THE FUNCTIONAL STABILITY OF THE UPPER LIMBS IN HEALTHY AND ROUNDED SHOULDER GYMNASTS

Ramin Beyranvand[1], Rahim Mirnasouri[2], Saeid Mollahoseini[1], Sadegh Mostofi[2]

[1]Faculty of Physical Education and Sport Science, Shahid Bahonar University of Kerman, Kerman, Iran
[2]Department of Physical Education and Sport Science, Lorestan University, Khorramabad, Iran

Original article

Abstract

We aimed to assess and compare functional stability of the upper limbs in healthy and rounded shoulder gymnasts. A total of 30 male gymnasts aged 9-12 were selected according to the study inclusion and exclusion criteria and were assigned into a healthy and a rounded-shoulder group. The Upper Quarter Y-balance test was used to assess the functional stability of the upper limbs on the dominant and non-dominant sides. The paired t-test was used to compare the dominant and non-dominant arms and the independent t-test to compare the results between the two groups. The results obtained showed no significant differences in the functional stability of the upper limbs between the dominant and non-dominant sides. Furthermore, the functional stability of the upper limbs was found to be significantly higher in the healthy group compared to the rounded-shoulder group. It can be concluded that having rounded shoulders can significantly affect the YBT-UQ scores obtained and increase the risk of future injuries by reducing the functional stability of the upper limbs in closed kinetic chains. Rounded-shoulders should therefore be further addressed and efforts should be made to correct this problem in gymnasts so as to reduce their risk of developing upper limb injuries.

Keywords*: Functional stability, upper limb, rounded shoulders, gymnastics.*

INTRODUCTION

The popularity of gymnastics has significantly increased among people in recent years and has led to a substantial increase in the number of people active this field, which may be due to the emphasis on women's exercise, the great talents in this field, the outstanding performances of some athletes and the inherent attractiveness of gymnastics(Sands, 2000). Following the increase in its popularity in different countries, the age of entry into gymnastics has decreased dramatically; for elite gymnasts to achieve sufficient competence, they need to begin their practices from age six to nine in order to get to its peak and raise the degree of difficulty of the movements at age ten (Caine & Maffulli, 2005). Another important change in gymnastics in recent years is the increasing complexity and the wide range of skills developed in this field, which in turn have led to changes in its movements. For instance, changes in the design of equipment, such as spring flooring, has caused changes in a variety of movements, and the increase in the number of rotations and spins and the increasing range of movement have made the field more difficult and increased the risks associated with these skills (Caine & Maffulli, 2005). Given the increasing popularity of gymnastics and the lower age of entry into the field and the start of training before the growth period, and also given the greater difficulty and complexity of gymnastics skills in recent years, concerns about the degree and severity of injuries in this field are well justified(Caine et al., 2008). Attention to upper limb injuries is particularly important in gymnastics, because, unlike in other fields, the upper limbs are extensively used for weight-bearing and dynamic closed chain exercises in gymnastics, which makes this part of the body the second most common part for gymnastics injuries(Webb and Rettig, 2008). According to studies, upper limb injuries may be responsible for more than half of the injuries caused by gymnastics; in one study, Dixon et al. (1993) reported that about 54% of injuries in elite gymnasts develop in the upper limbs (Dixon & Fricker, 1993).

The results of studies on the physical causes and risk factors of injuries in gymnasts suggest that injured gymnasts are larger in physical size (i.e. height and weight) and also have a greater body fat percentage compared to healthy and less-injured gymnasts (Lindner & Caine, 1993; Steele & White, 1986). The growth spurt age also contributes significantly to the risk of injury (Caine & Lindner, 1985; Micheli, 1983); in one study, Difiori et al. (2002) reported that 10 to 14 year-old gymnasts are significantly more likely to develop upper limb injuries compared to those outside this age range (DiFiori et al., 2002). A previous history of injury also contributes significantly to the risk of injury in elite gymnasts. About 30% of all injuries occurred in gymnastics have the potential to happen again (Caine et al., 2003).

Despite the numerous reports on upper limb injuries in gymnasts and the risk factors of injury in this part of the body, the role of musculoskeletal abnormalities in the incidence of these injuries has not yet been studied. Any deviation from the normal state of the body can adversely affect people’s performance and movement efficacy by changing the direction of the transfer of force and thus expose them to physical injuries by making them change the movement strategies they use (Desai et al., 2007).

Rounded shoulders comprise one of the most common musculoskeletal abnormalities that affect normal postural alignment in the upper limbs, making it deviate from its standard position (Peterson et al., 1997). This abnormality has been described as the protraction and elevation of the scapula and the forward positioning of the shoulders that makes the chest appear caved (Kendall et al., 1983; Kendall et al., 1970; Oyama, 2006). Researchers differentiate between rounded shoulders as an abnormality and kyphosis or excessive curvature of the spine; Kendall et al. (1970) showed that rounded shoulders occur on the horizontal plane while kyphosis occurs on the vertical plane (Kendall et al., 1970). Moreover, in rounded shoulders, the scapula are distanced, potentially resulting in winged scapula or the internal rotation of the humerus bones. Rounded shoulders cause changes in the static position of the scapula on the horizontal plane and may also cause the retraction of this muscle and subsequently the lengthening or attenuation of the rhomboid muscles by approximating pectoralis minor muscle heads to the coracoid process and 3rd, 4th and 5th ribs (Kluemper et al., 2006; Lynch et al., 2010). A reduction in the relaxation length of the pectoralis minor muscle can increase passive tension in this muscle when moving the arms, thereby limiting normal upward rotation, posterior slide and the outward rotation of the scapula (Borstad, 2006). Considering the changes that can occur in the pectoral girdle function due to rounded shoulders, this condition needs to be further addressed, especially among gymnasts compared to the general public, since the upper limbs are extensively used in gymnastics for weight bearing and closed kinetic chain activities, and thus any deformity in the pectoral girdle may increase the likelihood of injury in gymnasts by changing the physical function of the upper limbs (Webb and Rettig, 2008).

Of the tests designed to assess the performance of the upper limbs, very few evaluate the performance and dynamic stability of this region in closed kinetic chain activities (Falsone et al., 2002; Gorman et al., 2012; Jared Kitamura & Waitsc, 2007; Westrick et al., 2012). The Y-Balance Test-Upper Quarter (YBT-UQ) is a field test that assesses the unilateral dynamic performance of the upper limbs in a closed kinetic chain in conditions where stability is required during movement (similar to the conditions presenting in gymnastics) with minimum equipment (Gorman et al., 2012; Westrick et al., 2012). This test quantitatively assesses the functional stability of the subject when bearing his weight on only one hand in a three-point plank position and reaching maximum distance from the supporting hand in the medial, lower-side and upper-side directions (Butler et al., 2014). This test involves simultaneous central and shoulder stability and requires balance, neuromuscular control, proprioception, power and an extensive range of movement and is considered an efficient method for learning about performance, power and motor deficit in the shoulder (Butler et al., 2014; Gorman et al., 2012; Westrick et al., 2012). It thus appears that using this functional test can adequately predict the likelihood of injury in closed chain activities. Given the lack of studies on the effect of postural abnormalities on upper limb performance and the functional stability of the shoulders in closed chain activities, the present study was conducted to answer the question of whether or not rounded shoulders can affect the motor performance of the upper limbs in gymnasts in closed chain movements.

METHODS

The present causal comparative study was conducted to assess and compare the functional stability of the shoulder joint in a healthy group of gymnasts and another group with rounded shoulders. The study population consisted of 60 male gymnasts aged 9 to 12 who had regularly played gymnastics three days per week for the last three years. Participants' health status was determined prior to entering the study according to the General Health Questionnaire and written consents were obtained from them after they were briefed on the study objectives and methods. Ethical approval for this study has been granted by the Ethics Committee of the Lorestan University of Medical Sciences. Based on previous studies (Zandi et al., 2016), a total of 30 gymnasts were selected and placed in a healthy group (n=15) and a group with rounded shoulders (n=15). Participants with a history of head, spinal cord or upper limb fracture or surgery, those with 25<BMI<20 and those with a history of general joint hyperlaxity, neck osteoarthritis or pain in the neck and back were excluded from the study (Zandi et al., 2016).

The initial screening of the participants was performed using the New York physical examination with a chart screen (McRoberts et al., 2013) and 15 subjects with normal shoulders were randomly placed in the healthy group and 15 subjects with rounded shoulders were also randomly placed in the rounded-shoulder group.

The participants with rounded shoulders were quantified using a method consisting of percutaneous marking, digital photography (using Sony Cybershot DSC-WX200 camera) and AutoCAD 2014 (Aali et al., 2013; Raine & Twomey, 1994). In one study, Raine et al. (1994) reported a high validity and reliability for this method in the assessment of rounded shoulders (ICC=0.91)(Raine & Twomey, 1994). For this assessment, all the participants were first asked to remove their upper clothing and stand in front of the examiner. The seventh cervical vertebrae and the left and right acromion processes were marked as reference points, and in order to assume a normal position, the participants were asked to perform the military "at ease march" a number of times, rotate their shoulders forward and backward three times and then move their head backward and forward a few times (Najafi & Behpoor, 2012). Once the normal position was assumed, the examiner photographed the positioning of their head and shoulders in the sagittal view. This step was repeated three times, and in each repeat, participants' normal position was photographed, and the mean of the three angles obtained was ultimately recorded for each participant as the angle at which their shoulders were rounded. The photographs taken were uploaded into a computer and their different angles were assessed using AutoCAD. For this purpose, the angle between the horizontal line and the line passing through the seventh vertebrae and acromion process (Figure 1) was calculated and taken as the shoulder protrusion in degree(Aali et al., 2013; Raine and Twomey, 1994). All the measurements were taken at the same time (5-8 pm) by the same examiner.

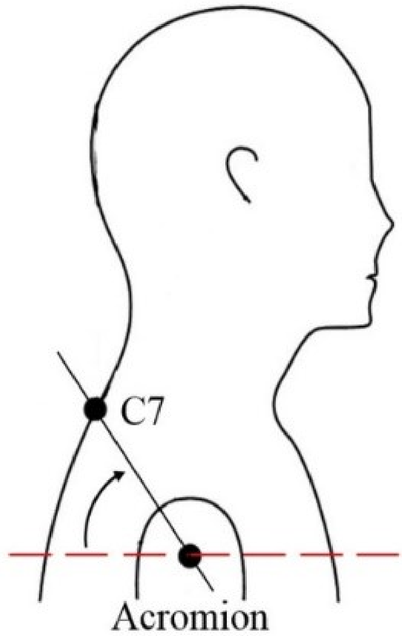

Figure 1. The photographic assessment of rounded shoulders.

The YBT-UQ was performed using special tools designed for the test, including a plane surface on which to place the supporting hand, and bars pointing at three directions in order to determine the reach in each direction. A movable cursor was placed on each bar to be slid by the free hand in order for the extension of reach in that particular direction to be measured (Zandi et al., 2016). To perform this test, the participant was asked to position the palm of his supporting hand so that the thumb and index finger were touching and the elbow was extended outward. In this stance, the toes had to be positioned as shown in Figure 2, and the spinal cord and lower limbs had to remain aligned. The position of the thumb was marked by a line and the feet were shoulder width apart. In this position, the participant was asked to reach as far as he could in the medial, lower-side and upper-side directions using his free hand while maintaining the position of his trunk, supporting hand and lower limbs (Figure 2).

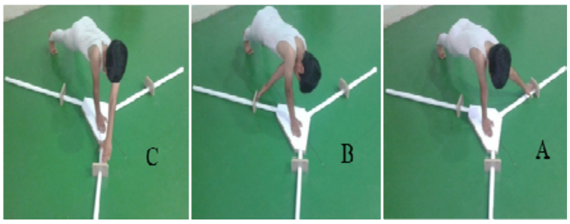

Figure 2. Reach in the medial (A), lower-side (B) and upper-side (C) directions.

The action of reaching was performed consecutively in all three directions without rest and without the free hand touching the ground, and after each round (i.e. a reach in all three directions), the participant was allowed to place his free hand on the ground and rest, and this process was to be repeated three times (Gorman et al., 2012; Zandi et al., 2016). The round had to be repeated if the participant removed his stationary hand from the plane surface or touched or leaned on the ground or cursor with his free hand and also if he was unable to return to the starting position with his free hand and lost his balance, or if one of his feet was lifted from the ground (Gorman et al., 2012). The participants were allowed to practice the move twice before performing the test.

To compare the participants, the extension of their reach was normalized using the length of their upper limbs (the distance between the seventh cervical vertebrae spinous process and the end of the longest finger at a 90-degree angle between the shoulder and the extended elbow, wrist and fingers). The highest extension of reach in each direction was eventually recorded (to the nearest 0.5 cm) and the overall combined score was calculated using the following equation (Cook, 2010; Zandi et al., 2016).

Combined score = (Medial reach + lower-side reach + upper-side reach)/(length of the upper limbs×3)

To compare the reach scores in the different directions, the scores were taken separately with the length of the upper limbs and the normalized reach score in each direction.

The collected data, including participants' details and the study variables, were analyzed in SPSS-20 using descriptive and inferential statistics. The Shapiro-Wilk test confirmed the normal distribution of the variables. The paired t-test was used to compare the results obtained about participants' dominant and non-dominant limbs, and the independent t-test was used to compare the results between the healthy group and the group with rounded shoulders ($P\leq0.05$). The examiner first performed a pilot run of the tests on four subjects and then proceeded to performing the tests on the study participants once they had resolved all the problems.

RESULTS

Table 1 presents participants' demographic details by group. The independent t-test was used to determine the homogeneity of the groups in terms of the noted indices; however, no significant differences were observed between them and the groups were found to be matching ($P\geq0.05$). The independent t-test was also used to compare participants in terms of their rounded-shoulder abnormality (Table 1).

Table 2 presents the results of the YBT-UQ for both the dominant and non-dominant limbs by group. According to the results, the highest reach was achieved in both groups in the medial, lower-side and upper-side directions and these values were slightly higher in the non-dominant compared to the dominant limbs.

The paired t-test was used to compare participants' dominant and non-dominant arms and the results showed no significant differences between the dominant and non-dominant arms in either group ($P\geq0.05$); however, the independent t-test showed a significant difference between the two groups in the YBT-UQ results ($P\leq0.05$). The results are presented in Tables 3 and 4.

Table 1
Participants' demographic details (mean ± SD).

Variable	Healthy group	Rounded-shoulder group	P Value
Age (year)	10/47±1/12	10/27±0/96	0/605
Height (cm)	137/60± 6/76	141/66± 9/15	0/178
Weight (kg)	41/53± 4/20	43/86± 6/05	0/231
BMI (kg/m^2)	21/90± 0/87	21/76± 1/01	0/700
Round-shoulder (degree)	75/33± 2/16	57/93± 1/79	0/001*

Table 2
The YBT-UQ results for upper limb length in percentage (mean ± SD).

	Healthy group		Rounded-shoulder group	
Direction	dominant arms	non-dominant arms	dominant arms	non-dominant arms
Medial	94/73±2/40	95/27±2/57	92/13±3/42	92/67±2/49
lower-side	85/07± 2/52	85/73± 3/73	82/80± 3/36	83/13± 3/09
upper-side	71/60± 3/29	72/13± 3/11	68/53± 4/05	69/07± 3/63
Combined	83/80± 2/52	84/37± 2/49	81/15± 3/54	81/62± 2/32

Table 3
A comparison of the balance scores obtained for the dominant and non-dominant arms using the paired t-test (mean ± SD).

	Direction	t	df	P Value
Healthy group	Medial	-1/331	14	0/205
	lower-side	-0/665	14	0/517
	upper-side	-0/816	14	0/428
	Combined	-1/136	14	0/275
Rounded-shoulder group	Medial	-0/900	14	0/383
	lower-side	-0/365	14	0/721
	upper-side	-0/913	14	0/377
	Combined	-0/847	14	0/411

Table 4
Comparison of the balance scores obtained for the healthy and rounded-shoulder groups using the independent t-test (mean ± SD.

	Direction	t	df	P Value
dominant arms	Medial	2/409	28	0/023*
	lower-side	2/089	28	0/046*
	upper-side	2/276	28	0/031*
	Combined	2/354	28	0/026*
non-dominant arms	Medial	2/806	28	0/009*
	lower-side	2/078	28	0/047*
	upper-side	2/482	28	0/019*
	Combined	3/129	28	0/004*

DISCUSSION

The present study was conducted to assess and compare the functional stability of the upper limbs between a healthy and a rounded-shoulder group of gymnasts using the YBT-UQ. The results showed that the highest reach scores obtained were in the medial direction in both groups, followed by the lower-side and the upper-side directions. These results are somewhat consistent with the results of previous studies; for instance, Westrick et al. (2012) reported the highest reach scores in the YBT-UQ in the medial, lower-side and upper-side directions (Westrick et al., 2012). In another study on the functional stability of the upper limbs in healthy volleyball players and those with anterior instability of the shoulder joint, Zandi et al. (2015) also reported the highest reach score in the medial direction in both groups, followed by the lower-side and upper-side directions (Zandi et al., 2016). Gorman et al. (2012) and Amasay et al. (2016) obtained similar findings (Amasay et al., 2016; Gorman et al., 2012). These findings can potentially be attributed to the positioning of the free hand in relation to the directions of reach when performing the test, since getting the highest reach score in the medial direction seems obvious, considering the position of the free hand in relation to the three directions and also given the lower-side and upper-side directions being in front of the free hand (Zandi et al., 2016). When reaching in the lower-side direction, the participants are somewhat able to boost their reach scores by rotating their body; in the upper-side direction, however, where the free hand is at a greater distance of the reach direction, the participant is unable to compensate for this distance using his body rotation and therefore gets lower reach scores in the upper-side direction compared to other directions (Zandi et al., 2016).

The findings also revealed higher reach scores for the non-dominant limbs compared to the dominant limbs in all three directions; however, Table 3 shows no significant differences between the reach scores obtained for the dominant and non-dominant limbs in the healthy and rounded-shoulder groups ($P \geq 0.05$). These results are consistent with the majority of previous findings on the functional stability of the dominant and non-dominant upper limbs (Butler et al., 2014; Gorman et al., 2012; Lite et al., 2013; Westrick et al., 2012). For instance, Westrick et al. (2012)

reported no significant differences between participants' YBT-UQ scores in the dominant and non-dominant limbs (Westrick et al., 2012). Gorman et al. (2012) also obtained similar results(Gorman et al., 2012). Nonetheless, some studies have reported disparate findings; for instance, Wilson et al. (2013) compared YBT-UQ results in water polo players and reported a significant difference between the reach scores obtained in the upper-side direction for the dominant and non-dominant limbs and attributed this difference to the stabilizing function of the non-dominant limbs in water polo players and argued that, since the supporting hand has a very similar role in the upper-side direction to the role of the non-dominant hand in stabilizing the body when passing and shooting in water polo, participants' are significantly more competent when performing the YBT-UQ using their non-dominant hand compared to the dominant hand in the upper-side direction, hence the significant difference between the reach scores of the limbs in the noted direction(Wilson et al., 2013). This stabilizing role is not observed in gymnastics movements and the dominant and non-dominant hands appear to be equally involved in gymnastics movements, which could be one of the reasons for the lack of a significant difference between the scores obtained for the different limbs in the present study. In another study, Zandi et al. (2015) also found a significant difference in the YBT-UQ scores between the dominant and non-dominant limbs (Zandi et al., 2016). The difference in the results between this and the present study can be explained by noting the difference in participants' characteristics; in Zandi’s study, the participants had anterior instability of the shoulder joint in one of their limbs and it is only normal that this asymmetry in the characteristics of the limbs should cause a difference in the functional stability of the shoulders and thereby a difference between the reach scores obtained in the YBT-UQ (Zandi et al., 2016). In the present study, however, participants’ dominant and non-dominant limbs were symmetrical. An inefficient sensory-motor system and the proprioception of the pectoral girdle are also likely to occur as a result of shoulder instability and can be considered another reason for the functional instability observed in the shoulders and the reduced reach scores obtained in the YBT-UQ in Zandi’s study (Lephart et al., 1994; Myers et al., 2006). Overall, in line with the results of most studies discussed (Butler et al., 2014; Gorman et al., 2012; Lite et al., 2013; Westrick et al., 2012), the present findings also suggest that, despite the little evidence on the greater tendency to use the non-dominant limbs for creating functional stability, the difference observed is negligible and cannot cause a significant difference in the results of the YBT-UQ, in which the reach mainly takes place in the mid-range of the shoulder movement.

As for the effect of rounded shoulders on upper limb movement in closed kinetic chains, the present study showed that this abnormality can significantly affect the YBT-UQ results and reduce the extension of the reach in all three directions. Studies have reported that rounded shoulders associated with static scapular position in the horizontal plane can restrict normal upward rotation, posterior sliding and the outward rotation of the scapula by changing the length and tension of the muscles surrounding the shoulder joint when moving the arms (Borstad, 2006) and ultimately expose the individual to injuries in this part of the body by reducing the functional stability of the upper limbs. As discussed earlier, this issue is significantly more important in gymnasts, because, unlike other fields of sports, the upper limbs are used extensively for weight-bearing and closed chain movements in gymnastics, making this part of the body the second most-exposed to injuries(Webb and Rettig, 2008). Since no studies have yet examined the effect of musculoskeletal abnormalities on YBT-UQ results and given the present findings, these factors appear to also adversely affect the functional stability of the upper limbs and reduce the extension of the reach in the YBT-UQ just like in other physical injuries of the pectoral girdle. These results are somewhat consistent with previous reports; for instance, Hazar et al. (2014) reported that the reach scores obtained in the YBT-UQ are significantly higher in healthy people compared to those with shoulder impingement syndrome (Hazar et al., 2014). Zandi et al. studied the functional stability of the upper limbs in healthy volleyball players and those with anterior instability of the shoulder joint and reported significant differences in the reach scores obtained in all three directions between the two groups and also in their combined YBT-UQ scores (Zandi et al., 2016); the researchers argued that the anterior instability of the shoulder joint can reduce the integrity and increase the length of the joint capsule tissues and the rotator cuff muscle tendons and also cause dysfunction in the joint stabilizing elements and ultimately lead to mechanical instability in the shoulder joint by causing dysfunction in the arm rotation and tear in the rotator cuff muscle tendons (Myers et al., 2004). They also reported that, due to shoulder joint instability, the impairments caused in the function of the mechanical receptors of the joint inhibit the stabilizing neuromuscular reactions of the joint and lead to frequent injuries and progressive deterioration of the joint by disrupting the proprioception system (Lephart et al., 1994; Myers et al., 2004; Myers et al., 2006). Given the present findings, musculoskeletal abnormalities of the shoulder joint appear to be associated with a reduced proprioceptive accuracy and changes in the direction of the transfer of force(Ha et al., 2011). These problems can adversely affect motor performance and efficacy and expose the individual to physical injuries by changing their motor strategies. Studies have reported that any change in the alignment of the scapular bone can lead to disruption in the feedback from the muscle spindle receptors and also change the motor patterns that should act according to precise feedback from the proprioceptive receptors by causing dysfunction in the joint afferents. In these conditions, the muscle patterns are unable to harmoniously control muscle contractions and the joint thus develops functional instability (Ha et al., 2011). Given the changes that can occur in the pectoral girdle due to rounded shoulders, this deformity should be further emphasized, especially among gymnasts. Upper limb abnormalities, especially rounded shoulders, should be studied among gymnasts in order to prevent future injuries, and sports planners and trainers should seek to give corrective exercises to gymnasts for improving the abnormalities identified in this part of the body.

CONCLUSION

Rounded shoulders can significantly affect gymnasts' YBT-UQ scores and expose them to future injuries by reducing the functional stability of their upper limbs in closed kinetic chains. Considering that rounded shoulders are known as one of the most common musculoskeletal abnormalities that affect normal posture in the upper limbs (Peterson et al., 1997), and since the upper limbs are used extensively in gymnastics for performing closed chain movements, this condition should be more addressed in gymnasts and efforts should be made to correct it in order to help reduce upper limb injuries in this group.

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Corresponding author:
Ramin Beyranvand
Pajohesh Square,
Shahid Bahonar University of Kerman,
Kerman, Iran
e-mail: ramin_beyranvand@yahoo.com;
ramin.beyranvand.68@gmail.com