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Original Article

Scapular Kinematic Measurement in Subjects with and Without General Hypermobility Syndrome Using Motion Analysis System: A Reliability Study

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ABSTRACT

Background: The purpose of the present study was to examine the reliability of scapular kinematic measurements using motion analysis system in subjects with and without General Hypermobility Syndrome.
Methods: A methodological study was designed to assess the reliability of scapular movement measurement in two groups of females with and without General Hypermobility Syndrome. Upward rotation, superior- inferior translation, medial-lateral translation, posterior tilt and medial rotation were measured during arm elevation in both frontal and sagittal planes using a motion analysis system. Intraclass Correlation Coefficient (ICC) and Standard Error Measurement (SEM) were used to assess intra-rater within-day reliability of the scapular kinematics measurements in both groups.
Results: The ICC values ranged from 0.72 to 0.98 and 0.69 to 0.98 for GHS and healthy subjects, respectively. In addition, the results showed that SEM for scapular rotation and translation are always lower than 1.72º and 1.65 cm, respectively.
Conclusion: Motion analysis system could be used as a reliable method to measure the scapular kinematics in subjects with and without General Hypermobility Syndrome.

Introduction

General Hypermobility Syndrome (GHS) is one of the most common musculoskeletal disorders, with the prevalence ranging from 0.6% to 31.5% in societies nowadays [1]. Kirk and colleagues were the first experts who recognized people with GHS have excessive range of motion. GHS prevalence depends on age, ethnicity and criteria for hypermobility assessment [1-3]. Epidemiological studies demonstrate that females are more affected than males [2-5]. GHS may affect proprioception [6] and result in different musculoskeletal complaints [2,5,7]. Shoulder hyper laxity is one of the most important factors that cause shoulder dislocation and shoulder instability in these individuals [1,8]. Increased humeral head translation predisposes these patients to rotator cuff syndrome [9].

During arm elevation, the humerus rotates around the scapula and scapula moves around the thorax at the scapulothoracic joint. This coordinated movement of scapula and humerus is known as the scapulohumeral rhythm [10]. Previous studies have indicated that subjects

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with GHS and patients with glenohumeral joint instability have different scapulohumeral rhythm ratio [11-14]. Scapular dyskinesia can influence shoulder pathologies and vice-versa. Several studies have shown that people with rotator cuff syndrome, shoulder instability, adhesive capsulitis and impingement syndrome have different scapular motions during arm elevation as compared with healthy individuals [15].

The assessment of scapular motions and positions is an integral part of shoulder complex examination [16]. Different clinical methods are available for assessing scapular position and orientation. Kibler's Lateral Scapular Slide test is performed by measuring the distance from lateral scapular border to the corresponding thoracic spinous process in the horizontal plane. Although the Kibler's procedure is relatively simple, this method is not a reliable and sensitive assessment in the presence of scapular asymmetry [17]. Palpation meter is another method used to determine horizontal distance of the scapula from the spine and vertical distance from the acromion to C7. These two-dimensional methods are unable to examine some of scapular movements such as scapular rotation and tilt [18].

For experimental studies, there is a necessity to provide a more comprehensive examination because scapula moves three dimensionally as the arm elevates for functional purposes. To achieve this and to make treatment outcomes more objective, several experimental methods have been introduced to monitor scapular kinematics. Recently, examining the kinematics of scapular motion by using motion capture systems has gained considerable attention [19]. A 6-degree-of-freedom Electromagnetic Tracking Device is one of the most popular devices that has been used for recording scapular kinematics [20]. Another device that can evaluate three dimensional movements of the scapula is the motion analysis system. Lukasiewics et al. developed an algorithm that simply extracts scapular kinematics. It was done by attaching six markers to the scapula. Scapular kinematics were recorded when subjects statically positioned the arm on a predetermined elevation angles. The simplicity of the analysis is an advantage of this method that makes the measurements less complex. There is evidence regarding assessment of scapular position and orientation in subjects with and without GHS using this method [14]. The results have shown that GHS had lower upward rotation, lateral scapular translation during arm elevation as compared with healthy individuals. Various investigations have been conducted to evaluate accessible methods that are valid and reliable for assessing scapular kinematics [20]. However, there is no investigation to studying the reliability of scapular position and orientation especially in subjects with GHS.

Scientific application of scapular assessment for clinical research requires conducting reliability studies [19]. Considering the fact that subjects with GHS and patients with multidirectional shoulder instability have different scapular kinematics, it seems reasonable that individuals with shoulder hyper laxity have different characteristics in scapular kinematics during shoulder movements. This may affect the reliability of scapular kinematics in subjects with GHS obtained with different instruments. Reliability is a perquisite for measurement validity. High level of reliability indicates that there is not a significant discrepancy between repeated measurements when the response variable is constant during trials [21]. The aim of the present study was to measure the intra-tester reliability of scapular kinematics using a motion analysis system in individuals with and without GHS in frontal and sagittal plane arm elevation.

Methods

Sixteen female subjects with GHS and 16 healthy female individuals participated in this study. The GHS group was diagnosed according to Beighton score. Based on Beighton score, GHS subjects had 5 or more positive tests out of nine criteria [4]. Subjects in the healthy group received a zero score of each of the 9 criteria (table 1). Participants were included if they had full arm elevation in both sagittal and frontal planes. Exclusion criteria for both groups were having any shoulder musculoskeletal disorder, shoulder pain, spinal deformity, severe trauma and history of ligament damage or history of shoulder surgery that may affecting scapular kinematics [22]. The healthy group was matched according to age, sex, body mass index (BMI) [23,24] and menstrual cycle [25]. Demographic properties of both groups are listed in table 2. Data collection was done in the biomechanics laboratory of the Ergonomic department in the University of Social Welfare and Rehabilitation Sciences. Before participation, all subjects read and signed the inform consent form that was approved by Ethical Committee of University of Social Welfare and Rehabilitation Sciences.

Table 1: Beighton score used for diagnosis of GHS patients

Clinical test	Side	Positive	Negative
Passive extension of the little finger over 90 degrees	Left	1	0
	Right	1	0
Passive opposition of the thumbs to the anterior surface of the forearms	Left	1	0
	Right	1	0
Elbow hyperextension over 10 degrees	Left	1	0
	Right	1	0
Knee hyperextension over 10 degrees	Left	1	0
	Right	1	0
Trunk flexion with palms placed flat on the floor		1	0
Total Score		9	0

Table 2: Demographic properties of both GHS and healthy individuals

Variables	GHS	Healthy	t	P value
	Mean (SD)	Mean (SD)		
Age (year)	21.56 (2.30)	21.81 (2.76)	0.49	0.69
BMI (kgm^{-2})	20.90 (2.49)	21.85 (1.51)	0.47	0.67
Menstrual cycle (day)	17.06 (9.33)	15.14 (9.78)	-0.44	0.69

SD: Standard deviation; BMI: Body Mass Index; GHS: General Hypermobility Syndrome; P values refer to results of independent-t-test between two groups.

A motion analysis system (Vicon V 460, UK) was used to determine the 3-dimensional position and orientation of the scapula. Four cameras were used for recording scapular kinematics and their placements were not changed during the study. At the beginning of each day, the system was calibrated by the operator. Then, Examiner attached markers to six bony landmark using double-sided adhesive tapes. These six bony landmarks included C7 spinous process, T7 spinous process, medial border of the scapula at the root of the scapular spine, posterior angle of the acromion and the inferior angle of the scapula. Kinematic variables were measured based on the study conducted by Lukasiewics et al. [26] (table 3). Kinematic data were sampled at 100 Hz, saved on a Pentium-based computer and then exported to excel file for measurement of scapular kinematics. A custom-written program using vector-dot formulae converted the raw data to scapular kinematic variables. The calculation process was done at each arm elevation angle.

Kinematic measurements were assessed by one examiner, in one session. These trials repeated four times with 15 minute intervals between each. The subjects, testing positions and the order of measurements were randomly selected. Participants were trained to elevate the arm to 30˚, 60˚, 90˚, 120˚ and full arm elevation in both sagittal and frontal planes using custom printed plastic goniometer (Medical Device Solutions AG, Oberburg, Switzerland), then the landmarks were digitized when the arm was positioned at different angles for a 3 second data collection period. Subjects stood upright in a determined position while the eyes fixed forward and arms were relaxed in the dependent position. The arm elevation in different angles was performed only on the dominant side.

Statistical Analysis

Kolmogrov-smirnov test was utilized to assess the normality of distribution for background variables. Independent -t-tests were used to assess statistical differences between both GHS and healthy groups.

The Intraclass correlation coefficient (ICC) was used by means of two way mixed effect model to assess intra-session relative reliability of the measurement. We calculated ICC^{3,1} as described by Shrout and Fleiss so that only one rater evaluated the same population of subjects [27]. For each ICC, 95% confidence interval (CI) was measured to have sampling distribution.

Relative reliability is not always sufficient to be interpreted in the context of an individual score. Therefore, we assessed the absolute reliability as calculated by Standard Error of Measurement (SEM) to make a decision about degree of measurement which was different among individuals. The SEM was calculated using the following formula: [$SEM=SD \sqrt{1-r}$] while SD is the standard deviation calculated from the measurements and r is the calculated ICC value [28]. These analyses were performed in SPSS software (version 15.5, SPSS Inc., Chicago, IL, USA). The alpha level was set at 0.05 for statistical analyses.

Results

Sixteen females with GHS (Beighton score: 5.81±0.83, age: 21.56±2.30, BMI: 20.90±2.49 and Menstrual cycle 17.06±9.33 days) and sixteen healthy females (Beighton score: 0.0±0.0, age: 21.81±2.76, Body mass index (kg/m^2): 21.85±1.51 and Menstrual cycle 15.14±9.78 days) participated in the present study. There were no significant differences in age, BMI, Menstrual cycle between two groups (table 2). Kolmogorov–Smirnov test showed that distribution of dependent variables were normal.

The results showed that the ICC values for upward rotation angle, superior-inferior translation, medial-lateral translation, posterior tilt and medial rotation angles in healthy group were 69% to 90%, 82% to 96%, 70% to 96%, 85% to 98% and 87% to 98%, respectively (table 4). The results also showed that the ICC values for upward rotation angle, superior-inferior translation, medial-lateral translation, posterior tilt and medial rotation angles in GHS group were 72% to 93%, 80% to 96%, 82% to 96%, 92% to 98% and 79% to 98%, respectively (table 4).

Table 5 shows the Standard Error Measurement (SEM) in healthy group in kinematic variables. The results

Table 3: Calculation of scapular positions and orientations using bony landmarks

Scapular kinematics variables	How to calculate
Upward rotation angle	The angle between the spine and the medial border of the scapula (Frontal plane projection)
Superior-inferior position	The vertical distance between C7 and the centroid of the digitize points on the scapula
Medial-lateral position	The horizontal distance between C7 and the centroid of the digitized points on the scapula
Posterior-tilt angle	The angle between a vector passing through C7 and T7 and a vector passing through the inferior angle and the root of the spine of the scapula (Sagittal plane projection)
Medial rotation angle	The angle between the frontal plane and a vector passing through the root of the spine of the scapula and the posterior angle of the acromion (Transverse plane projection)

Table 4: ICC measures for kinematic variables during different arm elevation angles in frontal and sagittal plane (95% confidence interval)

Kinematic variables	Arm elevation angles	Healthy subjects		GHS subjects	
		Plane of elevation		Plane of elevation	
		Frontal	Sagittal	Frontal	Sagittal
Upward rotation	0^0	0.86(0.69-0.94)		0.93(0.83-0.97)	
	30^0	0.79(0.37- 0.89)	0.69(0.34-0.88)	0.86(0.7-0.94)	0.87(0.71-0.95)
	60^0	0.69(0.34-0.88)	0.88(0.75-0.95)	0.90(0.78-0.96)	0.92(0.83-0.97)
	90^0	0.82(0.64-0.93)	0.90(0.72-0.95)	0.93(0.86-0.98)	0.82(0.60-0.94)
	120^0	0.87(0.70-0.95)	0.85(0.69-0.94)	0.72(0.36-0.90)	0.81(0.60-0.93)
	180^0	0.86(0.71-0.95)	0.90(0.76-0.96)	0.88(0.74-0.95)	0.84(0.64-0.94)
Superior-Inferior translation	0^0	0.93(0.85-0.97)		0.93(0.83-0.97)	
	30^0	0.86(0.70-0.94)	0.95(0.90-0.98)	0.90(0.78-0.96)	0.92(0.83-0.97)
	60^0	0.92(0.83-0.97)	0.95(0.89-0.98)	0.93(0.85-0.98)	0.95(0.88-0.98)
	90^0	0.93(0.85-0.97)	0.91(0.78-0.96)	0.88(0.75-0.96)	0.94(0.82-0.98)
	120^0	0.93(0.85-0.97)	0.82(0.62-0.93)	0.93(0.85-0.98)	0.96(0.91-0.99)
	180^0	0.91(0.80-0.96)	0.96(0.92-0.99)	0.80(0.57-0.93)	0.95(0.88-0.98)
Medial-Lateral translation	0^0	0.94(0.87-0.98)		0.96(0.84-0.97)	
	30^0	0.77(0.50-0.91)	0.91(0.81-0.96)	0.88(0.78-0.96)	0.89(0.77-0.96)
	60^0	0.86(0.71-0.95)	0.70(0.37-0.88)	0.90(0.79-0.96	0.95(0.90-0.98)
	90^0	0.94(0.86-0.97)	0.91(0.80-0.97)	0.95(0.89-0.98)	0.84(0.84-0.94)
	120^0	0.74(0.39-0.90)	0.94(0.87-0.98)	0.82(0.48-0.94)	0.87(0.70-0.96)
	180^0	0.91(0.82-0.97)	0.96(0.92-0.99)	0.88(-0.71-0.82)	0.95(0.88-0.98)
Posterior tilt	0^0	0.85(0.65-0.94)		0.97(0.93-0.99)	
	30^0	0.93(0.86-0.97)	0.96(0.90-0.98)	0.98(0.94-0.99)	0.92(0.82-0.97)
	60^0	0.94(0.87-0.98)	0.92(0.84-0.97)	0.96(0.92-0.98)	0.95(0.89-0.98)
	90^0	0.93(0.86-0.97)	0.96(0.90-0.98)	0.95(0.89-0.98)	0.94(0.85-0.98)
	120^0	0.92(0.82-0.97)	0.98(0.95-0.99)	0.94(0.87-0.98)	0.92(0.80-0.97)
	180^0	0.98(0.95-0.99)	0.96(0.91-0.99)	0.95(0.88-0.98)	0.97(0.94-0.99)
Medial rotation	0^0	0.95(0.90-0.98)		0.96(0.90-0.98)	
	30^0	0.96(0.90-0.98)	0.87(0.72-0.95)	0.95(0.89-0.98)	0.93(0.85-0.97)
	60^0	0.92(0.83-0.97)	0.95(0.90-0.98)	0.96(0.92-0.99)	0.95(0.89-0.98)
	90^0	0.95(0.89-0.98)	0.92(0.82-0.97)	0.97(0.92-0.99)	0.79(0.4-0.93)
	120^0	0.98(0.94-0.99)	0.89(0.86-0.96)	0.95(0.90-0.98)	0.94(0.86-0.98)
	180^0	0.96(0.91-0.98)	0.96(0.90-0.98)	0.96(0.92-0.99)	0.94(0.86-0.98)

GHS: General Hypermobility Syndrome

demonstrate that SEM range in upward rotation angle, superior-inferior translation, medial-lateral translation, posterior tilt and medial rotation angles ranged from 0.34 to 0.72, 0.38 to 0.96, 0.44 to 1.25, 0.56 to 1.34, and 0.34 to 0.76, respectively.

Table 5 shows the Standard Error Measurement (SEM) in GHS group for all kinematic variables. The results demonstrate that SEM range in upward rotation angle, superior-inferior translation, medial-lateral translation, posterior tilt and medial rotation angles were from 0.37 to 0.81, 0.62 to 1.65, 0.50 to1.44, 0.67 to 1.72, and 0.23 to 0.73, respectively.

Discussion

The purpose of the present study was to examine scapular kinematic reliability during sagittal and frontal planes of arm elevation in subjects with and without GHS using 3-D motion analysis system. Lukasiewics et al. conducted a study (mostly similar to our study) for measuring the reliability of scapular kinematics during scapular plane arm elevation. However, they did not report any detailed information about ICC and SEM values. Moreover, Lukasiewics et al. study was limited to non-impaired subjects. One of the advantages of the present study was to evaluate the reliability of scapular kinematics during sagittal and frontal plane arm elevation. In addition, the present results focused on healthy as well as GHS individuals.

The present results about relative reliability are similar to other results mainly report reliability of scapular kinematics in different populations. McQuade et al. , Myers et al. and Tsai et al. reported intrasession relative reliability using electromagnetic device, ICC values above 0.90 [29-31]. Lukasiewics stated that the reliability ranged from 0.88 to 0.99 in 3-D scapular kinematics using electromechanical digitizing device [26]. Relative reliability was reported in the present study as strong as reports that have been illustrated in the above mentioned studies. The results of the present study showed that ICC mean for tested variables was 0.91 in both groups.

However, one of the most important findings was related to the similarity of reliability results between the two groups. This result could be originated from matching of both group based on age and sex. Roy et al. reported higher level of reliability in patients with shoulder impingement syndrome as compared with healthy individuals. They stated that it could be a result of different age and gender between the groups. However, the present study controlled the role of age and gender by matching of both groups. In

Table 5: SEM measures for kinematic variables during different arm elevation angles in frontal and sagittal plane

Kinematic variables	Arm elevation angles	Healthy subjects		GHS subjects	
		Plane of elevation		Plane of elevation	
		Frontal	Sagittal	Frontal	Sagittal
Upward rotation (deg)	0^0	0.41	0.44	0.37	0.37
	30^0	0.64	0.55	0.56	0.57
	60^0	0.66	0.34	0.60	0.48
	90^0	0.50	0.47	0.44	0.63
	120^0	0.72	0.58	0.74	0.61
	180^0	0.52	0.53	0.55	0.81
Superior-Inferior translation (cm)	0^0	0.50	0.50	0.66	0.66
	30^0	0.82	0.38	0.72	0.73
	60^0	0.56	0.51	0.63	0.62
	90^0	0.63	0.96	1.03	0.85
	120^0	0.74	0.93	0.89	0.64
	180^0	0.66	0.56	1.65	0.87
Medial-Lateral translation (cm)	0^0	0.44	0.46	0.50	0.50
	30^0	0.86	0.51	0.79	0.86
	60^0	0.71	1.25	0.75	0.62
	90^0	0.51	0.96	0.67	1.40
	120^0	1.01	0.53	1.44	1.15
	180^0	0.45	0.56	1.28	0.87
Posterior tilt (deg)	0^0	0.92	0.92	0.79	0.79
	30^0	0.60	1.10	0.67	1.72
	60^0	0.90	1.27	0.78	1.49
	90^0	0.79	1.08	0.89	1.22
	120^0	0.56	0.79	0.95	1.58
	180^0	0.72	1.34	1.11	0.93
Medial rotation (deg)	0^0	0.42	0.42	0.36	0.36
	30^0	0.34	0.72	0.44	0.23
	60^0	0.76	0.44	0.40	0.33
	90^0	0.38	0.56	0.34	0.73
	120^0	0.50	0.69	0.46	0.51
	180^0	0.46	0.42	0.42	0.68

addition, the present study controlled the role of menstrual cycle between two groups to control its possible effect on joint hypermobility as well as scapular kinematic variation. This finding was supported by Shultz et al. study who demonstrated that females would have different knee laxity when the sex hormones change during the menstrual cycle [25]. Similarly, BMI is one factor that causes different scapular kinematics in both groups [24] and the present study has tried to control its possible effect on scapular kinematic variability.

Several studies have been established for evaluating the absolute reliability of 3-D scapular kinematics using different procedures or devices. One of the first studies measuring the absolute reliability of three-dimensional scapular kinematics was conducted by john et al. They used the Isotrak electromagnetic device and reported SEM values ranged from 0.89° to 2.69° during one session [32]. Meskers et al. reported the standard deviation of scapular kinematics as a measure of variability ranged from 1.96 to 2.46 [33]. In addition, Mcquade et al., Myers et al. and Tsai et al. reported SEM values ranged from 1.0 to 2.6. The SEM values in present result were lower than those of the above mentioned studies [29-31]. A possible explanation for these results may be related to dynamic active arm elevation. The reliability was measured during continuous arm elevation in mentioned results. The measurement of dynamic scapular kinematics is complex due to the sliding movement of the scapula under the skin surface [34]. However, the present results have shown that SEMs have mostly been less than one degree during most angles of arm elevation. Lukasiewics et al. reported that SEM values of scapular position and orientation arm elevation were lower than 2 degrees [35]. The present results are congruent with the result of Lukasiewics et al study. The similar results may be related to similar procedure and algorithm used for both studies. In addition, both studies have positioned the markers on scapular bony landmarks in each arm elevation angle, separately.

Measurement process was performed during one session and high reliability in scapular kinematic measurement may originate from this event. This method could be used as a reliable method for scapular kinematic examination in clinical and experimental studies. These results are mostly applicable for studies that compare the scapular kinematics between two groups in one session. It seems that 0.38 to 1.65 cm in medial-lateral translation and superior-inferior translation is an acceptable error for detecting experimental and clinical differences between GHS and healthy subjects. This value during the use of palpation meters method in Da costa's study ranged from 5.6 to 11.7 mm [18].

3-D scapular kinematic measurement requires professional skills that include correct markers placement and anatomical knowledge. It must be considered that soft tissue covering, subcutaneous motion and scapular shape, would make marker placement difficult for examiners. It seems that measurement precision as well as examiner skill would have a critical role in increasing reliability [21,37]. These findings suggested that this method could be used as a good method for scapular kinematic assessment during arm elevation.

Static humeral position was one of the major limitations using this method. It was not possible to record scapular kinematics continuously when participants elevated the arm, because marker movements over the bony landmarks made it impossible to record correct scapular kinematic. As such further studies are needed to evaluate inter-session reliability as well as inter-rater reliability to provide better understanding about the reliability analysis using this method as an alternative measure. Considering the fact that reliability is a subject dependent parameter, we suggest the examination of the reliability in subjects with different shoulder pathologies in future studies.

Conclusion

Motion analysis system with present method could be used as a reliable method to measure the scapular kinematics in subjects with and without GHS.

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