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Original Article

Reliability of measuring the passive range of shoulder horizontal adduction using a smartphone in the supine versus the side-lying position

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Abstract. [Purpose] The purpose of this study was to compare the reliability of the measurement of the passive range of motion (PROM) of shoulder horizontal adduction (SHA) measurements using a smartphone for the assessment posterior shoulder tightness (PST) between the side-lying and supine test positions. [Subjects and Methods] Forty-seven subjects (mean ± age, 24.9 ± 3.5 years) without shoulder pathology were included in this study. Intra-rater and inter-rater reliabilities were determined using intraclass correlation coefficients. The SHA PROM of each subject's dominant shoulder was measured using a smartphone by two investigators in two positions: the standard supine position, and a side-lying position on the tested side. [Results] The intra-rater reliability of the supine measurements was fair to good ($ICC_{3,1}$ = 0.72–0.89), and for the side-lying measurements was excellent ($ICC_{3,1}$ = 0.95–0.97). The inter-rater reliability of the supine measurements was fair ($ICC_{2,2}$ = 0.79) and for the side-lying measurements was excellent ($ICC_{2,2}$ = 0.94). [Conclusion] These results suggest that for healthy subjects, measurements of SHA using smartphones in the side-lying position has superior intra-rater and inter-rater reliabilities compared to the standard supine position.

Key words: Reliability, Horizontal adduction, Smartphone

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INTRODUCTION

Shoulder pain is one of the most common musculoskeletal complaints seen in clinical practice[1, 2)]. Repetitive overhead sports athletes, such as those who play baseball, basketball, volleyball, and tennis, experience considerable physical loads that can injure the shoulder[3, 4)], such as the loads applied to the posterior joint capsule in the deceleration phase during the motion of throwing a ball. It has been proposed that such a repetitive load can result in a secondary change, such as a posterior capsular contracture[5)]. Moreover, it could cause various pathological reactions, such as subacromial impingement[6)], superior labrum anterior to posterior (SLAP) lesions[7)], and rotator cuff tears[8)].

Shoulder pathology has been associated with limitations of shoulder range of motion (ROM), specifically shoulder internal rotation and abduction. Posterior shoulder tightness (PST) has been shown to produce restricted shoulder ROM[9)]. Therefore, an assessment of the internal rotation and adduction ROM due to PST is an important and essential part of understanding the pathological characteristics of shoulder joints in orthopedic evaluation[10)].

Myers et al.[11)] reported that throwing athletes with symptomatic internal impingement had reduced glenohumeral internal rotation, while Burkhart et al.[3)] suggested that contracture of the posterior-inferior shoulder joint capsule affected the loss of internal rotation ROM with the shoulders abducted to 90°. However, a decreased glenohumeral internal rotation may also result from increased humeral retroversion, and this kind of abnormal result due to the bony adaptation can be misinterpreted as posterior joint capsular contracture[12, 13)].

Several researchers have tested shoulder horizontal adduction (SHA) to measure PST[14–18)]. Warner et al.[18)] used a goniometer to measure SHA of subjects in the supine position. Appropriate scapular stabilization may not have been maintained, leading to accessory scapulothoracic movement. In the study by Pappas et al.[16)], the subjects required scapular stabilization from a rater while performing horizontal adduction in the supine position, but no data about the reliability or validity of the measurements was reported. Tyler et al.[17)] measured horizontal adduction while subjects performed scapular stabilization in the side-lying position with the test side upward. The first rater performed horizontal adduction while stabilizing the scapula in the retraction position with his or her hands. The second rater measured the distance to the test table from the medial epicondyle of the subjects. Their measurement results showed high intra-rater and inter-rater reliabilities. However, their distance measurements did not consider the different arm lengths of the subjects. In a

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study by Laudner et al.[15], two raters stabilized the scapula and measured horizontal adduction using a digital inclinometer in the supine position. Their measurement results demonstrated high intra-rater or inter-rater reliability. However, their measurement method required two clinicians to perform the assessment which is inconvenient in the clinical practice. To address this problem, the use of a smartphone has recently been proposed[19, 20].

The number of smartphone users in South Korea was 32.72 million people in December 2012 and smartphones have increased in popularity since they were introduced in 2009[21]. The most recent smartphone models are equipped with a gyro-sensor system that can be used as an inclinometer by application software and studies of their potential uses have increased in recent years[22, 23]. Although studies of patients with shoulder pain, stroke, and lumbar extension-rotation syndrome have proven the reliability of ROM measurements[21], few studies of SHA have been conducted. Therefore, this study performed angle measurements using smartphones to overcome the problems of existing measurement methods. The purpose of this study was to compare the intra-rater reliability and inter-rater reliability of measuring SHA using a smartphone to establish the accuracy of PST measurement with a smartphone in the supine and side-lying positions. This study further aimed to propose a more reliable measurement method than horizontal adduction in the typical supine position and to compare the reliability and clinical usability between the existing and new methods.

SUBJECTS AND METHODS

The subjects of this study were selected on the basis of the following criteria: no shoulder injuries or history of musculoskeletal and nervous system damage that could have affected shoulder ROM, no pain around the shoulder, and no performance of specialized shoulder muscle strength exercises or stretching in the preceding six months. The study subjects were 47 male and female university students attending Daegu University in Daegu Metropolitan City. The subjects were fully informed of all the experimental procedures before the experiment and gave their voluntary consent to participation before they participated in the experiment. This study was approved by the Institutional Review Board of Daegu University, in accordance with the ethical principles of the Declaration of Helsinki. Table 1 summarizes the general characteristics of the subjects.

Table 1. General characteristics of the subjects (N=40)

Characteristics	Mean±SD
Age (years)	24.9±3.5
Gender (male/female)	28/19
Height (cm)	168.6±4.7
Weight (kg)	65.3±8.6
BMI (kg/m^2)	22.9±2.4

BMI: body mass index, Mean±SD: mean±standard deviation

In this study, an iPhone V (A1429, Apple Inc., California, USA) smartphone with a size (length × width × thickness) of 123.8 × 58.6 × 7.6 mm and a weight of 112 g was used. The raters measured each subject's shoulder joint PROM using this smartphone. To evaluate the reliability of the smartphone measurements, Goniometer Pro (5FUF5 CO, Stephanskirchen, Germany) inclinometer application software was installed on the smartphone.

To determine the intra-rater reliability and inter-rater reliability during passive SHA measurement using the smartphone, two physical therapists who have worked in clinical practice in orthopedic physical therapy for one and nine years, and two assistant recorders participated in the experiment. The two raters measured the passive SHA of the subject's dominant shoulder in separate rooms, and both were blind to the other rater's measurement results. The subject's dominant hand was defined as the one that was used for eating and writing. The dominant hands of all of the subjects were their right hands. Each of the two assistant recorders recorded the measurements by pairing with a rater. The two raters received a 20-minute training session with the experiment's designer to ensure consistent PROM measurements. Each assistant recorder recorded the adduction ROM measured by the rater using the smartphone. The two assistant recorders also did not share their measured values with each other until the measurements were completed.

To minimize the effect of repetitive measurement, a 48-hour rest time was given between measurement once one of the two raters had finished all of the measurements. To increase the validity of inter-rater reliability, once the first measurement was complete, the other rater measured horizontal adduction in the same manner about one hour later. A DualFit armband (Belkin, Playa Vista, CA, USA) was attached to the front center of the subject's humerus for the measurement. The smartphone was attached with its screen facing the horizontal direction of the axis of the movement.

Each of the two raters measured the horizontal adduction ROM of all the subjects once in two test positions (the supine position and the side-lying position). The order of the subjects and the order of the testing positions were randomized using the random number generator of Excel software. The subjects were not allowed to warm up prior to the testing.

The movement was measured in the two positions as follows. To measure SHA in the supine position, the subjects positioned both their shoulders flat on the test table. A rater stood at the head of the test table and positioned the subject's shoulder and the elbow joints in flexion at 90°. This position was defined as horizontal adduction 0°. To restrict the unwanted movement of the scapula, the rater stabilized the scapula by holding its side-lying border. The rater applied a posteriorly directed force to maintain the start position of the scapula. Then, the rater held the proximal forearm of the subject with the other hand and adducted the humerus horizontally. When the first tissue resistance was felt, the movement was stopped and then the recorder touched the application screen on the smartphone to record the angle on display.

To measure SHA in the sidelying position, the subjects lay on their side positioned, so that the virtual line connecting the acromion and the test table was vertical. The shoul-

Table 2. Intra-rater reliabilities of the shoulder adduction range of motion measurements (Mean±SD)

	Measurement 1	Measurement 2	$ICC_{3,1}$ (95% CI)
Rater 1			
Supine (°)	25.6±5.9	25.1±5.9	0.89 (0.81, 0.94)
Side-lying (°)	19.7±5.1	19.6±5.2	0.97 (0.95, 0.99)
Rater 2			
Supine (°)	27.3±5.3	26.5±5.4	0.72 (0.54, 0.83)
Side-lying (°)	20.2±4.6	20.1±4.8	0.95 (0.91, 0.97)

CI: confidence interval, ICC: intraclass correlation coefficient

Table 3. Inter-rater reliabilities of the shoulder adduction range of motion measurements (Mean±SD)

Position	Rater 1	Rater 2	$ICC_{2,2}$ (95% CI)
Supine (°)	25.4±5.8	27.0±5.0	0.79 (0.62, 0.89)
Side-lying (°)	19.6±5.1	20.4±4.6	0.94 (0.88, 0.97)

CI: confidence interval, ICC: intraclass correlation coefficient

der and elbow joints were flexed to 90°. This position was defined as horizontal adduction 0°. A rater held the distal part of the humerus and moved it in the horizontal adduction direction, while the upper body or acromion was prevented from rotating in the front or rear direction. When the first tissue resistance was felt, the movement was stopped, and the recorder touched the application screen on the smartphone to record the angle on display.

To test the intra-rater and inter-rater reliabilities of SHA ROM measurements in the supine and side-lying positions using a smartphone, intraclass correlation coefficients ($ICC_{3,1}$ and $ICC_{2,2}$) and the mean difference at the 95% confidence interval were calculated[24]. The ICC values were classified for reliability using the following criteria: excellent over 0.90, good between 0.80 and 0.89, fair between 0.70 and 0.79, and poor below 0.69. The Statistical Package for the Social Sciences (SPSS) version 12.0 was used for the statistical analysis (SPSS Inc., Chicago, IL, USA).

RESULTS

The intra-rater reliability of the measurements using the smartphone showed that rater 1 had a good level of reliability (0.89) in the supine position and an excellent level of reliability (0.97) in the sidelying position. Rater 2 showed a fair level of reliability (0.72) in the supine position and an excellent level of reliability (0.95) in the side-lying position (Table 2).

The inter-rater reliability of the measurements using the smartphone showed a fair level of reliability (0.79) in the supine position and an excellent level of reliability (0.94) in the sidelying position (Table 3).

DISCUSSION

The purpose of this study was to compare the intra-rater reliability and inter-rater reliability of measuring SHA using a smartphone to establish the accuracy of PST assessments of normal healthy people in the supine and sidelying positions.

The study results show that the two raters both had excellent levels of intra-rater reliability when SHA ROM was measured using the smartphone. They also show that rater 1 had a good level of intra-rater reliability, while rater 2 had a fair level of intra-rater reliability in the supine position. The reason for the lower level of intra-rater reliability of rater 2 was that rater 2 had only one year of clinical practice in orthopedic physical therapy compared to the nine years of rater 1, so rater 2 did not control the scapular stabilization as well. Laudner et al.[15] reported an excellent level of intra-rater reliability during the measurement of horizontal shoulder adduction and internal rotation once the scapula was stabilized in the supine position. Their result was obtained because a rater in their study had an athletic trainer license and had experience of the assessment of more than 300 horizontal shoulder adductions. Their study result is consistent with our study result in which the nine years of clinical practice of rater 1 was responsible for the good level of intra-rater reliability in the supine position. Since SHA measurement in the supine position is significantly affected by the skill or expertise of the raters, it would be preferable to select a horizontal adduction measurement method in the side-lying position, which is less affected by the experience and technique of the raters.

The SHA measurements using the smartphone showed that the inter-rater reliability was fair in the supine position and lower than in the side-lying position. The study of Ellenbecker et al.[25] proposed the use of passive scapular stabilization during shoulder internal rotation measurements in the traditional supine position, but this method had a poor level of inter-rater reliability. Furthermore, Riddle et al.[26] also found that the inter-rater reliability of shoulder internal rotation measurements was poor due to the lack of constant scapular stabilization, which depends on the raters. In summary, the shoulder joint ROM measurement in the supine position has an inherent limitation due to inconsistent scapular stabilization among raters.

The inter-rater reliability in the side-lying position was an excellent. This result means that an equal weight load was applied to the subjects and that scapular stabilization was consistent between the raters. Tyler et al.[17] found excellent intra-rater (ICC = 0.92–0.95) and good inter-rater (ICC = 0.80) reliabilities for SHA performed in side-lying on the non-tested side. However, they was found that it was difficult to perform this method in clinical practice because it needs two therapists for assessment, and the scapular stabilization method is difficult. In the present study, a smartphone was used to increase the usability of the method and resolve the other issues of measurements of horizontal adduction in the side-lying position.

The convenience of measurement is one of the advantages of using a smartphone. Since the measured joint angle is represented by a number on a smart phone screen in real time, a measurement can be made immediately. In addition, the smartphone was attached to the subjects' arms with an armband, which minimized measurement errors caused by an unstable measurement position. The present study demonstrated that one therapist can measure ROM independently and use our method effectively in clinical practice.

In this study, the mean SHA angles in the supine and side-lying positions were approximately 25° and 19°. SHA is accompanied by scapular protraction. The reason for the higher angle measured in the supine position is because the rater's passive scapular stabilization was not controlled sufficiently during the horizontal adduction, resulting in scapular protraction. Furthermore, the reason for the lower angle measured in the side-lying position is that the horizontal adduction is measured when the glenohumeral joints are more isolated due to scapular stabilization by the weight load. Recent studies have also reported that when measurement is performed in the side-lying position, with the test side is positioned on the floor, improved scapular control is facilitated by the weight load applied to the scapula[27].

This study had some limitations. First, it did not completely match the horizontal adduction measurement method between the raters. Although a training session about the measurement method was provided prior to the measurement, the "end feel" of the measurement can be different between raters, so the measurement cannot be completely controlled. Second, it is difficult to generalize the study results, because this study was performed with only healthy, young, normal adults as subjects. Therefore, it will be necessary to study the suitability of our method for patients with shoulder pathologies.

In conclusion, a smartphone can be used effectively in the SHA measurement of healthy subjects in the side-lying position, as it had higher levels of intra-rater reliability and inter-rater reliability than the supine position.

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