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Original Research

Shoulder Rotational Strength Profiles of Danish National Level Badminton Players

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Background

Increased age has been shown to be associated with weaker external rotators and stronger internal rotators of the shoulder in pitchers and tennis players. Whether this age-associated change is present in elite badminton players is unknown.

Purpose

To compare the internal and external rotation strength of the shoulder in adolescent and adult elite badminton players.

Study design

Cross-sectional.

Methods

Thirty-one adolescent (12 females aged 16.8 ± 1.6 years and 19 males aged 17.1 ± 1.6 years) and 29 adult (10 females aged 25 ± 2.9 years and 19 males aged 26.2 ± 4.6 years) national level badminton players were tested pre-seasonally for external rotation (ER) and internal rotation (IR) isometric muscle strength bilaterally, using a hand-held dynamometer. Within-group ER to IR strength ratios were calculated (ER/IR×100%).

Results

The adolescents had stronger shoulder ER than the adults on both sides ($p < 0.05$). The adult males tended to have stronger IR of the dominant shoulder than the adolescent males ($p = 0.071$). In the dominant shoulders, the strength ratios for adult females and males were 77% and 78%, respectively, while the same ratio for adolescent females and males were 85% and 99%, respectively. In the non-dominant shoulders, the ER/IR strength ratios for adult females and males were 90% and 87%, respectively, while the ratios for adolescent females and males were 116% and 102%, respectively.

Conclusion

This study is the first to demonstrate that in shoulder injury-free national team badminton players, adolescents have stronger shoulder ER than adults on both sides. Therefore, increased age appears to be associated with weaker shoulder ER muscles in elite badminton players.

Level of evidence

3b.

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INTRODUCTION

Shoulder injuries are common in upper extremity sports, particularly at the elite level.[1–5] Many badminton players with shoulder pain continue their sport despite the risk of developing chronic conditions, such as subacromial pain syndrome and rotator cuff tendinopathy.[1,6] Thus, knowledge of shoulder profiles of upper extremity athletes is of great value in an injury preventive perspective.

In various upper extremity sports (baseball pitching, swimming, tennis and golf), the overhead throwing type motion is somewhat similar according to studies of motion and electromyography.[7–9] During the act of throwing, the eccentric forces/loads generated put excessive mechanical stress (load divided by tissue cross-sectional area) on the rotator cuff tendons and muscles, the capsule and the ligamentous structures of the shoulder,[10] and these repetitive high loads may lead to overuse tendon injuries.[11] It has been suggested that shoulder pathology in overhead sports is associated with external rotation (ER) muscle weakness[12–14] and imbalance in the ratio between ER to internal rotation (IR) strength.[15–17] Several authors have demonstrated ER muscle weakness of the dominant (DOM) shoulder compared to the non-dominant (NDOM) shoulder in high school and professional throwers[18,19] and other overhead athletes.[20]

The rotational shoulder strength of badminton players has only been minimally studied. Ng and Lam examined recreational badminton players and observed that male players have lower ER to IR strength of the DOM shoulder compared to the NDOM shoulder.[21] In young elite badminton players, the rotational strength appears to be similar between the DOM and NDOM shoulders in the males, while there was a greater IR strength on the DOM side that was not balanced by a greater ER strength in females.[17] The shoulder rotational strength profiles of shoulder injury-free adolescent and adult national level badminton players has not been compared previously.

Increased age has been associated with decreased shoulder strength, including of the internal and external rotators, in the more general population in the age range 20 to 39 years.[22] It is possible that testosterone, which peaks at the average age of 19 and 17 years in males and females, respectively, and subsequently declines, explain these observations.[23,24] Therefore, the present study was conducted to compare the ER and IR strength of the shoulder in adolescent and adult elite badminton players. It was hypothesized that compared to adult badminton players, adolescent badminton players have stronger shoulder ER and IR.

METHODS

PARTICIPANTS

Thirty-one adolescents; 12 females aged 16.8 ± 1.6 years and 19 males aged 17.1 ± 1.6 years, and 29 adults; 10 females aged 25 ± 2.9 years and 19 males aged 26.2 ± 4.6 years (mean ± standard deviation) from the Danish national badminton team volunteered and participated in this cross-sectional study as part of a pre-season screening in 2005. Subject consent was given in accordance with the policy statements of American College of Sports Medicine and the Danish Society of Sports Medicine. The complete methods are described elsewhere.[17]

The players underwent a screening for injuries and were only allowed to participate in the study if they were free from any current and previous shoulder injury. This screening included an evaluation of the spine and shoulders, including the Hawkins-Kennedy test, Jobe's test, Apprehension test, O'Brien's test and foraminal compression/distraction test.[25,26] One adolescent female player was excluded due to joint instability of the NDOM shoulder.

ASSESSMENTS

The strength measurements were performed with a handheld dynamometer (HHD) (J-Tech Power Track® dynamometer, JTECH Medical, Salt Lake City, UT, USA) in the same test position as used in other studies.[27,28] Shoulder ER and IR strength assessments were conducted with the participants lying in supine position with the shoulder abducted 90° and in the scapular plane.[27,29] The participants' elbows were flexed 90° and the examiner stabilized the upper arm by pressing it down toward the examination table. The participants grasped the table with their non-testing arm, thereby providing additional stabilization. This position was selected due to its similarity with the badminton smash, to obtain maximum strength values and minimize risk of shoulder injury.[30] The testing angle was checked visually. In the ER test, the participants externally rotated their shoulder against the HHD, while the HHD was located proximal to the ulnar styloid process. In the IR test, the participants internally rotated their shoulder against the HHD, while the HHD was located proximal to the ulnar styloid process. In both the ER and IR tests, the glenohumeral rotation was placed at midrange/neutral position, so the forearm was elevated to a vertical position.[17] These were isometric "make tests" consisting of a 5–6 s maximum voluntary contraction (MVC) by the player. The "make test" is isometric in nature and therefore associated with less risk of muscle damage or soreness compared with the "break test". The specific HHD can register 0–500 N with a sensitivity of 0.2 N and it was calibrated prior to each trial. Two examiners tested the players blinded to side dominance, and for practical reasons, one examiner tested the adolescent group and another examiner tested the adult group. Intertester-reliability was thus evaluated. The player warmed up by performing 15 repetitions of ER and IR with a 1 kg dumbbell in side lying prior to the strength assessments, without becoming fatigued. The players were instructed in a standardized manner only to move their testing arm during the assessments. Prior to the trials, the players were reminded in a standardized manner of the importance of providing their MVC. A standardized verbal encouragement was given during each effort. A mean of three MVCs was recorded for IR and ER each. A 20-30 s pause was mandatory between each trial.[22] The order of assessments was constant, i.e., right ER, right IR, left ER and left IR.[31] Torque was calculated as strength (N) ¥ full arm length (m) and normalized to body weight (N m/kg). Full arm length was measured just proximal to the ulnar styloid process and just below to the acromion.[17]

Table 1: Participants' age, arm length and body weight. Values are mean ± standard deviation.

	Females		Males	
	Adolescents	Adults	Adolescents	Adults
Number of players	12	10	19	19
Age (years)	16.8 ± 1.6	25.0 ± 2.9	17.1 ± 1.6	26.2 ± 4.6
Arm length (m)	0.54 ± 0.04	0.55 ± 0.03	0.60 ± 0.03	0.60 ± 0.03
Body weight (kg)	61.1 ± 7.0(*)	65.0 ± 6.3	74.2 ± 7.4(†)	78.4 ± 5.9

Female adolescents versus female adults: (*) p = 0.139
Male adolescents versus male adults: (†) p = 0.065

The selected test position has proven sensitive to detecting side-to-side differences.[21,27] The HHD assessment is valid[29] and has shown to be more precise[32] and sensitive[33] to ER muscle weakness in the same test position when compared to an isokinetic strength test instrument. Also, assessment with HHD has proven to be intra- and inter-rater reliable.[27,34]

STATISTICAL ANALYSIS

Within- and between-group statistical comparisons were made with Wilcoxon's rank-sum test and Mann-Whitney *U*-test, respectively, since the data by visual inspection appeared not to be normally distributed. p-values of < 0.05 were considered to be statistically significant. Within-group ER to IR strength ratios were calculated using the formula ER/IR×100%. Intra- and inter-rater reliability of the strength measurements were calculated and reported as typical error.[35] All statistical analyses were performed using the software package GraphPad Prism® 6.0 (San Diego, CA, USA).

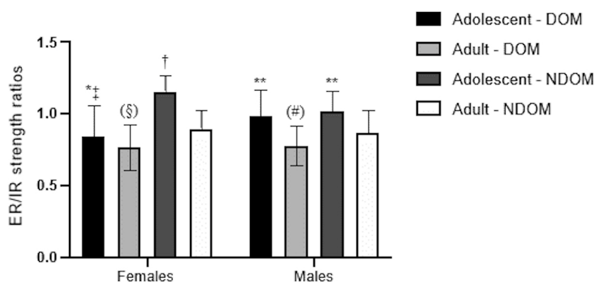

Figure 1: External/internal rotational shoulder strength ratios. Values are presented as mean (SD). ER: External rotation, IR: Internal rotation, DOM: Dominant shoulder, NDOM: Non-dominant shoulder

Female adolescents versus female adults: * p < 0.05; † p < 0.01
Male adolescents versus male adults: ** p < 0.01
Dominant versus non-dominant side: (§) p = 0.065; (#) p = 0.061; ‡ p < 0.05

RESULTS

INTRA- AND INTER-RATER RELIABILITY

For adolescents, the intra-rater reliability of the measurements was substantial with a typical error in percentage for IR and ER strength assessments of 5.4% (3.9-6.9%) and 5.4% (5.3-6.8%), respectively. The typical error in percentage for the IR and ER strength assessments of the adults was 4.6% (2.9-5.3%) and 4.8% (3.9-5.5%), respectively. A Spearman's rank correlation coefficient (r) value was calculated to determine the strength of the relationship between the two highest values. The r-value was 0.99. There were no systematic differences (paired t-test) between the two highest values. Inter-rater reliability on seven participants demonstrated a typical error in percentage for IR strength measurements of 6.8% and for ER strength measurements of 6.2%. There were no significant differences between the two examiners in any of the testing movements.

BODYWEIGHT AND ARM LENGTH OF THE GENDER AND AGE GROUPS

The body weight and arm length of the gender and age groups are presented in Table 1.

EXTERNAL AND INTERNAL ROTATIONAL SHOULDER STRENGTH

The males were generally stronger than the females. The adolescents had stronger shoulder ER than the adults ($p < 0.05$). The adolescent and adult females and the adult males had stronger IR of the DOM shoulder compared to the NDOM shoulder ($p < 0.05$). Expressed as a percentage, the adolescent females and males had 25% and 13% stronger DOM and 27% and 15% stronger NDOM shoulder ER than the adult females and males, respectively (Table 2). The adult males tended to have 12% stronger IR of the dominant (DOM) shoulder than the adolescent males, although this was not statistically different ($p = 0.071$) (Table 2). In the DOM shoulders, the ER/IR strength ratios for adult females and males were 77% and 78%, respectively, while the ratios for adolescent females and males were 85% and 99%, respectively. In the NDOM shoulders, the ER/IR strength ratios for adult females and males were 90% and 87%, respectively, while the ratios for adolescent females and males were 116% and 102%, respectively (Table 2 and Figure 1).

Table 2: The badminton players shoulder torque normalized to Nm/kg. Values are mean ± standard deviation.

	Females		Males	
	Adolescents	Adults	Adolescents	Adults
ER DOM	1.11 ± 0.5† (††)	0.89 ± 0.19	1.39 ± 0.20§	1.23 ± 0.31
ER NDOM	1.19 ± 0.19†	0.94 ± 0.13	1.44 ± 0.28§	1.25 ± 0.31
IR DOM	1.31 ± 0.31§§	1.16 ± 0.20§§	1.40 ± 0.30(‡)	1.57 ± 0.30§§
IR NDOM	1.03 ± 0.19	1.05 ± 0.18	1.37 ± 0.26	1.44 ± 0.20
ER/IR ratio DOM	0.85 ± 0.21* §§	0.77 ± 0.16(#)	0.99 ± 0.18**	0.78 ± 0.14(‡‡)
ER/IR ratio NDOM	1.16 ± 0.11†	0.90 ± 0.13	1.02 ± 0.14**	0.87 ± 0.16

ER: External rotation, IR: Internal rotation, DOM: Dominant shoulder, NDOM: Non-dominant shoulder
Female adolescents versus female adults: * $p < 0.05$; † $p < 0.01$
Male adolescents versus male adults: (‡) $p = 0.071$; § $p < 0.05$; ** $p < 0.01$
Dominant versus non-dominant side: (††) $p = 0.067$; (#) $p = 0.065$; (‡‡) $p = 0.061$; §§ $p < 0.05$

DISCUSSION

The objective of this study was to describe and compare the shoulder rotational strength of adolescent and adult elite badminton players. The main findings were that the adolescent players had stronger shoulder external rotation (ER) than the adult players on both sides. These first data suggest that advanced age is associated with weaker shoulder ER in elite adult badminton players, which may warrant strengthening of the ER muscles as a player ages, which could be a potential strategy to reduce the risk of future shoulder injury.

BADMINTON INDUCED ADAPTATIONS

The badminton smash and the adaptations to the shoulder muscles are similar in other extremity sports involving the throwing motion.[7,36] As mentioned, the adolescents in the present study were stronger than the adults, in terms of shoulder ER of both sides. Furthermore, the adult females and males had ER/IR strength ratios of 77% and 78% of the DOM shoulder, respectively, while the ratios were considerably more balanced (closer to 1:1) in the adolescent groups. These results are consistent with those of elite tennis players in the age of 10-20 years.[37]

The stronger shoulder ER of the adolescent groups could be age-associated as observed in the more general population, where ER strength of both shoulders typically decreases during the adult life[22,31,38] and/or as a consequence of possible overuse in the ER muscles-tendons due to the enormous demand for eccentric deceleration in the IR smashing motion. Of note, the results of the present study could also be influenced by different training behaviors (e.g., training type, intensity and frequency) in the different age and gender groups. The strength and power of the IR muscles may increase as an adaptation to the smashing motion. One function of the ER muscles is to decelerate the arm in throwing of follow through; they do not increase their strength proportionally like the IR muscles, probably due to the size of muscle-tendon structure. The ER rotator cuff muscle-tendons are smaller than the IR rotator cuff muscles-tendons, which could explain why some shoulder injuries occur from repetitive smashing and throwing.

It should be noted that, while weak ER strength was associated with higher risk of shoulder injury in a cohort study of 144 baseball pitchers ($p = 0.003$)[12] and in a cohort of 206 elite male handball players (odds ratio = 1.29),[13] such relation was not confirmed in a cohort of 329 elite handball players (odds ratio = 1.05).[14]

GENDER DIFFERENCES

As expected, in the present study, the males were stronger than the females after adjustment for body weight, and this can be explained by the physical sex difference. The results of the female age groups should be interpreted with caution, as the analyses may lack statistical power due to the relatively small sample sizes. Notably, Fahlstrom et al. observed that in world class badminton players, females generally perform less shoulder training than males.[1] Thus, it was hypothesized that the same was evident in the current study and that it would be reflected in the results. However, based on the present data, it can be hypothesized that preventive strength training with proper restitution to stabilize and balance the rotator cuff is even more important in females than in males to reduce the risk of overuse injury in the shoulder.[39,40]

ADDITIONAL CONSIDERATIONS AND LIMITATIONS

This study has some limitations worth mentioning. It is cross-sectional in design and had a relatively small sample size, which prohibits conclusions about causality between shoulder rotational strength and aging with badminton play; future studies should be prospective in design and risk of injury should be correlated with shoulder strength.

Furthermore, shoulder strength was only tested isometrically, however, measuring eccentric strength would have provided more valid results.[5,16,33] Also, the moment arm was measured just proximal to the ulnar styloid process and just below the acromion (full arm length) instead of the forearm length, thereby likely overestimating ER and IR torque.[17]

The number of hours played was not recorded and this may be a confounding factor; by recording hours played, it may be possible to separate badminton specific muscle strength/weakness adaptations from general aging factors. It is plausible that hours played is associated with weaker ER and stronger IR of the DOM shoulder due to repeated forceful internal rotational movements that may leave the smaller external rotators vulnerable to large eccentric forces.

CONCLUSION

This study is the first to demonstrate that in injury-free national team badminton players, adolescent players have greater isometric shoulder ER strength than adult players on both sides. It is plausible that increased age is associated with weaker shoulder ER in elite badminton players.

FUNDING

No outside funding was received for this work.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

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