VALIDITY OF A MAKER-BASED LOCATOR FOR MEASURING *IN VIVO* THREE-DIMENSIONAL SCAPULAR STATIC POSES USING STEREOPHOTOGRAMMETRY

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The study aimed to (1) develop a marker-based scapular locator for measuring scapular poses and (2) to design an *in vivo* experimental procedure for this static marker-based measurement method to decrease measurement errors, and (3) to validate this scapular locator and the experimental procedure. Six young male adults were implanted into the spine of the scapula with two bone-pins that were attached with a cluster of four retro-reflective markers (bone markers). The scapular poses were measured simultaneously using the developed scapular locator and the bone markers. The results showed that very high validity for scapular rotations and for the acromial angle (AA), the root of spine (RS) and the inferior angle (IA) of the scapular translation were achieved. Two main reasons contributed to the results: (1) the adjustable scapular locator and (2) careful palpation of the bony landmarks over the scapula.

KEY WORDS: Scapular Kinematics.

INTRODUCTION: The shoulder complex plays a critical role in all sorts of sports and exercises. Accurate assessment of the static scapular kinematics is essential to understand the interactions between the scapula and the bones of the shoulder complex for injury prevention and treatment design. However, precise measurement of the scapular kinematics is difficult because the scapula moves a lot underneath the skin during motion. A scapular locator integrated with magnetic tracking devices has been proposed to measure the poses of the scapula (Johnson, 1993; Karduna, 2001). Since skin marker-based stereophotogrammetry has been widely used for motion analysis, there is a need to develop locators with retro-reflective markers for measuring scapular poses. Therefore, the purposes of the study were (1) to development a marker-based scapular locator for measuring scapular kinematics and (2) to design an *in vivo* experimental procedure to reduce measurement errors and (3) to validate this scapular locator and the experimental procedure.

METHODS: Six young adults (age= 21.2±1.3y/o, mass= 69.6±5.6kg, height= 173.8± 3.6 cm) without shoulder complex pathologies participated in the current study, giving informed written consent as approved by the Institutional Research Board of China Medical University Hospital in Taiwan. The subjects were implanted into the spine of their right scapula with two 1.6mm Kirschner wires (K-wires) for at least 2cm in depth under local anaesthesia. The K-wires were connected by bone cement with a cluster of four 9mm-diameter markers (2g in weight) called bone markers (BM) (Fig. 1). A shape-adjustable marker-based scapular locator (SL) with three 9mm-diameter markers was designed and built, and used to measure the scapular poses by pointing each of its three pointers to the root of spine (RS), the inferior angle (IA) and the acromial angle (AA) of the scapula (Fig. 1). The coordinates in space of all the markers were measured using a seven-camera motion analysis system (Vicon 370, Oxford Metrics, U.K.) at 60Hz.

The subjects were asked to perform shoulder elevations of 0, 20, 40, 60, 80, 100 and 120 degrees in the scapular plane, with the elbow extended. An experienced physical therapist palpated carefully the AA, RS and IA of the scapula for each subject, adjust the locator according to the landmarks, and then position the scapular locator to define the pose of the scapula (Fig. 1). Five trials were performed for each elevation position for each subject. The data of the BM gave the true scapular poses against which comparisons with those of the SL were made to determine the validity. The differences between the means from BM and SL were calculated for scapular rotations and the positions of the AA, RS and IA. Validity of the SL was assessed in terms of the intra-class correlation coefficients (ICC) calculated using a 2-way mixed-effects model (ICC 1,k). The values of the ICC ranging from 0.81 to 1.0 indicate very good validity; 0.61–0.80 is good; 0.41– 0.60 is moderate; 0.21– 0.40 is fair; and below 0.2 is poor. Statistical analysis was performed using SPSS 13.0 (SPSS Inc., Chicago, U.S.A.).

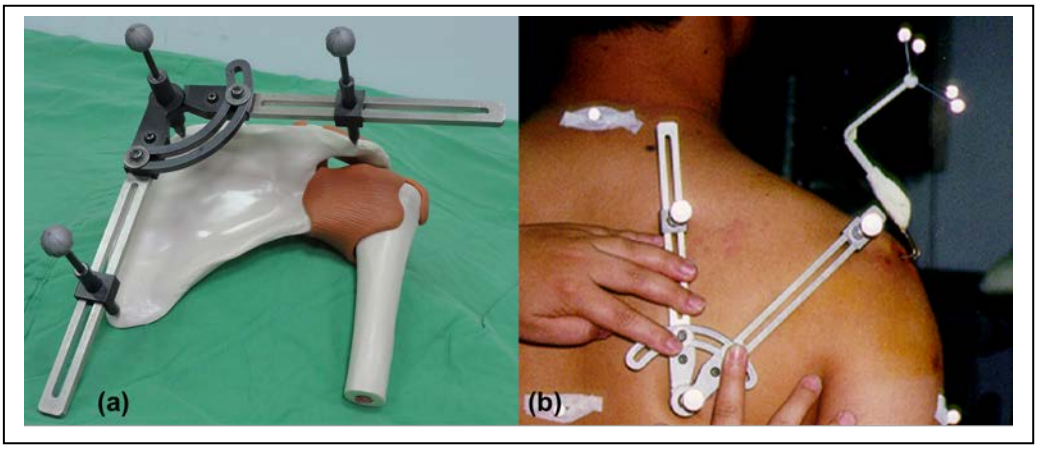

Figure 1: (a) The shape-adjustable marker-based scapular locator with the three pointers pointing to the AA, RS and IA of the scapula. (b) The bone-pins with a cluster of four 9mm-diameter markers and the scapular locator.

RESULTS: Differences between the means of BM and SL were 0.11-3.85 degrees for scapular rotations. For scapular displacements, the differences were 0.01-4.59 mm for the AA, 0.33-5 mm for the RS and 0.05-10.36 mm for the IA (Table 1). The results showed increased differences between the means of the IA displacements with increasing arm elevation from 80, 100 to 120 degrees in the lateral/medial and posterior/anterior directions. The ICC values were 0.89-0.99 for scapular rotations and 0.88-0.99 for the displacements of the AA, RS and IA for shoulder flexion at 0, 20, 40, 60, 80, 100 and 120 degrees in the scapular plane.

Table 1
Differences (Diff) between means and ICC for scapular rotations and the displacements of the acromia angle (AA), the root of spine (RS) and the inferior angle (IA) of the scapula

Arm Elevation	Rotation (degree)		Displacement (mm)					
			AA		RS		IA	
	Diff	ICC	Diff	ICC	Diff	ICC	Diff	ICC
	Protraction /Retraction		Lateral/ Medial					
0	0.11	0.98	0.04	0.97	0.33	0.99	2.08	0.98
20	1.42	0.97	0.86	0.97	1.53	0.98	2.18	0.99
40	1.83	0.98	0.13	0.94	2.54	0.98	0.05	0.98
60	2.71	0.97	0.01	0.98	3.75	0.98	3.42	0.92
80	2.39	0.98	0.03	0.94	4.08	0.98	6.3	0.94
100	2.06	0.97	0.56	0.95	4.74	0.97	7.5	0.95
120	1.45	0.99	0.01	0.97	1.33	0.98	7.4	0.94
	Lateral/ Medial Rotation		Superior/ Inferior					
0	0.85	0.98	2.60	0.98	0.99	0.99	1.00	0.99
20	0.28	0.98	4.59	0.98	4.35	0.99	5.22	0.99
40	0.38	0.96	3.94	0.97	4.95	0.99	5.55	0.99
60	1.73	0.95	2.47	0.96	5	0.99	6.19	0.99
80	3.85	0.96	0.14	0.98	1.7	0.99	3.3	0.99
100	3	0.9	2.79	0.99	1.9	0.99	2.04	0.99
120	2.5	0.92	2.25	0.99	2.45	0.99	1.21	0.99
	Posterior/ Anterior Tilt		Posterior/ Anterior					
0	0.87	0.99	0.18	0.95	0.27	0.96	0.18	0.97
20	2.82	0.99	0.51	0.97	2.67	0.99	1.43	0.98
40	2.78	0.99	0.35	0.88	2.49	0.99	2.8	0.94
60	2.75	0.99	1.83	0.85	2.19	0.99	5.79	0.96
80	2.48	0.98	2.04	0.94	0.39	0.98	10.36	0.97
100	3.24	0.97	1.64	0.96	2.59	0.98	10.18	0.98
120	2.78	0.98	2.29	0.99	4.39	0.96	10.06	0.99

DISCUSSION: This study aimed to quantify the validity of the marker-based scapular locator developed for the use with stereophotogrammetry against the data obtained from bone markers. This is in contrast to previous studies that evaluated skin marker-based methods for the scapular kinematics using data from scapular locators of their own design as gold standard. The current study showed that very high validity for scapular rotations and for the displacements of AA, RS and IA could be achieved using the current scapular locator with careful palpations. These results suggest that it would be acceptable to use data from the current scapular locator as gold standard in future studies without having to use bone pins.

The current design of the marker-based scapular locator improved the previous magnetic device based scapular locator developed by Johnson et al. (1993) for the measurement of scapular poses using stereophotogrammetry. The new shape-adjustable design enabled fast customization of the locator to individual subjects, thus reducing the potential errors because of the mismatch of the shapes of the locator and the scapula, and the positioning of the locator during the measurement process. Although careful palpation was exercised to reduce the locator positioning error during the experiment, measurement errors in the scapular displacements from muscle contractions around the scapular region were inevitable. However, it appears that such muscular effects did not affect significantly the validity of the locator.

CONCLUSION: Data of the scapular rotations and translations in terms of displacements of AA, RS and IA measured by the newly developed shape-adjustable scapular locator were in very good agreement with the bone marker data. These results showed that the scapular locator was valid and reliable in the measurement of the scapular poses for future research and clinical applications.

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