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Measurement Errors of a Test to Determine the Scapular Position Using a Tape Measure

Kazuya Yoshida, MS, RPT[1)], Ryusuke Isoya, RPT[2)], Hiroki Ejiri, RPT[2)], Kazuhiko Hara, PhD, RPT[3)], Osamu Fujinawa, PhD, MS, OMT, RPT[3)]

[1)] *Course of Physical Therapy, Department of Rehabilitation, Faculty of Health Sciences, University of Human Arts and Science: 354–3 Shinsyouji Kuruwa, Ota-aza, Iwatsuki-ku, Saitama-shi, Saitama 339-8555, Japan.*
TEL: +81 48-758-7111, FAX: +81 48-758-7110, E-mail: kazuya_yoshida@human.ac.jp
[2)] *Department of Rehabilitation, Sekimachi Hospital*
[3)] *Department of Physical Therapy, School of Health and Social Service, Saitama Prefectural University*

Abstract. [Purpose] Investigation of intra- and inter- measurer errors employing a scapular position measurement method using a tape measure designed by us. [Methods] Two measurers, a physical therapist (RPT) and a student on a physical therapist training course (PTS), measured the scapular position relative to the spine twice using a tape measure, and intra- and inter- measurer measurement errors were investigated. For statistical analysis, Bland-Altman analysis was employed. The limits of agreement (LOA) were determined when a systematic error was present, and the 95% confidence interval of the minimal detectable change (MDC_{95}) was calculated when no systematic error was detected. The significance level was chosen as 5%. [Results] Regarding intra- measurer measurement error, the mean value of the second measurement was greater than that of the first. Regarding inter- measurer error, the mean value measured by PTS was lower than that measured by RPT. [Conclusion] The mean of the first measurement was greater than that of the second measurement as the intra- measurer measurement error of this measurement method, and the mean measured by PTS was lower than that measured by RPT, showing a fixed error. By sufficiently practicing the measurement and applying markers to the bone index points, the measurement error may become small enough to be clinically acceptable.
Key words: Scapular position, Measurement errors, Tape measure

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INTRODUCTION

In clinical practice, evaluation of the scapulothoracic joint function (scapular position, movement and action of the surrounding muscles) is important for conducting physical therapy for impairment of the shoulder joint complex. The motor function of not only the glenohumeral joint but also the scapulothoracic joint has recently been getting attention in the physical therapy field, but treatment of the scapulothoracic joint has lower priority because impairment of the shoulder joint complex more markedly manifests in the glenohumeral than in the scapulothoracic joint[1)]. Accordingly, the scapulothoracic joint function is not often evaluated in examinations of shoulder joint movement in many cases. At present, it is difficult to determine the scapular position while the shoulder joint moves because the scapula floats on the thorax. Therefore, no method of measuring the scapular position has been established.

Measurement methods to evaluate the scapular position, such as the Kibler lateral scapular slide test (LSST) using a tape measure[2)] and DiVeta test[3)], have been reported. In Kibler LSST, the distance between the inferior angle of the scapula and point of interception of a horizontal line passing the angle and thoracic spinous process is measured in the following 3 positions, dropped arm, with the hands placed on the lower back and posture with the shoulder joint in 90° abduction / internal rotation, and the difference in the upward rotation between the bilateral scapulae is determined to evaluate the scapular position and fixing force of the muscles around the scapula[2)]. In the DiVeta test, the distances between the 3rd thoracic spinous process and posterior angle of the acromion (A) and between the medial margin of the scapular spine and the posterior angle of the acromion (B) are measured in a standing position, and the value calculated by dividing A by B (A / B) is considered the abduction position of the scapula relative to the spine[3)]. These measurement methods can be readily applied using a tape measure and are frequently employed in clinical practice. Gibson et al.[4)] and T'Jonck et al.[5)] verified the intra- and inter- measurer reliabilities of these methods, but there has been no report on measurement error. Moreover, Kibler LSST is applicable only for upward and downward scapular rotations, and the DiVeta test is only applicable in the one direction, abduction / adduction; thus, 3-dimensional evaluation of the scapula is difficult.

In this study, we designed a scapular position measurement method using a tape measure, and investigated intra- and inter- measurer measurement errors.

SUBJECTS AND METHODS

The measurers were a registered physical therapist (RPT) in the 3rd year of clinical practice and a student on a 3-year physical therapist training course (physical therapy student: PTS). The subjects measured were 9 adult males (18 shoulders) who had no motor, organ or shoulder joint impairment (age: 25 ± 4 years (mean ± standard deviation), height: 174.2 ± 2.9 cm, body weight: 65.7 ± 5.2 kg). The RPT had experience of applying this measurement method, whereas the PTS did not. Subjects with severe motor or organ disease / impairment or asymmetric spinal alignment in the forehead plane were excluded. This study was performed after approval by the Ethics Committee of Saitama Prefectural University. The objective of the study was orally explained to the subjects using a document and their written consent was obtained in conformity with the Declaration of Helsinki.

For the measurement, the 7th cervical spinous process (C7) served as the origin (o), and the positions of the medial margin of the scapular spine (a) and inferior angle of the scapula (b) relative to the origin (o) were defined as the scapular position, referring to the analysis of the scapular coordinate shift reported by Miura et al 6). Using a tape measure, the following 4 distances (cm) were measured the distance between the point of interception (a’) of the vertical line drawn from the origin (o) and the horizontal line passing (a) and the origin (distance oa’); the distance between (a) and (a’) (distance aa’); the distance between the intercept point (b’) of the vertical line drawn from the origin (o) and horizontal line passing b and the origin (o) (distance ob’); and the distance between b and b’ (distance bb’). The measurement was performed using a tape measure referring to the anatomical bone index points reported by Lewis et al7,8). The subject stood in a natural standing position with the upper half of the body naked, and the bilateral scapular positions were measured twice on the same day. To compare the measurers with and without experience and investigate differences in the measured values, no skin marker was applied to the bone index points. The measurers palpated the bone index points to measure the position. The subjects breathed naturally during the measurement.

Statistical analysis was performed following the method reported by Shimoi et al.[9,10], with a significance level of 5%. To investigate the type, level, and acceptable range of error in the measured values, Bland-Altman analysis was performed, and the limits of agreement (LOA) and 95% confidence interval of minimal detectable change (MDC_{95}) of measurement error were calculated. Systematic error between the 2 measured values was analyzed employing Bland-Altman analysis. Systematic error represents deviation in a specific direction, and is divided into fixed error and proportional bias. Fixed error represents deviation with a specific width in a specific direction regardless of the true value, while proportional bias represents deviation which changes in a specific direction in proportion to the true value.

For the Bland-Altman analysis, the difference (d) between the 2 measured values and the mean of the 2 values ($\bar{d}$) were plotted on the y and x axes, respectively, to prepare a Bland-Altman plot. The 95% confidence interval of the mean difference between the 2 values was determined, and when 0 was not included in this interval, the measured values were considered to distribute in a specific direction, showing the presence of a fixed error. To investigate the presence of proportional bias, a regression equation was established from the Bland-Altman plot, and the significance of the regression was tested. When the regression was significant, it was judged that proportional bias was present. When systematic error was detected in the Bland-Altman analysis, LOA was determined to investigate whether the difference between the measured values was problematic for clinical application. When no systematic error is detected, only accidental error is considered to reduce measurement reliability. Accidental error is divided into biological individual differences and measurement error produced on measurement. To investigate this measurement error, MDC_{95} was determined. The calculation formulas for LOA and MDC_{95} are shown below[10]:

Lower LOA = $(\bar{d} - 1.96 \times SD_{\bar{d}}) \pm t \times SE_{LOA}$

Upper LOA = $(\bar{d} + 1.96 \times SD_{\bar{d}}) \pm t \times SE_{LOA}$

$MDC_{95} = 1.96 \times SD_{d}$

n: number of measured subjects, d: difference between measured values SD_d: standard deviation of d, $\bar{d}$: mean difference between measured values, $SD_{\bar{d}}$: standard deviation of $\bar{d}$, SE_{LOA} : $\sqrt{\frac{3SD_{\bar{d}}^2}{n}}$

RESULTS

Intra- and inter- measurer measurement errors of values obtained employing the measurement method are shown in Table 1. Regarding the mean difference between the first and second measured values as intra- measurer measurement error, the mean ± standard deviation of differences in the scapula position measured by RPT and PTS were respectively –0.72 ± 1.07 and –0.31 ± 1.02 cm for oa’, –0.03 ± 0.83 and –0.31 ± 0.58 cm for aa’, respectively, –0.81 ± 1.19 and 0.14 ± 1.15 cm for ob’, and 0.31 ± 0.79 and –0.33 ± 0.94 cm for bb’. The mean of the first measured value tended to be greater than the mean of the second value ($p<0.01$). As inter-measurer measurement error, the difference in the mean of the first measured distance of oa’ between RPT and PTS was 1.00 ± 0.14 cm, and those of aa’, ob’, and bb’ were 0.14 ± 0.09, 0.86 ± 0.15, and 1.41 ± 0.27 cm, respectively. Regarding the second measured values, the differences in oa’, aa’, ob’, and bb’ were 1.41 ± 0.09, –0.22 ± 0.11, 1.80 ± 0.08, and 0.78 ± 0.27 cm, respectively. The mean values measured by PTS tended to be lower than those measured by RPT ($p<0.01$).

The test results of intra- measurer measurement error are shown in Table 2. LOA and MDC_{95} were –2.11 ~ 0.50 and 1.55 ~ 2.25 cm, respectively. Fixed errors were detected in

Table 1. Results of the scapular position measurement method and measurement errors
Two measurers, 9 subjects (18 shoulders)

Measurer	Measurement order	Scapular position			
		Distance oa’	Distance aa’	Distance ob’	Distance bb’
RPT	First	9.00 ± 1.30	7.97 ± 1.28	22.67 ± 1.39	10.58 ± 1.19
	Second	9.72 ± 1.19	8.00 ± 1.34	23.47 ± 1.41	10.28 ± 1.09
	Difference	–0.72 ± 1.07**	–0.03 ± 0.83	–0.81 ± 1.19**	0.31 ± 0.79**
PTS	First	8.00 ± 1.26	7.83 ± 1.19	21.81 ± 1.24	9.17 ± 1.46
	Second	8.31 ± 1.10	8.22 ± 1.23	21.67 ± 1.33	9.50 ± 1.36
	Difference	–0.31 ± 1.02	–0.39 ± 0.58**	0.14 ± 1.15	–0.33 ± 0.94

Mean ± standard deviation (cm) ** $p < 0.01$. RPT: physical therapist; PTS: physical therapy student; difference: the value calculated by subtracting the mean of the first measured value from that of the second; distance oa’: distance between the 7th cervical spinous process (origin o) and intercept point (a’) of a vertical line drawn from (o) and a horizontal line passing the medial margin of the scapular spine (a); distance aa’: distance between a and a’; distance ob’: distance between the origin (o) and intercept point (b’) of a vertical line drawn from the origin (o) and a horizontal line passing the inferior angle of the scapula; distance bb’: distance between b and b’.

Table 2. Test results of intra- measurer error of the scapular position measurement method

	Measurer	LOA (cm)	MDC_{95} (cm)	Bland-Altman analysis	
				Fixed error (cm)	Proportional bias
				95% confidence interval	Regression line
Distance oa’	RPT	–1.26, 0.46		–1.26, –0.19	0.11
	PTS		1.99	–0.81, 0.20	0.17
Distance aa’	RPT		1.63	–0.44, 0.39	–0.08
	PTS	–1.03, 0.25		–0.68, –0.10	0.07
Distance ob’	RPT	–2.11, 0.50		–0.40, –0.21	–0.01
	PTS		2.25	–0.43, 0.71	–0.09
Distance bb’	RPT		1.55	–0.09, 0.70	0.14
	PTS		1.84	–0.80, 0.13	0.11

LOA was calculated when a fixed error was detected, and MDC_{95} was calculated when no fixed error was detected.

Table 3. Test results of inter- measurer error employing the scapular position measurement method

	Measurement order	LOA (cm)	MDC_{95} (cm)	Bland-Altman analysis	
				Fixed error (cm)	Proportional bias
				95% confidence interval	Regression line
Distance oa’	First	–0.52, 1.69		0.31, 1.69	0.03
	Second	0.14, 2.70		0.84, 2.00	0.09
Distance aa’	First		1.77	–0.31, 0.59	0.11
	Second		1.27	–0.54, 0.10	0.18
Distance ob’	First	–1.00, 2.72		0.02, 1.70	0.12
	Second	0.39, 3.22		1.17, 2.44	0.07
Distance bb’	First	0.22, 2.61		0.88, 1.95	–0.27
	Second	–0.54, 2.10		0.18, 1.38	–0.26

LOA was calculated when a fixed error was detected, and MDC_{95} was calculated when no fixed error was detected.

distances oa’ and aa’ measured by RPT and aa’ measured by PTS, but no proportional bias was identified in any scapular position (distances oa’, aa’, ob’, and bb’). The test results of inter- measurer measurement error are shown in Table 3. LOA and MDC_{95} ranges were –1.00 ~ 3.22 and 1.27 ~ 1.77 cm, respectively. Fixed errors were detected in distances oa’, aa’, and bb’, but no proportional bias was detected in any scapular position.

DISCUSSION

Regarding the intra- measurer error of this measurement method, the mean of the second measured value was greater than that of the first, and the LOA and MDC_{95} were –1.00 ~ 3.22 and 1.27~1.77 cm, respectively. One possible reason for the error was that the palpated region was inconsistent, and the posture of the subjects was not consistent. In addition, repeated palpation of the bone index points to obtain the true value may have extended the muscle and produced a difference in the measured value. Measurement was performed within a day, no marker was applied to the bone index points, and the measurement region was palpated in each measurement. About 10 minutes were taken for a single measurement per subject. Since each subject was measured twice by the 2 measurers, each subject was palpated at the bone index points and measured for about 40–50 minutes. The student took longer over palpation.

Regarding the inter- measurer error of this measurement method, the mean value measured by PTS was greater than that measured by RPT, showing a fixed error ($p<0.01$). We considered inconsistency of the palpated region was a possible cause of the error, similar to the results of intra-measurer error. Since the measurers were a physical therapist with experience of clinical practice and performing this method and a student lacking clinical practice and experience, the palpation technique of PTS may have been inferior to that of RPT. PTS took longer over palpation, even though bone index points readily palpable for measurers without experience were selected. The presentation of points and sufficient practice of palpation may minimize measurement error. To investigate the difference between measurers with and without experience, measurement was performed without marking. Marking the bone index points (application of markers or marking with a pen) may also minimize measurement error.

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