J. Phys. Ther. Sci.
25: 1181–1184, 2013

Reliability of Upper Quadrant Posture Analysis Using an Ultrasound-based Three-dimensional Motion Analyzer

Daisuke Uritani, PT, PhD[1)]

[1)] *Department of Physical Therapy, Faculty of Health Science, Kio University: 4-2-2 Umaminaka, Koryocho, Kitakatsuragigun, Nara 635-0832, Japan. TEL: +81 745-54-1601, FAX: +81 745-54-1600*

Abstract. [Purpose] The aim of this study was to evaluate the reliability of upper quadrant posture analysis using an ultrasound-based three-dimensional motion analyzer. [Subjects] Subjects were 72 healthy young adults. [Methods] Neck inclination angle formed by a line connecting C7 and the tragus with a horizontal line, angle of the shoulder formed by a line connecting C7 and the acromial angle with a horizontal line, and cranial rotation angle formed by a line connecting the tragus and corner of the eye with a horizontal line were measured using an ultrasound-based three-dimensional motion analyzer. Intra- and inter-rater reliabilities of two testers, standard error of measurements, minimal detectable change at the 95% confidence level, and systematic bias were evaluated. [Results] Intra-class correlation coefficients (1,1) were 0.65 to 0.82. Intra-class correlation coefficients (2,1) were 0.76 to 0.82. High measurement error was found in the cranial rotation angle. Fixed bias was found for the angle of the shoulder in the inter-rater reliability. [Conclusion] Posture analysis using an ultrasound-based three-dimensional motion analyzer appears useful for assessing neck inclination angle and the angle of the shoulder in individuals, and cranial rotation angle in patient groups.
Key words: Reliability, Systematic bias, Ultrasound-based three-dimensional motion analyzer

(This article was submitted Mar. 29, 2013, and was accepted May 4, 2013)

INTRODUCTION

Although posture analysis has been performed to assess relationships between posture and musculoskeletal disorders using various methods in clinical practice, the reliabilities of the various methods have yet to be established. For example, studies investigating relationships between temporomandibular disorders (TMD) and upper quadrant posture have often made analyses based on photographic images[1, 2)]. However, such studies have yielded conflicting results regarding whether abnormal head and neck posture are associated with TMD[1, 2)]. Olivo et al.[3)] indicated in a systematic review that one reason for such inconsistency among the results of these studies is methodological issues regarding posture analysis. Although posture analysis based on photographic images is easily performed, various errors arise from the precision of the camera, the positional relationship between the camera and subject, and misidentification of landmarks on photographic images. Visual observation of a patient's posture is often used in clinical practice, but neither its validity nor reliability have been proven[4)]. Reliable methods of posture analysis are thus needed to assess relationships between posture and musculoskeletal disorders.

Ultrasound (US)-based three-dimensional (3D) motion analyzers have been used to investigate spinal range of motion[5)]. Cagnie et al.[5)] described motion analysis using a US-based 3D motion analysis system that could record, calculate, and display spatial head position as a significant breakthrough in the measurement of cervical motion in a comparison with their previous study[6)]. This equipment has also been used for the analysis of static posture based on identification of anatomical points which are defined by the system's software routines[7)]. However, few reports have discussed posture analysis using US-based 3D motion analyzers. The aim of this study was to determine intra- and inter-rater reliabilities, and to clarify systematic bias in upper quadrant posture analysis using a US-based 3D motion analyzer.

SUBJECTS AND METHODS

Subjects

Subjects comprised 72 healthy volunteers, including 42 volunteers with a mean age of 32.1 (SD 13.3) years who were used to determine intra-rater reliability, and 30 others with a mean age of 21.3 (SD 2.7) years who were used to determine inter-rater reliability. Descriptive characteristics of the subjects are presented in Table 1. No subject had severe head, neck or shoulder pain or dysfunction at the time of testing. Written informed consent was obtained from all the participants, and the study protocol was approved by the research ethics committee of Kio University (approval ID: H22-24).

E-mail: d.uritani@kio.ac.jp

Table 1. Characteristics of the participants

	Intra-rater reliability	Inter-rater reliability
Men / Women (n)	8 / 34	15 / 15
Age (years)	32.1 (13.3)	21.3 (2.7)
Height (cm)	160.6 (7.5)	163.9 (6.9)
Weight (kg)	54.0 (8.5)	56.2 (8.1)

All data are presented as mean (SD).

Methods

We measured the spatial position of landmarks using a Zebris CMS20S US-based 3D motion analyzer (Winspine Pointer; Zebris Medizintecnik, Isny, Germany). This system consists of a central unit, a US transmitter, a personal computer, and a pointer. The emitters are built into the three ends of the T-shaped head of the transmitter in one plane. The pointer contains two microphones. Using the pointer, the anatomical points can be determined. The distance between the anatomical points and sensors is calculated based on the known speed of ultrasound and the measured time. With knowledge of the spatial coordinates of the emitters and microphones, the spatial coordinates of the determined anatomical points are calculated. The spatial positions of the determined anatomical points are graphically displayed on the screen of a personal computer in real time. In this study, the sampling rate was 20 Hz.

We measured posture while the subjects were standing. Subjects stood relaxed and facing forwards, with the hands along the sides of the body. Subjects were positioned at a distance of about 1 m from the US transmitter. Reference points were the eye edge, ear tragus, spinous process of C7 and acromial angle. Except for the spinous process of C7, all reference points were identified on the right side. We identified reference points by palpation and inspection, and pointing with the pointer. These procedures were repeated in the same order as dictated by the software routines of the system.

Postural parameters were the neck inclination angle formed by a line connecting C7 and the tragus with a horizontal line[1, 8], the angle of the shoulder formed by a line connecting C7 and the acromial angle with a horizontal line[1], and the cranial rotation angle formed by a line connecting the tragus and the corner of the eye with a horizontal line[8]. These angles were calculated based on the spatial positions of the determined anatomical points on the screen.

The testers were two physical therapists: Tester A had 3 years of clinical experience, and Tester B had 12 years of clinical experience. For determining intra-rater reliability, testers measured the 4 reference points stated above twice. The interval between the two measurements was about 10 min. Subjects were allowed to move freely during this interval. To determine inter-rater reliability, the two physical therapists measured the same participant alternately.

Statistical analysis was performed using SPSS version 20 software (IBM Japan, Tokyo, Japan). The intraclass correlation coefficient (ICC) and 95% confidence intervals (CI) for analysis were calculated. ICC (1.1) was calculated to determine the intra-rater reliability, and ICC (2.1) to determine the inter-rater reliability for each parameter. Standard error of the mean (SEM) and minimal detectable change at the 95% confidence level (MDC_{95}) were also calculated for the three parameters[9]. SEM and MDC_{95} are expressed as absolute values and in relative values as percentages of the grand mean. To explore systematic bias, proportional bias and fixed bias were evaluated using Bland-Altman analysis[10]. Fixed bias exists when the 95%CI for the difference between two measurements does not include zero. Proportional bias exists when the correlation between the mean of two measurements and the difference between two measurements is significant. Lower and upper coefficient limits were calculated and the most optimistic range was adopted as the limit of agreement. A value of $p < 0.05$ was considered statistically significant.

RESULTS

ICC, SEM, and MDC_{95} values for intra- and inter-rater reliability are presented in Table 2. Regarding intra-rater reliability, ICC (1,1) ranged from 0.65 for cranial rotation angle to 0.82 for neck inclination angle. SEM ranged from 2.6% for neck inclination angle to 19.8% for cranial rotation angle. MDC_{95} ranged from 14.6% for neck inclination angle to 54.3% for cranial rotation angle. Regarding inter-rater reliability, ICC (2,1) ranged from 0.76 for angle of the shoulder to 0.82 for neck inclination angle. SEM ranged from 4.4% for neck inclination angle to 13.5% for cranial rotation angle. MDC_{95} ranged from 12.0% for neck inclination angle to 37.0% for cranial rotation angle.

Regarding systematic errors, proportional bias was not found in the measurements of either intra- or inter-rater reliability (Table 3). Fixed bias was found only in the measurement of the angle of the shoulder in inter-rater reliability (Table 3).

DISCUSSION

The present findings show that intra- and inter-rater reliability ranged from moderate to almost perfect agreement based on the criteria described by Landis and Koch[11]. Particularly for neck inclination angle and angle of the shoulder, ICC (1,1) was more than 0.77. ICC (2,1) was more than 0.76 for all outcomes. Knols et al.[12] described ICC >0.75 as representing acceptable reliability in their study investigating the reliability of measuring knee extension force using a hand-held dynamometer. Our present results indicate that upper quadrant posture analysis using a US-based 3D motion analyzer is reliable.

SEM for the cranial rotation angle was >14.5%, while those for the neck inclination angle and angle of the shoulder were <5.8% (Table 2). MDC_{95} of the cranial rotation angle was >39.7%, while those of the neck inclination angle and angle of the shoulder were <16.1% (Table 2). Knols et al.[12] reported in their study that SEM was <6.73% and the smallest detectable difference was <18.66%, and they concluded that the measurement error observed was modest. Meanwhile, Koblbauer et al.[13] concluded that the smallest detectable difference between 19.0% and 57.5% was a high measurement error. Considering the measurement error in

Table 2. ICC, SEM and SDD values for the intra- and inter-rater reliabilities

Intra-rater	Angle (degrees)		Reliability		
	Mean (SD) Test 1	Mean (SD) Test 2	ICC (95%CI)	SEM*	MDC_{95}*
Tester A					
Neck	56.5 (7.5)	57.2 (6.5)	0.82 (0.68–0.90)	3.0 (2.6%)	8.3 (14.6%)
Shoulder	112.2 (13.3)	111.1 (13.5)	0.77 (0.61–0.87)	6.5 (5.8%)	18.0 (16.1%)
Cranial	20.6 (6.9)	19.9 (6.5)	0.65 (0.44–0.80)	4.0 (19.8%)	11.0 (54.3%)
Tester B					
Neck	55.9 (6.2)	56.4 (5.7)	0.78 (0.59–0.89)	2.8 (2.5%)	7.8 (13.9%)
Shoulder	102.1 (14.3)	101.7 (13.0)	0.85 (0.72–0.93)	5.3 (5.2%)	14.7 (14.4%)
Cranial	22.0 (5.6)	20.8 (5.3)	0.68 (0.43–0.83)	3.1 (14.5%)	8.5 (39.7%)
Inter-rater	**Angle**		**Reliability**		
	Mean (SD) Tester A	Mean (SD) Tester B	ICC (95%CI)	SEM**	MDC_{95}**
Neck	55.5 (5.4)	54.7 (5.7)	0.82 (0.65–0.91)	2.4 (4.4%)	6.6 (12.0%)
Shoulder	102.8 (12.4)	107.4 (11.1)	0.76 (0.43–0.89)	5.1 (4.9%)	14.0 (13.3%)
Cranial	22.6 (6.4)	23.3 (7.0)	0.79 (0.61–0.90)	3.1 (13.5%)	8.5 (37.0%)

Mean, SD, SEM, and MDC_{95} values are presented in degrees.
* Percentages of mean degrees of Test 1 and 2
** Percentages of mean degrees of Tester A and B
SD, standard deviation; ICC, intraclass correlation coefficient; 95%CI, 95% confidence interval; SEM, standard error of the mean; MDC_{95}, minimal detectable change at the 95% confidence level; Neck, neck inclination angle; Shoulder, angle of shoulder; Cranial, cranial rotation angle

Table 3. Systematic bias

	r	t	Proportional bias	Mean of difference (95%CI)	Fixed bias	Limits of agreement
Intra-rater						
Tester A						
Neck	0.24	1.59	No	−0.73 (−2.05, 0.59)	No	−6.76, 5.30
Shoulder	−0.02	−0.15	No	1.06 (−1.79, 3.92)	No	−11.96, 14.08
Cranial	0.09	0.59	No	0.70 (−1.05, 2.46)	No	−7.29, 8.70
Tester B						
Neck	0.13	0.69	No	−0.55 (−2.03, 0.93)	No	−6.06, 4.97
Shoulder	0.18	0.96	No	0.35 (−2.45, 3.15)	No	−6.24, 6.93
Cranial	0.06	0.32	No	1.14 (−0.47, 2.75)	No	−4.63, 6.91
Inter-rater						
Neck	−0.11	−0.56	No	0.76 (−0.50, 2.02)	No	−3.67, 5.19
Shoulder	0.19	0.98	No	−4.6 (−7.27, −1.93)	Yes	−13.99, 4.79
Cranial	−0.15	−0.81	No	−0.74 (−2.35, 0.88)	No	−6.42, 4.95

Limits of agreement are presented in degrees.
Neck, neck inclination angle; Shoulder, angle of shoulder; Cranial, cranial rotation angle; r; Pearson's correlation coefficient; 95%CI, 95% confidence interval

our study referring to these studies[12, 13], neck inclination angle and angle of the shoulder showed low measurement errors, while cranial rotation angle showed a high measurement error.

The results of our present study indicate that, although measuring neck inclination angle and angle of the shoulder using a US-based 3D motion analyzer can be adopted to assess individual postural changes, measuring cranial rotation angle using this approach is not suitable for assessing individual postural changes. Reliability can be reported in terms of relative and absolute reliability[14]. Relative reliability indicates the degree of association between 2 or more measures, such as ICCs, but does not provide clinical guidance for assessing real changes at the individual patient level[15, 16]. Absolute reliability reflects the magnitude of difference between two measures[17]. Examples of these statistics are SEM, the corresponding 95%CI, MDC_{95}, and the limits of agreement[12]. A retest difference in patients with a value smaller than the SEM is likely to be the result of measurement noise; a difference greater than the MDC_{95} is likely to represent a real difference with 95% certainty[18]. The measurement of cranial rotation angle is not advised for use in clinical settings, but it could be used for evaluating patient groups. Cranial rotation angle was determined by the eye edge and ear tragus. Although these locations can be identified easily, because they can be confirmed by inspection, relative positional relationships between them might be influenced by changes in the direction of the line of vision. We instructed subjects to stand relaxed and to face the front, but did not set a focal point for them to look at. This might have affected the measurement values of the cranial rotation angle.

Regarding systematic bias, while no proportional biases were found in either the intra- or inter-rater reliabilities, fixed bias was found for the angle of the shoulder in inter-rater reliability. This indicates that the accuracy of measurements of neck inclination angle and cranial rotation angle were comparable between the two testers, and between the two measurements. Measurement values consist of a true value and error. The error in turn comprises random error and systematic bias. Random error includes biological variation and measurement error. Although random error can be resolved by repeated measurement and increased sample size, systematic bias cannot be removed. Systematic bias has to be resolved at the stage of study design. In this study, the result would have been influenced by the testers' palpation skills. The spinous process of C7 was identified by palpation. Because the reliability of palpation for C7 remains somewhat controversial[19], we identified C7 using two procedures: one reported in a previous study[19], and another procedure that discriminated C7 from Th1 by neck rotation. C7 was thus considered to have been precisely identified. However, because the acromial angle is the most difficult to palpate among the anatomical points used in this study, fixed bias would have occurred in the angle of the shoulder in inter-rater reliability. To resolve this issue, consistency in the palpation method for how to palpate to the acromial angle must be achieved among testers.

The key limitation of this study was that reliability was based on healthy young adults. Palpating anatomical points is sometimes difficult, e.g. when obese individuals are palpated. Elderly individuals often display severe deformities. To achieve precise assessment, well-defined palpation procedures and well-honed skill in palpation are required. Regarding blinding of testers, one tester did not receive an explanation of the purpose of this study, but blinding was not complete, because measurement was performed by the two testers at the same time.

In conclusion, posture analysis using a US-based 3D motion analyzer appears useful for assessing the neck inclination angle and angle of the shoulder of individuals, and the cranial rotation angle in patient groups.

REFERENCES

1) Braun BL: Postural differences between asymptomatic men and women and craniofacial pain patients. Arch Phys Med Rehabil, 1991, 72: 653–656. [Medline]
2) Visscher CM, De Boer W, Lobbezoo F, et al.: Is there a relationship between head posture and craniomandibular pain? J Oral Rehabil, 2002, 29: 1030–1036. [Medline] [CrossRef]
3) Olivo SA, Bravo J, Magee DJ, et al.: The association between head and cervical posture and temporomandibular disorders: a systematic review. J Orofac Pain, 2006, 20: 9–23. [Medline]
4) Fedorak C, Ashworth N, Marshall J, et al.: Reliability of the visual assessment of cervical and lumbar lordosis: how good are we? Spine, 2003, 28: 1857–1859.
5) Cagnie B, Cools A, De Loose V, et al.: Reliability and normative database of the Zebris cervical range-of-motion system in healthy controls with preliminary validation in a group of patients with neck pain. J Manipulative Physiol Ther, 2007, 30: 450–455. [Medline] [CrossRef]
6) Dvir Z, Werner V, Peretz C: The effect of measurement protocol on active cervical motion in healthy subjects. Physiother Res Int, 2002, 7: 136–145. [Medline] [CrossRef]
7) Mária T, Ervin R, Ildikó J, et al.: Survey among school-aged children with ultrasound-based motion analyzing system at two primary schools in szolnok. Biomechanica Hungarica, 2010, 3.
8) Harrison AL, Barry-Greb T, Wojtowicz G: Clinical measurement of head and shoulder posture variables. J Orthop Sports Phys Ther, 1996, 23: 353–361. [Medline]
9) Haley SM, Fragala-Pinkham MA: Interpreting change scores of tests and measures used in physical therapy. Phys Ther, 2006, 86: 735–743. [Medline]
10) Bland JM, Altman DG: Statistical methods for assessing agreement between two methods of clinical measurement. Lancet, 1986, 1: 307–310. [Medline] [CrossRef]
11) Landis JR, Koch GG: The measurement of observer agreement for categorical data. Biometrics, 1977, 33: 159–174. [Medline] [CrossRef]
12) Knols RH, Aufdemkampe G, de Bruin ED, et al.: Hand-held dynamometry in patients with haematological malignancies: measurement error in the clinical assessment of knee extension strength. BMC Musculoskelet Disord, 2009, 10: 31. [Medline] [CrossRef]
13) Koblbauer IF, Lambrecht Y, van der Hulst ML, et al.: Reliability of maximal isometric knee strength testing with modified hand-held dynamometry in patients awaiting total knee arthroplasty: useful in research and individual patient settings? A reliability study. BMC Musculoskelet Disord, 2011, 12: 249. [Medline] [CrossRef]
14) Sole G, Hamren J, Milosavljevic S, et al.: Test-retest reliability of isokinetic knee extension and flexion. Arch Phys Med Rehabil, 2007, 88: 626–631. [Medline] [CrossRef]
15) de Vet HC, Terwee CB, Knol DL, et al.: When to use agreement versus reliability measures. J Clin Epidemiol, 2006, 59: 1033–1039. [Medline] [CrossRef]
16) Guyatt G, Walter S, Norman G: Measuring change over time: assessing the usefulness of evaluative instruments. J Chronic Dis, 1987, 40: 171–178. [Medline] [CrossRef]
17) Liaw LJ, Hsieh CL, Lo SK, et al.: The relative and absolute reliability of two balance performance measures in chronic stroke patients. Disabil Rehabil, 2008, 30: 656–661. [Medline] [CrossRef]
18) Faber MJ, Bosscher RJ, van Wieringen PC: Clinimetric properties of the performance-oriented mobility assessment. Phys Ther, 2006, 86: 944–954. [Medline]
19) Robinson R, Robinson HS, Bjorke G, et al.: Reliability and validity of a palpation technique for identifying the spinous processes of C7 and L5. Man Ther, 2009, 14: 409–414. [Medline] [CrossRef]