusion angle (Fig 1) was different between the 2 groups. The mean head posture angle values for group 1 and group 2 were found to be 53.11 degrees and 50.82 degrees, respectively, when the subjects were barefoot.[15]

The most common method to evaluate the thoracic kyphosis angle (Fig 6) is the radiographic method, wherein generally a Cobb angle is determined.[4] However, currently photogrammetry is also used for quantitative estimation of thoracic kyphosis, and this eliminates the risk of radiation exposure from x-rays. Rodrigues et al.[4] placed markers perpendicular to the skin at the C7 and T12 levels to calculate the Cobb angles in women with osteoporosis or osteopenia. Greater angles, indicating a greater degree of thoracic kyphosis, were found in women with osteoporosis compared with those with osteopenia. Van Niekerk et al.[2] used a similar approach to assess high school students, but with markers at C7 and T8.

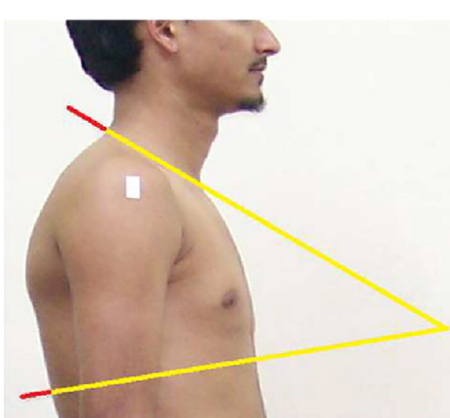

Fig 6. *Thoracic flexion angle.*

A comparison of photogrammetric methods and radiographic methods, along with verification of intrarater reliability, was done by Weber et al. in a study performed on 80 females aged 19-35 years.[7] These authors measured forward head posture by using the CV angle for the photogrammetric method and the craniocervical postural line to horizontal (CPL-Hor) angle (analogous to the CV angle) for the radiographic method (angle formed between the CPL line and horizontal), using SAPO software with the subjects in the standing position. Intraclass correlation coefficient values for CV angle (0.978) and the CPL-Hor angle (0.901) signified excellent intrarater reliability upon repeating the measurements for the second time after an interval of 1 week. The value of Pearson's correlation coefficient between both the angles was found out to be r = 0.68, signifying a moderate correlation between the 2 approaches for the evaluation of degree of forward head posture.

Recommendations for Clinical Use

Measurement of these angles using photogrammetry provides objective and reproducible data that can be saved and analyzed later on. The CV angle provides measurement of position of head relative to the neck; the sagittal head tilt measures the posture of upper cervical spine; the sagittal shoulder-C7 angle indicates the degree of roundedness of shoulders; and the thoracic kyphosis angle indicates the degree of kyphosis of thoracic spine. In contrast, the coronal head tilt and the coronal shoulder angle indicate the left-right symmetry of the head and shoulders, respectively, in the frontal plane. Anatomic landmarks for all these angles can be located easily, and hence, lesser time is consumed when assessing posture in clinical settings. Moreover, a variety of types of measurement software is available for free on the Internet. The clinician who wishes to use these assessment methods has to make some decisions, such as the type of software, distances between the camera and the subject, and the height of the camera from the ground, and these factors vary among published studies.

Limitations

This is not a systematic review, and it is limited in its scope. A rigorous process of study selection was not followed as to the number of records identified, screened, and excluded. Also, the review only considered studies based on the CV angle, sagittal head tilt, sagittal shoulder-C7 angle, coronal head tilt, the coronal shoulder angle, and thoracic kyphosis angle; other assessments of posture do exist and have clinical value. The authors' literature search was limited to free full-text articles in the English language; an expansion of those criteria might have turned up additional reference sources. However, the studies found and presented above give a good overall illustration of these angles, which are routinely used in the clinic by the authors for patients presenting with biomechanical faults.

Conclusions

The CV angle, sagittal head tilt, sagittal shoulder-C7 angle, and thoracic kyphosis angle provide reliable and easy assessment of head, neck, shoulder and thoracic regions, respectively, in the sagittal plane. However, only subsequent values of a particular angle can be compared to ascertain changes in posture. Nonuniformity found in studies regarding methods used to obtain values of angles precludes the availability of normative data for postural angles in different populations; hence, some standardization of protocols is required.

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No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): D.S., Z.V.
Design (planned the methods to generate the results): D.S., M.E.H.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): Z.V., D.S.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): D.S., M.E.H.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): D.S., Z.V., M.E.H.
Literature search (performed the literature search): D.S.
Writing (responsible for writing a substantive part of the manuscript): D.S.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): D.S., Z.V., M.E.H.

Practical Applications

- Use of postural angles seems to be a practical and convenient method to assess posture.
- Researchers and clinicians could use these angles for postural evaluation.

References

1. Harrison AL, Barry-Greb T, Wojtowicz G. Clinical measurement of head and shoulder posture variables. *J Orthop Sports Phys Ther.* 1996;23(6):353-361.
2. van Niekerk SM, Louw Q, Vaughan C, Grimmer-Somers K, Schreve K. Photographic measurement of upper-body sitting posture of high school students: a reliability and validity study. *BMC Musculoskelet Disord.* 2008;20(9):1-11.

3. Raine S, Twomey LT. Head and Shoulder Posture Variations in 160 Asymptomatic Women and Men. *Arch Phys Med Rehabil.* 1997;78:1215-1223.
4. Rodrigues ACC, Romeiro CAP, Patrizzi LJ. Evaluation of thoracic kyphosis in older adult women with osteoporosis by means of computerized biophotogrammetry. *Rev Bras Fisioter.* 2009;13(3):205-209.
5. Singla D, Veqar Z. Effect of playing basketball on the posture of cervical spine in healthy collegiate students. *Int J Biomed Adv Res.* 2015;6(2):133-136.
6. Iunes DH, Bevilaqua-Grossi D, Oliveira AS, Castro FA, Salgado HS. Comparative analysis between visual and computerized photogrammetry postural assessment. *Rev Bras Fisioter.* 2009;13(4):308-315.
7. Weber P, Corrêa ECR, Milanesi JM, Soares JC, Trevisa ME. Craniocervical posture: cephalometric and biophotogrammetric analysis. *Braz J Oral.* 2012;11(3):416-421.
8. Ruivo RM, Pezarat-Correia P, Carita AI. Cervical and shoulder postural assessment of adolescents between 15 and 17 years old and association with upper quadrant pain. *Braz J Phys Ther.* 2014;18(4):364-371.
9. Raine S, Twomey LT. Posture of the head, shoulders and thoracic spine in comfortable erect standing. *Aust J Physiother.* 1994;40(1):25-32.
10. Lau HM, Chiu TT, Lam TH. Measurement of craniovertebral angle with electronic head posture instrument: criterion validity. *J Rehabil Res Dev.* 2010;47(9):911-918.
11. Christie HJ, Kumar S, Warren SA. Postural aberrations in low back pain. *Arch Phys Med Rehabil.* 1995;76(3):218-224.
12. Falla D, Jull G, Russell T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. *Phys Ther.* 2007;87(4):408-417.
13. Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *J Orthop Sports Phys Ther.* 2005;35(2):72-87.
14. Chansirinukor W, Wilson D, Grimmer K, Dansie B. Effects of backpacks on students: measurement of cervical and shoulder posture. *Aust J Physiother.* 2001;47(2):110-116.
15. Iunes DH, Monte-Raso VV, Santos CBA, Castro FA, Salgado HS. Postural influence of high heels among adult women: analysis by computerized photogrammetry. *Rev Bras Fisioter.* 2008;12(6):454-459.
16. Greenfield B, Catlin PA, Coats PW, Green E, McDonald JJ, North C. Posture in patients with shoulder overuse injuries and healthy individuals. *J Orthop Sports Phys Ther.* 1995; 21(5):287-295.
17. Guedes PF, João SM. Postural characterization of adolescent federation basketball players. *J Phys Act Health.* 2014;11(7): 1401-1407.
18. Coelho JJ, Graciosa MD, de Medeiros DL, Pacheco SC, da Costa LM, Ries LG. Influence of flexibility and gender on the posture of school children. *Rev Paul Pediatr.* 2014;32(3):223-228.
19. Helmy NA, El-Sayyad MM, Kattabei OM. Intra-rater and inter-rater reliability of Surgimap Spine software for measuring spinal postural angles from digital photographs. *Bull Fac Phys Ther.* 2015;20(2):193-199.
20. Hazar Z, Karabicak GO, Tiftikci U. Reliability of photographic posture analysis of adolescents. *J Phys Ther Sci.* 2015;27(10):3123-3126.
21. Porto AB, Quirino CM, Moura TBMA, Faquin BS, Okazaki VHA. Interrater reliability in thoracic and lumbar angles analysis using photogrammetry. *XXIV Congress of the International Society of Biomechanics, XXV Brazilian Congress of Biomechanics*. 2013. p. 1-2.