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Research Article

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Sport Specific Adaptation in Rotation Range of Motion in the Elite Golfer's Shoulder

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Abstract

Objective: Shoulder rotation in golfers is thought to determine the length of the back swing, which in turn influences club-head speed and ball drive distance. In athletes a decrease in shoulder internal rotation in the dominant shoulder when compared with the opposite side has been noted and is associated with increased risk of shoulder injury. It was hypothesised that golfers would bilaterally have more rotation range of motion compared to controls and that golfers would exhibit a unique pattern of rotation range of motion between their dominant and non-dominant/lead shoulders. The aim of the study was to compare rotation range of shoulder motion within and between male elite golfers and male non-athlete controls.

Method: Forty five male golfers on European Challenge Tour and thirty six non-athlete control volunteers meet the inclusion criteria for the study. An inclinometer was used to determine the passive shoulder rotation range with the participant in supine.

Results: Golfers' shoulders have significantly more rotation range than controls in total arc of rotation (dominant side Δ15.30°, non-dominant/lead side Δ21.98°, p=0.01) and in external rotation (dominant side Δ7.94°, non-dominant/lead side Δ11.04°, p=0.01). In golfers there are no differences in side to side comparison in: shoulder total arc of rotation (p=0.48), internal rotation (p=0.52), or in external rotation (p=0.54).

Conclusion: Golfers' shoulders have significantly more range than controls in total arc of rotation and in external rotation but the professional golfers in this study were not found to have a unique pattern of shoulder rotations between sides. This study endorses screening of shoulder rotation range in healthy elite professional golfers using side to side comparison. If unique loss of range is noted between sides in the context of a loss of total rotation range it may have consequences for the efficacy of the swing technique and potentially imply risk to injury

Keywords

Shoulder rotation; Golf; Screening; Rehabilitation

Introduction

The shoulder may biomechanically adapt to the demands of sport. Furthermore what influences shoulder biomechanical characteristics in athletes may be pertinent to the specific sport [1]. Shoulder injury in sport can result in ending sport careers. If screening and exercise intervention is going to be used to prevent athletes from injury then it is important to determine whether altered motion patterns observed in athletes are detrimental or beneficial. Increased or decreased mobility is often noted in the sporting population. A resultant decrease in shoulder internal rotation of 20° or more on the dominant side when compared with the opposite side has been noted in athletes [2-8]. This loss of internal rotation is referred to as GIRD (glenohumeral internal rotation deficit). The presence of frank GIRD must correspond to a loss of range in the total motion of shoulder rotation [9]. A 'total arc shift phenomenon' can be present without GIRD [10]. Apart from literature reporting rotation range in baseball players [2,4,5,7,8,11-13], swimmers [14,15], handball [16-18], and tennis players [19,20] there is a lack of reported norms of clinical measurements of passive shoulder internal and external rotation range of motion in skeletally mature male elite athletes. Since the demands on the shoulder vary in differing sporting disciplines research into sport specific norms of shoulder rotation range of motion in elite male golfers is warranted.

For the reason that the incidence of shoulder injuries in golf is reported to be 17% [21,22] it was decided to investigate shoulder rotation range in this population. The non-dominant/lead shoulder is three times more likely to be injured than the dominant shoulder [21]. In professional golfers the swing is complex and repetitive, and elite golfers swing an average of 2000 times per week [22]. The anatomical characteristics of the golfers' shoulder will dictate the dynamics of the swing [23,24]. If the demands on the shoulder during the golf swing exceed the physiological limits of the shoulder this will result in injury [25]. Kinetics and kinematics using 3D analysis techniques of the swing are plentiful [26,26-30]. With data derived from 3D swing analysis active dominant shoulder rotation at top of back swing ranged from 78°-102° and in follow through active external rotation in the non-dominant/lead shoulder ranged between 59°-80° [26,28]. The range was reported to depend on age and level of proficiency of the player [26,28]. Range of shoulder rotation in the golfers' shoulder is thought to determine the length of the back swing [26], which in turn influences club-head speed and ball drive distance [23]. Golfers may have increased shoulder flexibility to maximise their ability to rotate the shoulders relative to the hips to generate maximum club speed [22]. Greater shoulder external rotation has been correlated to lower handicaps [31,32]. Previous literature reporting shoulder rotation range of motion in golf was collected in a golfing population with handicaps less than 5 [32,33] and with a wide age range (Table 1). No unique passive shoulder rotation pattern was reported between sides. Since older golfers are reported to have as much as 38° less shoulder external rotation than younger players [30] it is possible that in the study the wide age range of the participants confounded results. From the literature it can be deduced that passive shoulder rotation range of motion plays a role in determining the range the golfer can achieve during the swing. To date no literature has investigated this variable in the professional elite male golfers. This is important if screening of golfers is to be based on scientifically rigorous data [23]. Without this knowledge, it is not possible to know confidently what degree of loss or gain in shoulder rotation is related to sport-specific adaptation and what could contribute to a pathomechanical process. It was hypothesised that golfers would bilaterally have more rotation range of motion compared to controls and that golfers would exhibit a unique pattern of rotation range of motion between their dominant

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Table 1: Passive shoulder rotation range of motion in golfers reported in the literature. Abbreviations: ER=External Rotation; IR=Internal Rotation; TAR=Total Arc Of Rotation; STD=Standard Deviation; NR=Not Reported; Dom=Dominant Side.

Author	**ER degrees Mean (STD)**	**IR Degrees Mean(STD)**	**TAR Degrees Mean (STD)**	**Proficiency Age range years**	**Method to determine end of range**
Brumitt et al., 2008 [33]	Dom 91.04 (7.85) Lead 90.32 (6.54)	50.11 (9.34) 51.76 (10.40)	141.15(10.87) 142.08(13.67)	<5 24-57	Capsular feel
Sell et al., 2007 [32]	Dom 106.30 (11.5) Lead 99.30 (12.2)	Dom 59.7 (13.7) Lead 65.4 (12.8)	NR	Scratch 32-58	
Current study	Dom 89.68 (11.65) Lead 90.29 (9.05)	Dom 58.46 (11.72) Lead 63.19 (12.12)	Dom 149.03(11.55) Lead 154.11(15.87)	Professionals on European Challenge tour 23-33	Motion of coracoid

and non-dominant/lead shoulders. The aim of the study was to compare rotation range of shoulder motion within and between male elite golfers and male non-athlete controls.

Method

Power analysis

Based on pilot data it was calculated that to perform an independent t-test a sample size of at least 32 per group is required to be able to detect a difference with 81.54° means score, with an 80% power and a 5% (0.05) significance level. This is based on a STD of 6.96 for the measure of shoulder rotation. For a paired t-test a sample size of 22 per group is required to be able to detect an absolute difference of 6.9° in the variable total rotation arc and shoulder rotations between groups with a 80% power at a 5% (0.05) significance level.

Participants

Forty five of 53 male golfer volunteers met the inclusion criteria for the study. Thirty six of 46 non-athlete control volunteers met the inclusion criteria for inclusion in the study. All golfers were professionals currently playing on the European Challenge tour and evaluated during the 48 hours prior to start of tournament. Controls were recruited via letters of invitation to staff and students of the host university. A total of 46 volunteers were recruited, however, 10 of these volunteers were excluded from the study as they were either not within the age matched range, had previously played golf, were amateur golfers, or played sports involving the upper limbs on a regular basis. Furthermore, all participants included in the study had to be of full musculoskeletal development, and have asymptomatic shoulders. Participants were excluded from the study if they had: cervical, shoulder, or elbow pain within six months before testing. Participants were also excluded from the study if they had a past history of: previous shoulder girdle or spinal fractures; previous shoulder surgery; previous dislocation of the upper limb; scoliosis; or a rheumatologic condition.

The XXXXXX Ethics Panel approved the study protocol. All participants were provided with a detailed information sheet, comprising details of the study and any associated risks. Participants gave written informed consent to testing and anonymised use of the data collected.

Data analysis

Statistical Package for Student Statistics for Windows version 20.0 (SPSSinc., Chicago,IL), was used for statistical analysis. Shoulders included in analysis were sorted according to dominant and non-dominant (lead shoulder in the golfer) sides. The mean of three measures was calculated. Outliers were removed using a previously established method [34]. Normality of distributions was ensured with Shapiro Wilk and Kolmogorov-Smirnov tests. Descriptive analysis was run and paired t-tests used for within group analysis and independent t-tests used for between group analyses (significance level set at 0.05).

Instrumentation

A 360° inclinometer with digital protractor and angle finder gauge (Universal Supplies Limited), was used to determine the degree of arm abduction during data collection and to measure internal and external rotation ranges of glenohumeral joint motion (Figure 1). The instrument was used to provide a real-time digital reading of angles in relation to the vertical plane. The manufacturer reports accuracy to 0.1°. The inclinometer was adapted with a 30cm plastic ruler (Figure 1) attached along the length of the inclinometer, and the ruler was used to align the inclinometer between the olecranon process and the ulnar styloid. In a pilot study, reliability of the inclinometer to quantify shoulder rotation was established. Excellent intra-rater inter-session reliability (24 hours apart) was established on 52 shoulders (ICC3.1=0.91. 95% CI=0.85-0.96).

Procedure

Measurement of shoulder rotations was undertaken with the participant in the supine position on an examination plinth to control for accessory scapulothoracic motion and represent more valid measures of GHJ motion [35]. A small pillow was placed under the participant's head for comfort, taking care to ensure that the pillow was not under the shoulder girdle. The arm on the side being tested was abducted to 90° and positioned with the humeral shaft aligned to the horizontal. The upper arm was supported on the plinth with a small towel to ensure maintenance of the neutral horizontal position of the humerus. The elbow was flexed to 90°. To determine this position, an inclinometer and goniometry were used. Participants were instructed to relax while the examiner passively moved and measured the joint range of rotation. For measures of external shoulder rotation, the examiner moved the shoulder passively to end of range, while noting that no compensatory movement occurred at the shoulder girdle. If resistance was felt or the shoulder girdle moved this was considered the end point of range. For internal range of shoulder rotation, the examiner palpated the anterior aspect of the acromion with one hand and moved the shoulder into passive internal rotation. End of range was considered to be the last point in range before the acromion started to move. Interrater reliability of the method has been determined in previous research [35]. Between three repeated measures of both internal and external rotation angles the arm was repositioned in the neutral position.

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Results

Data from 45 male golfers (28 STD 5 years) and from 36 male controls (24 STD 7 years) were included in the study. Descriptive statistics for both groups are reported in Table 2.

Within group analysis

Results from paired t-tests showed that there were no differences in side to side comparison in golfers in: shoulder total arc of rotation (dominant side 149.03° STD 11.55° and non-dominant/lead side 154.11° STD 15.87°, p=0.48), internal rotation(dominant side 58.47° STD 11.72° and non-dominant/lead side 63.19° STD 12.12°, p=0.52), or in external rotation(dominant side 89.68° STD 11.65° and non-dominant/lead side 90.29° STD 9.05°, p=0.54). Results from paired t-tests showed that in male controls there were no significant differences in side to side comparison in: shoulder total arc of rotation (dominant side 133.73° STD 13.76° and non-dominant side 132.13° STD 13.49°, p=0.74), internal rotation (dominant side 52.25° STD 23.81° non dominant side 55.25° STD 12.04°, p=0.91), or in external rotation (dominant side 81.18° STD 11.13° and non-dominant side 79.25° STD 10.91°, p=0.45).

Between group analysis

Significant difference was found in shoulder total arc of rotation with a greater total arc of rotation in golfers on both sides (dominant side Δ15.30°, CI95%=9.70-20.89, SEM=1.72°-2.29°, non-dominant/lead side Δ21.98°, CI95% =15.36-28.50, SEM=2.36°-2.48°)(p=0.01). Internal rotation in the golfers non-dominant/lead shoulder was greater by 8.50° (CI95%=2.56-13.32, SEM=1.80°-2.00°) than in the non-dominant shoulder of controls (p=0.01). Golfers had greater internal rotation on the dominant side compared to controls by 2.52° (CI95%=1.68-14.10, SEM=1.74°- 3.86°) but this difference did not achieve significance (p=0.55). Golfers had significantly more shoulder external rotation bilaterally than controls (dominant side Δ7.94°, CI95%=3.40-13.50, SEM=1.74°-1.85°, non-dominant/lead side Δ11.04°, CI95%= 6.62-15.45, SEM=1.35°-1.81°) (p=0.01).

Discussion

Between groups, golfers' shoulders had significantly more range of motion than controls in total arc of rotation and external rotation. Golfers also had more internal rotation than controls, this was significant in the non-dominant/lead shoulder but not in the dominant shoulder. Within both groups no statistical differences in side to side comparison in shoulder rotations were noted. Physical attributes of the golfers shoulder will influence good swing mechanics [24]. Based on active ranges of shoulder rotation during the golf swing, analysed in kinematic studies [26,28], it was anticipated that golfers' shoulders would have adapted to exhibit more passive external rotation in the dominant shoulder and more passive internal rotation in the non-dominant/lead shoulder. The results of the present study do not support this. The professional golfers in this study were not found to have a unique pattern of shoulder rotations between sides. Results are in keeping with those of Brummit [33] and Sell et al. [32] in players with a lower handicap and a wider age range than golfers included in this study (Table 1). Methods used to determine the end of rotation range differs between studies so care needs to be taken when comparing the definite measurements. The present study used the movement of the coracoid as an indication of end of range. Whereas previous studies used over pressure and capsular end feel to determine the limit of range. As a result definite measurements would be expected to be less in the current study. Based on this probability it could be concluded that the professional elite golfers in the present study exhibited greater range of shoulder rotations than those reported in the previous studies, but this appraisal is conjecture.

Changes in rotation ranges of motion have been associated with injury risk in other sport disciplines [1,2,18,19,36-44]. The current study endorses screening of shoulder rotation range in healthy elite professional golfers using side to side comparison. If unique loss of range is noted between sides in the context of a loss of total rotation range it may have consequences for the efficacy of the swing technique as well as imply risk to injury.

When interpreting the results of this study the following limitations need bearing in mind: professional elite golfers were chosen for this study because they are likely to have optimized their physical characteristics for superior golf performance. Therefore, the relevance of result of this study cannot be generalised to the

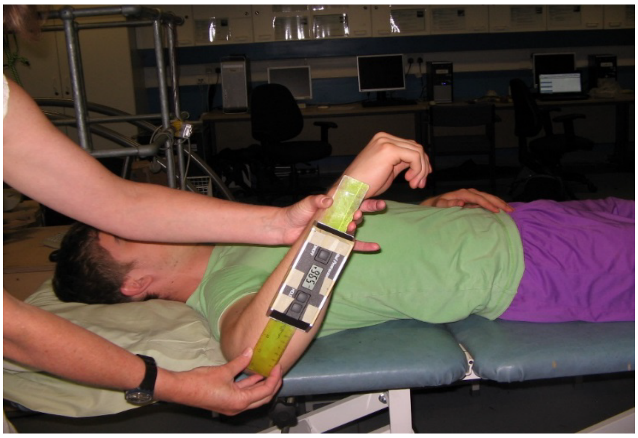

Figure 1: The inclinometer was adapted with a 30cm plastic ruler attached along the length of the inclinometer, and the ruler was used to align the inclinometer between the olecranon process and the ulnar styloid. The angle was measured in the vertical plane.

Table 2: Descriptive statistics and results of independent t-tests for shoulder rotation range.

	Golfers (28 ±5 years) (Ave BMI=23) Mean (STD) degrees	Controls (24 ±7 years) (Ave BMI=23.8) Mean (STD) degrees	Mean difference degrees	Independent t- test p value
Dominant TAR	149.03 (11.55)	133.73 (13.76)	15.30	0.01
Non-dominant/lead TAR	154.11 (15.87)	132.13 (13.49)	21.98	0.01
Dominant IR	58.46 (11.72)	52.25 (23.81)	2.52	0.55
Non- dominant/lead IR	63.19 (12.12)	55.25 (12.04)	8.50	0.01
Dominant ER	89.68 (11.65)	81.18 (11.13)	7.94	0.01
Non- dominant/lead ER	90.29 (9.05)	79.25 (10.91)	11.04	0.01

Abbreviations: STD=Standard Deviation; TAR=Total Arc Of Rotation; IR= Internal Rotation; ER=External Rotation.

non-elite and amateur golfer. This study endorses screening of shoulder rotation range in golfers using side to side comparison. And although increased shoulder rotation ranges are linked to golf proficiency with previous research advocating the benefits of stretching of the shoulder for golfers [24] this is not established in the professional elite golfers in the current study. Research into the benefits of stretching the golfers' shoulder was done in golfers with a mean age of 47 (STD 11.4) years with varied golf experience levels [24]. In this population the outcomes may be attributed to the fact that golfers lose shoulder range with increased age [45] and the parameters for improvement were greater due to varied experience levels. In addition, rotation during the back swing does not only occur at the shoulder, although awareness of the golfer's anatomical shoulder make up is useful, it is only one component of the kinetic link in the summation of forces between the hip, and trunk, and upper limbs. Future research screening the physical characteristics of golfers' shoulders with a long-term prospective follow up would be beneficial to determine the link between these characteristics and potential risks to injury.

Conclusion

Scientific evidence of what physical characteristics are sport specific adaptations will give clinicians parameters for training programs and prevention of injury. Golfers' shoulders have significantly more range of motion than controls in total arc of rotation and external rotation. The professional golfers in this study were not found to have a unique pattern of shoulder rotations between sides. If unique loss of range is noted between sides in the context of a loss of total rotation range it may have consequences for the efficacy of the swing technique and potentially imply risk to injury in golfers.

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