

REFERENCE VALUES FOR GLENOHUMERAL JOINT ROTATIONAL RANGE OF MOTION IN ELITE TENNIS PLAYERS

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ABSTRACT

Background: Due to the repetitive overhead activity involved in playing tennis and the physical demands of the game, shoulder joint injury is common. There is limited research available describing sport specific risk factors for injury in tennis, however, changes in shoulder rotational range of motion (ROM) have been associated with injury in other overhead 'throwing' type sports.

Purpose: This study had two purposes: i) to identify reference values for passive glenohumeral joint rotational ROM in elite tennis players, and, ii) to investigate differences in ROM between various age groups of players.

Study design: Cross-sectional analysis.

Methods: Data was collected at national performance camps held at a National Tennis Centre between September 2012 and July 2015. One hundred and eighty-four tennis players aged between 11 and 24 years took part. All had a top eight national ranking within their respective age group. Participants were divided into three age groups; under 14 years, 14-15 years, and 16 years and over. The main outcome measures were dominant and non-dominant internal and external rotation as well as total glenohumeral joint passive ROM.

Results: Reduced internal, and greater external rotation passive ROM were identified on the dominant side ($p < 0.05$), however, no side-to-side differences in total rotation ROM were found ($p > 0.05$). A glenohumeral joint internal rotation deficit (GIRD) was prevalent on the dominant side, which increased in magnitude with rising player age. Differences in dominant side internal and external rotation ROM were identified between age groups with the 14-15-year olds having less internal and greater external rotation than the under 14-year olds and the over 16-year old athletes ($p < 0.05$). The total range of motion values were not found to differ between age groups ($p > 0.05$).

Conclusions: This study provides reference values for glenohumeral joint rotational ROM in elite tennis players and demonstrates age specific differences. Future studies should investigate links between changes in ROM and injury risk.

Level of evidence: 3

Keywords: Glenohumeral joint, overhead athlete, range of motion, tennis

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INTRODUCTION

Participation in tennis at elite levels comes with a risk of musculoskeletal injury,¹ due to both the high volume of play and the strenuous physical demands of the sport. Injury rates range between 0.05 to 2.9 injuries per player per year² with a greater frequency of injury with increased court time.³ Elite junior players (aged 13-19 years) have been found to participate in an average of 2.3 hours of tennis per day over six days per week.⁴ Despite this, no randomized controlled trials have investigated injury prevention in tennis² and there is a paucity of sport specific studies linking risk factors and injury rates.

Repeated high force demands placed on the shoulder during tennis have often been associated with gradual onset type injuries.⁵ A change in glenohumeral joint rotation range of motion (ROM) is a common musculoskeletal adaptation observed in overhead type athletes that may be associated with injury risk.⁶ In recent tennis literature reduced dominant side internal rotation ROM, larger external rotation ROM and smaller total rotation ROM, (TROM = sum of available internal and external rotation) have been reported.⁷ Greater losses of both internal ROM and TROM with increasing age and tennis exposure have also been suggested,⁸ however, it is not clear at which age these changes develop.

A glenohumeral joint internal rotation deficit (GIRD) is thought to develop from a combination of posterior capsular thickening, rotator cuff stiffness and humeral retroversion, which are thought to be adaptations to the stresses occurring during the acceleration and deceleration phases of throwing.⁹ Increased humeral retroversion is thought to be performance enhancing;¹⁰ as the bony adaptations enable an increased external rotation position during the throw.¹¹ This additional ROM theoretically allows for a longer acceleration phase enabling greater upper limb rotational speeds to be achieved.¹⁰

Two types of GIRD have been described by Manske *et al.*¹⁵; i) an anatomical type with dominant side internal rotation loss greater than 18-20° but symmetrical TROM bilaterally, and, ii) a pathological GIRD where the internal rotation loss is combined with a greater than 5° loss of dominant side TROM. Ellenbecker *et al.*⁷ reported a 10° loss of internal rotation

on the dominant side in 117 tennis players, however, Kibler and Chandler¹² found a mean 18° loss in their longitudinal study involving 51 tennis players.

There is also debate as to whether the presence of a GIRD is predictive of injury; it could be an adaptation to the overhead demands of the sport and improve performance or alternatively increase the injury risk.⁴ Reducing the arc of motion is thought to fatigue the posterior rotator cuff leading to greater force through the posterior capsule¹³ increasing the likelihood of injury. However, GIRD has not been identified as a specific injury predictor.¹¹ Pluim *et al.*² found no evidence that limited glenohumeral joint rotation was related to tennis injury. There are also inconsistencies when describing a clinically significant GIRD. This is supported by Manske *et al.*¹⁵ who stated a GIRD is required to generate sufficient force during serving and does not lead to pathology. In contrast both Kibler & Chandler,¹² and Wilk *et al.*¹⁶ suggest the loss of internal rotation ROM is one of the intrinsic risk factors for overhead injury.

Total glenohumeral rotation ROM is also thought to be a useful indicator of shoulder pathology and a decreased TROM was associated with shoulder injury in baseball players.^{12, 15-17} Wilk *et al.*¹⁶ found a greater than 5° side-to-side difference in TROM which had a two and a half times higher injury risk than those within 5°. The equivalent data is not yet available in tennis. Ellenbecker *et al.*⁷ describe side-to-side TROM as equal in baseball players but reduced in tennis players in their study involving 163 athletes. This emphasises why more tennis data is needed, as overhead sports with different musculoskeletal demands cannot be compared.

Glenohumeral joint external rotation changes and their relation to injury risk have not been widely investigated. The concept of an external rotation difference (ERD) has been discussed by Manske *et al.*¹⁵ A difference between the external rotation of the dominant and non-dominant shoulder of less than 5° has been suggested to contribute to an increased injury risk due to the increased stress on the static glenohumeral stabilizers.¹⁵ This is consequently an area warranting further research in tennis players.

A few studies describe GIRD in tennis.^{5,7,8,14,18} Cools *et al.*¹⁸ investigated age-related shoulder girdle

adaptations in 59 elite junior players and found reduced internal, increased external, and smaller TROM on the dominant side.¹⁸ Despite relatively low participant numbers, the findings were the first to identify age specific differences. However, a clinically relevant correlation between ages was not determined and larger scale research across age groups is warranted.

Elite tennis players often commence high volume training in early childhood, which overlaps the period of rapid skeletal and muscular development.¹⁸ The tennis literature has considerable gaps regarding injury risk factors and preventative measures. The determination of age specific reference values for ROM would be valuable for screening, and are prerequisite in determining whether changes in ROM are linked to injury. This study had two purposes: i) to identify reference values for passive glenohumeral joint rotational ROM in elite tennis players, and, ii) to investigate differences in ROM between various age groups of players.

METHODS

Participants

The glenohumeral joint rotational range of motion (ROM) measurements of 184 elite participants, male ($n = 122$), and female ($n = 62$), aged 11 to 24 years, were collected and analyzed by one physiotherapist at performance camps held at a National Tennis Centre between September 2012 and July 2015. Sixteen participants were left hand dominant, and 168 were right hand dominant and all were deemed fit to play at the time of testing. The national performance camps were divided by gender and into eight different age groups of players; under 12 years, 12 years, 13 years, 14 years, 15 years, 16 years, 17 years and 18 years and over. All participants selected to attend had top eight national rankings in their respective age groups and where a top player was unavailable due to either injury, school or tournament commitments, the next available ranked player was invited.

For this research, three sub-groups were created to contrast glenohumeral joint ROM between ages; these were chosen to correlate with the age groups used in other research¹⁸. The groups were under 14 years ($n = 69$ participants), 14-15 years ($n = 56$), and 16 years and over ($n = 59$).

Ethical approval was obtained from the Cardiff School of Sport & Health Sciences (Sport) Ethics Sub-committee. All participants were sent information forms detailing the data collection process before attending the camps, and depending on their age, participants or their parents provided written informed consent to participate.

Data collection

The participants were tested while supine with the glenohumeral joint positioned in 90° abduction, as suggested by Ellenbecker.¹⁹ A universal goniometer was used to measure glenohumeral joint internal and external rotation ROM. The scapula was fixed and the glenohumeral joint passively rotated into full internal and then external rotation. The scapula was fixed to ensure isolated glenohumeral joint movement, and the coracoid process and spine of the scapula were palpated to determine the onset of scapular movement. Measurements were taken at the end of range at the point immediately before scapular movement was appreciated.

The testing order was randomized with some participants tested on their left side first and others on their right. It was not possible to blind the tester; however, the participants' upper limb dominance was not ascertained until after data collection.

Measurements were taken on the first day of each camp before starting any tennis training or gym exercises. Some participants were screened multiple times if they attended several camps. For these participants, their first screening data was used and subsequent measurements were excluded.

Data that could be used to estimate intra-rater reliability was gathered before the experimental data collection and involved the therapist measuring bilateral glenohumeral joint rotational ROM twice (test and retest) on five participants, with 10 minutes between measurements.

Data analysis

GIRD was calculated as the difference in glenohumeral joint internal rotation ROM between the dominant and non-dominant sides. Total range of motion (TROM) was calculated as the sum of the internal and external rotation ROM for each side. The total range of motion difference (TROMD) was calculated

as the difference between the dominant side TROM value and the non-dominant side TROM value. The external rotation difference (ERD) was calculated as the difference between the dominant side ER value and the non-dominant side ER value. The values for GIRD, TROMD and ERD were divided into 10° increments with the number of participants in each counted.

Statistical analyses

Test-retest reliability was estimated in terms of: i) the intraclass correlation coefficient (ICC (3,1)), ii) the standard error of measurement [95%SEM = $\pm 1.96 \times (s_x \times \sqrt{1 - \text{ICC (3,1)}})$] where: s_x = sample standard deviation, and, iii) the minimal detectable change [95%MDC = $\pm (1.96 \times \sqrt{2} \times \text{SEM})$].²⁰ For all the outcome measures a mixed-design analysis of variance (GLM 5 ANOVA)²¹ was used to analyze the mean scores due to having repeated measures on the side dominance independent variable (non-dominant *vs.* dominant) and independent measures on the age groups (under 14 years *vs.* 14-15-years *vs.* 16 years and over).²¹ In all cases, residuals were saved when running the ANOVAs and were confirmed as being drawn from a population that was normally distributed on the variables of interest (Anderson-Darling test). Homogeneity of variance about means was confirmed in relevant cases using Levene's test. Where main effects were identified for differences between dominant and non-dominant sides, paired *t*-tests were used as *post-hoc* tests for the ANOVAs. Where main effects were identified for differences between age groups, two-sample *t*-tests were used as *post-hoc* tests for the ANOVAs. To avoid inflating familywise error rates, the level of statistical significance (α) was corrected for each of the paired and two-sample *t*-tests using the Dunn-Sidak correction (α'): $\alpha' = 1 - (1 - \alpha)^{1/c}$, where $c = (k(k - 1)/2)$ and k = the number of comparisons being considered. Statistically significant differences, (α) were described at ≤ 0.05 throughout the data analyses; however, the Dunn-Sidak corrections had the effect of reducing $\alpha \leq 0.05$ to an $\alpha' \leq 0.017$ (paired *t*-tests) and 0.008 (two sample *t*-tests). To determine the meaningfulness of the effects identified by the *t*-ratios, Cohen's d^{22} was computed for all comparisons. Statistically significant interactions identified between age groups and side dominance were considered with respect

to contrast plots of the estimated marginal means. Statistical analyses were performed using IBM SPSS Statistics v22. Data are reported as means \pm standard deviations unless otherwise highlighted.

RESULTS

Reliability of the tester

Intraclass correlation coefficients (ICC (3,1)) were calculated for both internal (IR) and external rotation (ER) values. For IR: ICC (3,1) = 0.745, $F_{9,9} = 6.854$, $p = 0.004$, 95%CI = 0.26 - 0.93. For ER: ICC (3,1) = 0.718, $F_{9,9} = 6.10$, $p = 0.006$, 95%CI = 0.21 - 0.92. The standard error of measurement (SEM) and minimal detectable change (MDC) were also calculated for IR: 95%SEM = $\pm 9.0^\circ$ and 95%MDC = $\pm 12.7^\circ$, and for ER: 95%SEM = $\pm 4.5^\circ$ and 95%MDC = $\pm 12.4^\circ$.

Glenohumeral joint internal rotation range of motion (IR ROM) and glenohumeral joint internal rotation difference (GIRD)

Table 1 shows that for IR ROM there was a significant main effect for side dominance means ($F_{1,181} = 59.812$, $p < 0.001$), there were also main effect differences between dominant side and non-dominant side IR ROM means for all the three age groups ($F_{2,181} = 5.017$, $p = 0.008$). Dominant side IR ROM was greatest in the under 14-year-olds and this mean was significantly different to that for the 14-15-year-olds ($p = 0.005$) with a moderate effect size. There were no significant differences for dominant side IR ROM means between the 14-year olds and the over 16-year olds, and between the 14-15 year olds and the over 16 year olds. On the non-dominant side, IR ROM was greatest in the 16 years and over players and this mean was significantly different to that for the 14-15-year olds ($p = 0.001$) with a moderate effect size. However, there were non-significant differences between the non-dominant side means for, the under 14-year olds and 14-15-year olds, and the under 14-year olds and the 16 years and over players ($p > 0.008$). Table 1 also shows that there was a significant main effect for the interaction between side dominance and age group means ($F_{2,181} = 4.846$, $p = 0.009$). However, this interaction main effect was only observed between the mean GIRD for the under 14-year olds and the over 16-year olds ($p = 0.003$), again with a moderate effect size. Interestingly,

Table 1. Summary data and statistical outcomes for glenohumeral joint internal rotation range of motion (ROM) and glenohumeral joint internal rotation deficit (GIRD) for all age groups. These data are presented in degrees of rotation.

Age groups (n)	Mean ± SD internal rotation ROM		Differences between means: D vs ND	Glenohumeral joint internal rotation difference (GIRD) Mean ± SD (95% CI)
	Dominant side (95% CI)	Non-dominant side (95% CI)	T_{df} -ratio (p-value) Effect size (ES = d)	
Under 14 yrs (69)	44 ± 11 ^a	47 ± 11	$T_{68} = 2.76$ (0.007)	3 ± 9 (1 to 6) ^c
	41 to 47	44 to 50	0.33	
14 – 15 yrs (56)	38 ± 10 ^a	45 ± 10 ^b	$T_{55} = 4.84$ (< 0.001)	6 ± 10 (3 to 9)
	35 to 41	42 to 48	0.65	
Over 16 yrs (59)	43 ± 13	52 ± 14 ^b	$T_{58} = 5.37$ (< 0.001)	9 ± 13 (6 to 12) ^c
	40 to 46	49 to 55	0.70	

^a Denotes a difference between age group means: difference between means ± SD = 6 ± 11, 95% CI = 2 to 9, d = 0.55; $T_{123} = 2.84$, P = 0.005
^b Denotes a difference between age group means: difference between means ± SD = 7 ± 12, 95% CI = 3 to 12, d = 0.58; $T_{113} = 3.26$, P = 0.001
^c Denotes a difference between age group means: difference between means ± SD = 6 ± 11, 95% CI = 2 to 10, d = 0.55; $T_{126} = 2.99$, P = 0.003

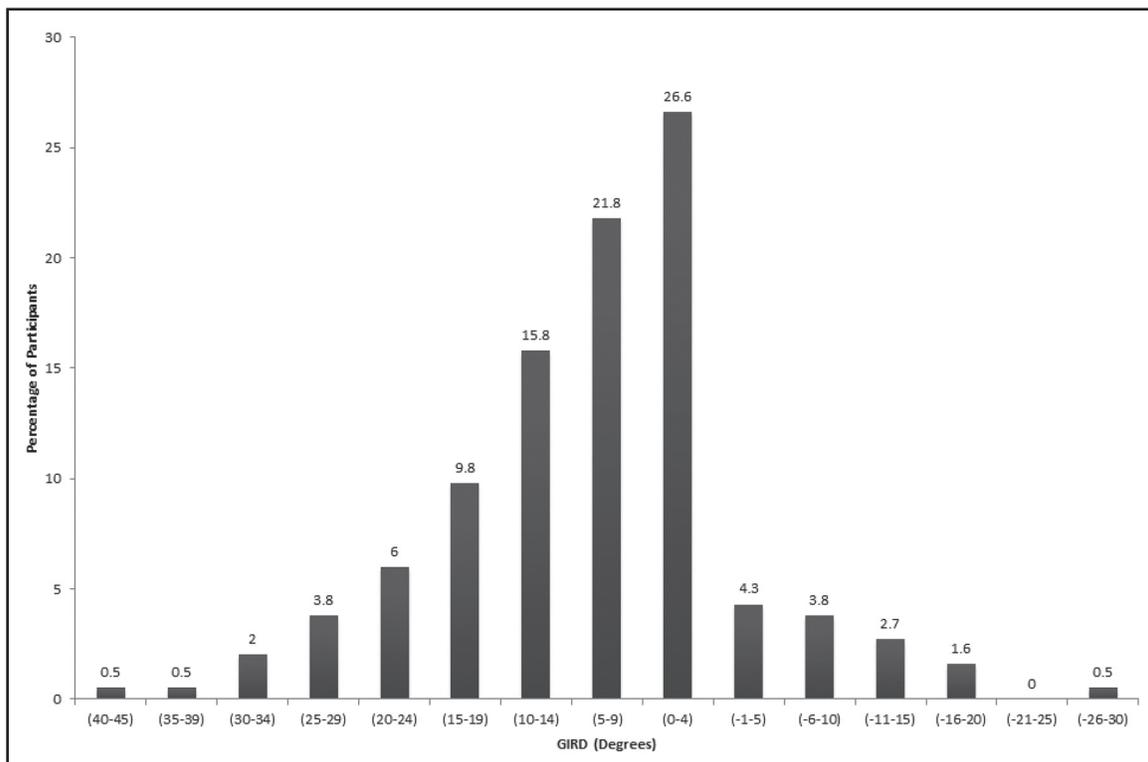


Figure 1. Percentage of participants against the GIRD (Degrees)

mean GIRD increased with participant age, as it was lowest in the under 14-year-olds and greatest in the 16 years and over group.

The percentage of participants with glenohumeral joint internal rotation differences in each 5° increment is shown in Figure 1.

Glenohumeral joint external rotation range of motion (ER ROM) and external rotation difference (ERD)

Outcomes for ER ROM are summarized in Table 2 and show that there was a significant main effect for side dominance means ($F_{1,181} = 56.631$, $p < 0.001$), there were also main effect differences between

Table 2. Summary data and statistical outcomes for glenohumeral joint external rotation range of motion (ROM) and glenohumeral joint external rotation difference (ERD) for all age groups. These data are presented in degrees of rotation.

Age groups (n)	Mean ± SD external rotation ROM		Differences between means: D vs ND	
	Dominant side (95% CI)	Non-dominant side (95% CI)	T_{dr} -ratio (p-value)	Difference in external rotation ROM (ERD)
			Effect size (ES = d)	Mean ± SD (95% CI)
Under 14 yrs (69)	103 ± 8 ^a	100 ± 7	$T_{68} = 3.69 (< 0.001)$	3 ± 6 (1 to 4)
	101 to 105	99 to 102	0.44	
14 – 15 yrs (56)	107 ± 9 ^{a,b}	102 ± 8 ^c	$T_{56} = 4.85 (< 0.001)$	6 ± 9 (3 to 8)
	105 to 110	100 to 104	0.65	
Over 16 yrs (59)	101 ± 10 ^b	97 ± 10 ^c	$T_{58} = 4.16 (< 0.001)$	4 ± 7 (2 to 6)
	98 to 103	94 to 100	0.55	

^a Denotes a difference between age group means: difference between means ± SD = 4 ± 8, 95% CI = 2 to 7, d = 0.54; $T_{123} = 3.01, P = 0.003$
^b Denotes a difference between age group means: difference between means ± SD = 7 ± 9, 95% CI = 3 to 10, d = 0.78; $T_{113} = 3.86, P = < 0.001$
^c Denotes a difference between age group means: difference between means ± SD = 5 ± 9, 95% CI = 1 to 8, d = 0.52; $T_{113} = 2.76, P = 0.007$

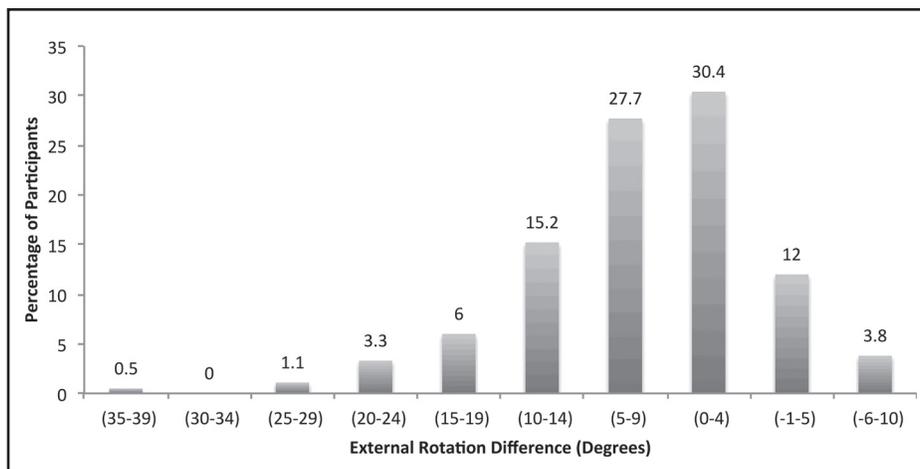


Figure 2. Percentage of participants against the ERD (Degrees)

dominant side and non-dominant side ER ROM means for all the three age groups ($F_{2,181} = 7.119, p = 0.001$). Mean dominant side ER ROM was greatest in the 14-15-year olds, and this was significantly different to the mean value for the under 14-year olds ($p = 0.003$) with a moderate effect size. Dominant side ER ROM was lowest in the 16 years and over age group, and this mean was also significantly lower than that for the 14-15-year old athletes ($p < 0.001$). This difference was characterised with a large effect size. The difference between means for the dominant side ER ROM in the under 14-year olds and the 16 and over athletes was non-significant ($p = 0.162$).

With reference to the non-dominant side ER means, once again, this was greatest in the 14-15-year olds and it was significantly different to that for the 16 years and over athletes ($p = 0.007$) with a moderate effect size. The other age group comparisons on the non-dominant side did not differ significantly. In terms of the interaction between side dominance and age groups main effect, exemplified by the ERD, resulted in a non-significant outcome ($F_{2,181} = 2.237, P = 0.067$).

The percentage of participants in each 5° ERD increment is shown in Figure 2.

Glenohumeral joint total rotation range of motion (TROM) and total range of motion difference (TROMD)

The data summarized in Table 3 shows that there were no statistically significant outcomes for all the main effects interrogated in this analysis of the TROM data. For differences between side dominance means, ($F_{1,181} = 0.044$, $p = 0.835$), for differences between age group means ($F_{2,181} = 2.604$, $p = 0.077$), and for the interaction effect between side

dominance and age groups (TROMD) ($F_{2,181} = 2.451$, $p = 0.089$).

The percentage of participants' TROMD in each 5° increment is shown in Figure 3 with 23% of participants having a difference between 0° and 4°.

DISCUSSION

The aim of the present study was to determine reference values for glenohumeral joint rotational range

Table 3. Summary data and statistical outcomes for glenohumeral joint total range of motion (TROM) and glenohumeral joint total ROM difference (TROMD) for all age groups. These data are presented in degrees of rotation.

Age groups (n)	Mean ± SD total ROM		Differences between means: D vs ND	
	Dominant side (95% CI)	Non-dominant side (95% CI)	T_{df} -ratio (p-value)	Difference in total ROM (TROMD)
			Effect size (ES = d)	Mean ± SD (95% CI)
Under 14 yrs (69)	147 ± 12	147 ± 12	$T_{68} = 0.27$ (0.791)	0 ± 11 (-2 to 3)
	144 to 150	145 to 150	0.03	
14 – 15 yrs (56)	146 ± 12	148 ± 12	$T_{55} = 1.68$ (0.098)	2 ± 10 (-0 to 5)
	143 to 149	145 to 151	0.22	
Over 16 yrs (59)	140 ± 35	138 ± 34	$T_{58} = 1.68$ (0.098)	2 ± 9 (0 to 5)
	131 to 149	129 to 147	0.22	

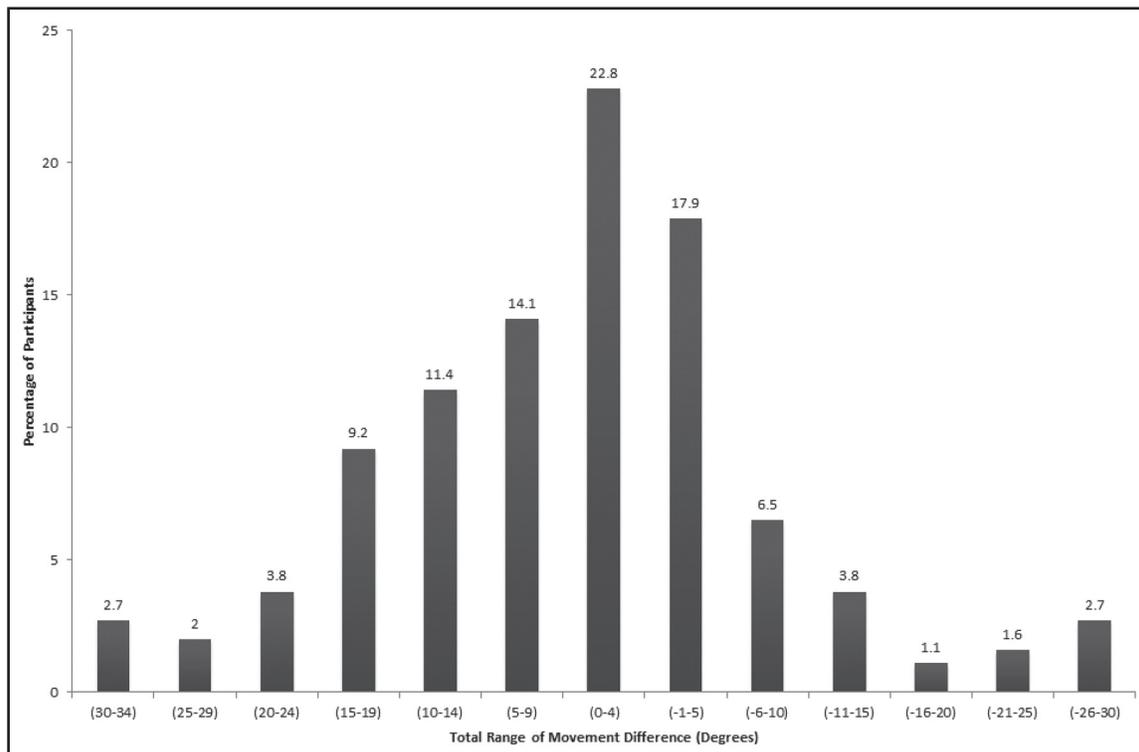


Figure 3. Percentage of participants against the TROMD (Degrees)

of motion (ROM) in elite tennis players, and also to investigate differences in ROM between three age groups, i) under 14 years, ii) 14-15-year olds, and, iii) 16 years and over. These are presented in Tables 1, 2 and 3. As anticipated, there were significant differences in glenohumeral joint ROM on the dominant compared to the non-dominant side with a reduced internal rotation (IR) and increased external rotation (ER) ROM on the dominant side.

Significant between age group differences were found in dominant side IR and ER ROM between the under 14-year olds and the 14-15-year old participants, and also the 14-15-year olds and the 16 and over age group. The reduced IR ROM in the 14-15-year olds compared to the under 14-year olds suggests the 14-15-year olds should be identified as a potential target for preventative mobility programs if the ROM reaches the levels considered for injury risk.

Reduction in posterior capsule mobility is found in older overhead athletes compared to younger ones; and this could be due to more force travelling through the posterior shoulder resulting in greater thixotropic changes and capsular strain.¹¹ This may explain the lesser degree of IR ROM adaptation in the younger participants and account for the differences between the youngest two age groups in the present study. However, the oldest age group demonstrated the highest IR values. An explanation for this could be that the older players undertake more extensive mobility exercises within their preparation programs than the younger players, thereby contributing to the increased IR ranges found. Assessing the effect of mobility exercises was not carried out in this study, but as these participants had access to high-level support teams, it would be interesting to compare them to other players without such input.

The presence of a glenohumeral joint internal rotation deficit (GIRD) in elite tennis players is supported by the results. However, the 6° mean is lower than the 13° recorded by Cools *et al.*¹⁸ as well as the 18-20° for the anatomical and pathological definitions described by Manske *et al.*¹⁵ In accordance with previous research, in the present study GIRD increased with increased athlete age.⁸ A higher percentage of participants with larger values of GIRD were identified in the older groups which is relevant

because increased GIRD has been associated with injury in other sports.¹⁶ This is also linked to research by Kibler *et al.*⁸ who found the greatest reduction in IR ROM and TROM occurred in those players with less than six or more than nine years of tournament experience. Their study involved 39 tennis players aged between 14 and 21 years. The number of years the present participants had been playing tennis was not assessed as part of this study; however, as greater changes in GIRD were found with increasing participant age, the IR values may have decreased in relation to the increased years of competition in the older players.

Interestingly, the present results also demonstrate differences in both glenohumeral joint IR and ER ROM on the non-dominant side. In particular, there was less non-dominant side IR and greater ER ROM in the 14-15-year olds compared to the 16 years and over age group. Although not measured directly in this study it was observed that the older athletes incorporated more frequent bilateral IR ROM stretches into their program, which may have influenced the IR changes. Alternatively, these changes could be due to the process of normal maturation. Glenohumeral joint ER stretches were not routinely performed and consequently this additional ER ROM in the 14-15-year olds may not have been maintained in the older age group. Nevertheless, the decrease in humeral retrotorsion, thought to take place during childhood and adolescence,¹⁰ may have contributed to the non-dominant side IR ROM increasing and the external rotation ROM decreasing with increased athlete age. It is unclear to what extent changes identified on the non-dominant side could have influenced the calculated values for GIRD in each of the present age groups.

Despite the ER ROM side-to-side differences not being statistically significantly different between the age groups, the results demonstrate a greater than 5° difference in the 14-15-year old age group but less than 5° in both the under 14-year old and the 16 years and over athletes. According to Mankse *et al.*¹⁵ it would be anticipated that both the youngest and oldest age group categories may have a greater likelihood of injury compared to the 14-15-year olds. As previously described, a side-to-side difference in TROM was not found in the present study. These

athletes consequently are within the 5° described by Manske *et al.*¹⁵ and would not be considered to be at any increased injury risk.

Study limitations

There are several limitations to consider when interpreting the results from this study. Firstly, it cannot be assumed that all participants started to play tennis at the same age and total years of participation was not recorded. Consequently, there may have been greater adaptations in ROM in some participants than in others due to starting playing tennis at different ages. Secondly, the testing was performed during busy training camps, which meant that the time of day the measurements were taken could not be standardized, and the players' activity levels before testing was not consistent. The volume of training before testing may have altered the ROM and some players could have performed specific posterior capsule stretches thereby impacting on the results. Finally, an important consideration is that it was not possible to blind the tester from the scores as the data was collected at performance camps and needed to be fitted around player and staffing commitments.

Future research

This study has highlighted areas for additional research. Reviewing the GIRD results against the retrospective and prospective injury history of the players would be a useful adjunct to the available literature. This knowledge would help ascertain whether restricting match numbers, and training volume, should be introduced to prevent overuse injuries particularly in junior players. It would also guide preventative stretching programs to maintain glenohumeral joint rotational ROM to prevent future shoulder pathology.

This study involved a sample of elite tennis players. However, individuals not involved in overhead type sports may also have a small GIRD because of limb dominance.¹⁴ It would be useful, therefore, to compare an elite group to an aged-matched control group to ascertain reference values in non-throwing type athletes.

Future research could also incorporate insight into the skeletal maturity of the players. In this study, it

was not apparent which players had reached skeletal maturity; the addition of radiographs to confirm closure of the individual's proximal humeral physis would help determine the relative contributions of bony versus soft tissue to adaptations in ROM. Ultrasound measurements of humeral torsion alongside rotational ROM could also be valuable.

A larger scale longitudinal study looking at changes in the glenohumeral rotational arc of individual players over time would be useful. It would be challenging to keep enough athletes over an extensive timeframe but would help exclude some of the limitations discussed previously including standardizing the number of years of play and the skeletal maturity level of the participants.

CONCLUSIONS

The results of this study provide reference values for glenohumeral joint rotational range of motion (ROM) specific to elite tennis players. Reduced internal rotation (IR) and increased external rotation (ER) on the dominant, compared to the non-dominant side, of the participants was found. No statistically significant differences in glenohumeral joint total range of motion were identified. Glenohumeral joint IR deficit was present on the dominant side, which increased with rising player age. Trends were also identified across the age groups, with age specific differences in IR and ER ROM found between the under 14 years age group and the 14-15-year-olds, as well as the 14-15-year olds and the 16 years and over athletes. These results provide a baseline for reference of glenohumeral joint rotational ROM values in tennis to be contrasted with other sports. It is important for future studies to correlate changes in glenohumeral joint ROM with injury data, which will be a valuable adjunct to injury prevention programs.

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