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Original Research

The effects of playing two consecutive matches in the shoulder rotational profiles of elite youth badminton players

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ABSTRACT

Objective: The aim of the present study was to analyse the effects of playing two badminton matches on the same day on the shoulder profile (i.e., range of motion (ROM) and strength) of young badminton players.
Design: Cross-sectional study.
Setting: Indoor sports facility.
Participants: Thirty-one elite junior badminton players (age 16.6 ± 1.0 years, body mass 63.9 ± 6.1 kg, height 174.8 ± 6.1 cm), including 19 boys and 12 girls.
Main outcome measures: Shoulder passive internal rotation (IR) and external rotation (ER) ROM as well as shoulder IR/ER maximal isometric strength were measured before and after a competition including two competitive matches.
Results: Significant decreases ($p < 0.05$) were found in the shoulder ROM (i.e., dominant and non-dominant ER ROMs as well as in the dominant and non-dominant total arc of motion [TAM]) in boys, while in girls, significant increases ($p < 0.05$) were found in the non-dominant ER absolute strength, with significant decreases were found in the non-dominant ER ROM and the non-dominant TAM.
Conclusion: Playing two badminton matches on the same day led to gender-specific changes on the shoulder profile (i.e., ROM and strength) of young elite badminton players, with more impact on the shoulder profile of boys compared to girls.

1. Introduction

In badminton singles matches, the rules state that a match consists of the best of 3 games, with the first player scoring 21 points winning the game. When one side reaches 11 points, both players are given a 60-s break and there is a 2-min break between games (Fernandez-Fernandez, de la Aleja Tellez, Moya-Ramon, Cabello-Manrique, & Mendez-Villanueva, 2013; Ming, Keong, & Ghosh, 2008). The activity pattern during a match is intermittent, with repetitive short periods of exercise (i.e., 1–9 s) and recovery (i.e., low-intensity activities such as standing or walking for 6–15 s) interspersed with longer breaks in play (i.e., "time outs" of 2 min between games) (Abian-Vicen, Castanedo, Abian, & Sampedro, 2013; Fernandez-Fernandez et al., 2013; Lees, 2003; Manrique & Gonzalez-Badillo, 2003). During the game, the overhead motion (i.e., with the shoulder in abduction, with a combination of internal rotation [IR] and external rotation [ER]) is a typical action, accounting for approximately 30% of the shots played (Fahlström, Yeap, Alfredson, & Söderman, 2006), therefore applying high loads to the shoulder complex. As shown by previous research, this could lead to an increased risk of shoulder pain (Moreno-Pérez, Moreside, Barbado, & Vera-Garcia, 2015; Pluim, Staal, Windler, & Jayanthi, 2006). In adolescent and adult overhead athletes, chronic shoulder pain is often associated with glenohumeral internal-rotation deficit (Wilk et al., 2015), rotator cuff weakness, and

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scapular dyskinesia (Kibler & Sciascia, 2017).

Alterations in the shoulder range of motion (ROM) and strength have been documented in other racket sports, such as tennis (Cools, De Wilde et al., 2014; Cools, Palmans, & Johansson, 2014; Gillet, Begon, Sevrez, Berger-Vachon, & Rogowski, 2017; Roetert, Ellenbecker, & Brown, 2000), with data obtained analysing young and adult competitive players, showing a gradual decrease in IR ROM of the dominant shoulder, with increasing age and years of practice. Also, an increased ER ROM of the dominant shoulder has been reported in the literature (Cools, Palmans, et al., 2014; Moreno-Pérez et al., 2015). From a pathological perspective, shoulder IR problems have been identified when there is a loss of rotation greater than 18° to 20°, with a corresponding loss of total ROM greater than 5° when compared bilaterally (Cools, Ellenbecker, & Michener, 2017). Regarding the shoulder strength profile, on the dominant side, with practice, IR strength increases more than ER, leading to an unbalanced shoulder function profile (Gillet et al., 2017). To the best of our knowledge, only one previous study has analysed the shoulder profile of young badminton players (Couppe et al., 2014), reporting males to be generally stronger than females, and the IR strength of the dominant side to be greater than the non-dominant side in females only; however, they did not find any differences between IR and ER strength. Moreover, the total arc of motion (TAM = IR ROM + ER ROM) was reduced on the dominant side compared to the non-dominant side.

In badminton, match scheduling, participation in multiple draws (singles, doubles and mixed doubles) and training demands require young elite badminton players to often complete numerous training sessions and/or competitive matches on consecutive days (Abian-Vicen et al., 2014; Abian et al., 2016). Thus, players usually take part in two or three consecutive badminton matches in a day (i.e., morning and afternoon sessions) as part of their competition schedule. In this regard, training/competitive volume has been described as the major risk factor for overuse injuries (DiFiori et al., 2014; Jayanthi, Pinkham, Dugas, Patrick, & LaBella, 2013). To the best of our knowledge, only a single previous study (Abian-Vicen et al., 2014) analysed the influence of the competitive round on muscle strength (i.e., counter-movement jump (CMJ) performance and grip strength), during a real competition. The authors reported that the completion of one singles badminton match led to an increase in CMJ height, with no changes in handgrip strength in either hand, suggesting that little fatigue is induced in well-trained players during a single competitive match.

Thus, the aim of the present study was to analyse the effects of playing two badminton matches on the same day on the shoulder profile (i.e., ROM and strength) of young badminton players. We hypothesised that performance would be significantly reduced after the completion of two competitive matches.

2. Method

2.1. Design

Three weeks before the XI Spanish Junior International 2017, held in Oviedo (Spain), all of the players who were going to participate in the men's and women's singles/doubles/mixed doubles modalities were informed by mail about the purpose of the investigation. A cross-sectional repeated measures experimental design was carried out on two consecutive days to observe the effects of playing real badminton matches on the same day on elite junior players, with the rationale of providing useful practical information for coaches and players when planning tournament schedules, as well as preparing match and recovery strategies. Each participant took part in two experimental trials (pre- and post-competition) separated by approximately 24 h and conducted in morning sessions under similar experimental conditions (21.0 ± 2.4 °C; 50.6 ± 6.3% relative humidity). Between the trials, players participated in a junior championship, including the completion of one singles match and one doubles/mixed doubles match on the same day. Post-test was conducted 10 min after the second match (Fig. 1).

One day before the start of the tournament, on arrival at the badminton facility (9 a.m.), participants were randomly distributed in groups. Every group followed the same testing protocol separated by lapses of 10 min between each stage. To reduce the interference of uncontrolled variables, all of the participants were lodged in a players' residence within the training facility to control meals and rest times and were instructed to maintain their habitual lifestyle during the study. The participants were previously familiarised with the measuring protocols corresponding to the maximal effort tests.

2.2. Participants

Thirty-one elite junior badminton players (age 16.6 ± 1.0 years, body mass 63.9 ± 6.1 kg, height 174.8 ± 6.1 cm) participated in this study. Of these, nineteen were boys (age 16.4 ± 1.1 years, body mass 65.6 ± 5.3 kg, height 179.6 ± 7.3 cm), and twelve were girls (age 16.9 ± 0.7 years, body mass 61.3 ± 6.7 kg, height 167.3 ± 5.6 cm). The players were ranked between 1 and 40 in their respective national singles ranking (U18), trained for 18.4 ± 2.8 h per week and had a training background of 6.3 ± 1.2 years. As an inclusion requirement participants had to be free of musculoskeletal injuries during the previous three months and free of excessive overload/soreness in the shoulders. Moreover, they were not taking medications for the duration of the study. Before taking part in the study, participants and their parents/guardians were fully informed about the protocol and provided their written informed consent. All players who provided their consent participated in the study. The institutional ethics review committee approved the procedures in accordance with the latest version of the Declaration of Helsinki and was coordinated with the Spanish Badminton Federation.

2.3. Procedures

2.3.1. Shoulder range of motion (ROM)

The passive glenohumeral rotation was assessed following a previously described method (Cools, De Wilde et al., 2014) (Fig. 2). Each participant lay supine on a bench, with their shoulder in 90° of abduction and the elbow flexed to 90° (forearm perpendicular to the bench). From this starting position, an examiner held the participant's proximal shoulder region (i.e., clavicle and scapula) against the bench to stabilise the scapula while another examiner rotated the humerus in the glenohumeral joint to produce maximum passive ER and IR (Moreno-Pérez et al., 2015). Two attempts at both IR and ER, as well as for both dominant and non-dominant sides, were performed. Values (°) for both repetitions

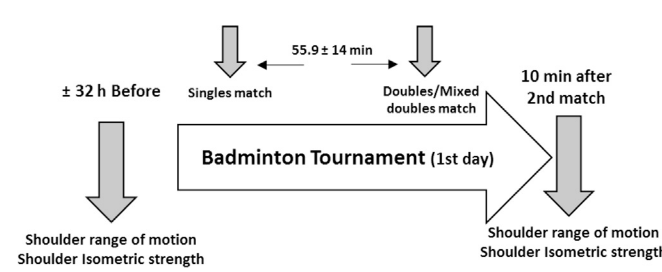

Fig. 1. Schematic representation of the intervention.

were averaged, and then used to calculate both the TAM, and the bilateral difference in IR (side-to-side asymmetry = dominant - non-dominant). The intraclass correlation coefficient (ICC) for this test ranged from 0.88 to 0.93.

2.3.2. Isometric maximal voluntary contraction (MVC) of the dominant/non-dominant shoulder

Isometric internal and external shoulder rotation of the dominant and non-dominant limb were assessed with a portable handheld dynamometer (Nicholas Manual Muscle Tester, Lafayette Indiana Instruments) in a supine lying position on a plinth with the participant's shoulder in 90° of abduction and the elbow flexed to 90°, following the methodology described by (Cools, De Wilde et al., 2014; Couppe et al., 2014) (Fig. 3). The mean of the two most closely related maximal trials (5 s) was used for subsequent statistical analyses. There was a 30-s rest period between trials. A side-to-side difference greater than 10% was defined as bilateral asymmetry. Moreover, shoulder rotational strength values normalised to bodyweight (Nm/kg) were also calculated. The ICC ranged from 0.83 to 0.94.

2.4. Analysis

The distribution of raw data sets was checked using the Kolmogorov–Smirnov test and demonstrated that all data had a normal distribution ($p > 0.05$). Dependent t-tests were performed to assess pre-to-post differences for each dependent variable in both groups. Independent sample t-tests were run to evaluate baseline and post-test differences between groups (boys vs. girls) for each dependent variable using the software PASW statistics (version 22.0; SPSS Inc., Chicago, IL, USA). In addition, the standardised difference or effect size (ES) of changes in each variable was calculated using the pooled pre-test standard deviation (SD) (i.e., ES of ≤0.4 = small; 0.41–0.7 = moderate; >0.7 = large magnitudes of change, respectively) (Hopkins, Marshall, Batterham, & Hanin, 2009).

To perform comparisons with the results reported in previous similar studies, magnitude-based inferences on differences between genders (boys vs. girls), limbs (dominant vs. non-dominant) and pre-post intervention were determined using a specific spreadsheet (Batterham & Cox, 2006). This analysis determines the chances that the differences are substantial or trivial when a value for the smallest worthwhile change is entered. The cut-off score of >18° proposed in previous research (Cools et al., 2017) determined the smallest substantial/worthwhile change for both of the interlimb comparisons for each of the ROM variables; a difference score of at least 0.2 Cohen's units (representing a small effect) was considered to be practically worthwhile in pre-post and gender differences. Also, based on Cools et al. (2017), the number of players with side-to-side differences (>18°) in the shoulder, internal and external ROM and TAM (>5°) measures were calculated. Moreover,

Fig. 2. Evaluation of the shoulder ROMs (internal and external rotation on the left and right pictures, respectively).

Fig. 3. Evaluation of the MVC of the shoulder (internal and external rotation on the left and right pictures, respectively).

qualitative descriptors were used to interpret the probabilities that the true affects are harmful, trivial or beneficial: <1%, almost certainly not; 1–4%, very unlikely; 5–24%, unlikely; 25–74%, possibly; 75–94%, likely; 95–99%, very likely; and >99%, almost certainly (Hopkins, 2002). Differences were rated as unclear when the likelihood exceeded >5% in both positive/negative directions.

3. Results

Match duration was 28.1 ± 5.7 min and 27.7 ± 6.2 min for the singles and doubles/mixed doubles, respectively. Moreover, players had 55.9 ± 14 min between the first and the second match.

Baseline tests (pre-tests) showed that there were paired intergroup differences ($p < 0.05$) in the shoulder strength variables, with boys showing higher strength values than girls for both absolute and normalised values (Large ES ranging from 1 to 2.6), but not for shoulder ROM. Moreover, there were significant post-test differences between genders ($p < 0.05$) in absolute and normalised shoulder strength values, with large ES, ranging from 0.8 to 2.1, but not for shoulder ROM.

The pre- and post-intervention results of each group are reported for descriptive purposes in Tables 1 and 2. T-tests showed significant decreases ($p < 0.05$) in dominant and non-dominant shoulder ER ROMs as well as in the dominant and non-dominant TAMs, between pre- and post-tests in boys (Table 1), with moderate ES, ranging from 0.6 to 0.8. Regarding shoulder strength, although the results were not significantly different, attending to the qualitative inference, IR absolute and normalised strength values were possibly and likely negative, respectively, in the post-tests, with a small ES (0.3). Moreover, absolute and normalised IR and ER values of the non-dominant side were found to be likely positive in the post-tests, with moderate ES (0.5). In girls (Table 2), when comparing pre- and post-tests, significant increases ($p < 0.05$) were found in the non-dominant ER absolute strength (ES = 0.4), while significant decreases were found in the non-dominant ER ROM (ES = 1.1), and the non-dominant TAM (ES = 0.9). Regarding strength, although the results were not significantly different, attending to the qualitative inference, absolute and normalised ER, normalised IR and ER of the dominant side as well as normalised IR and ER of the non-dominant side were possibly positive in the post-tests, with a small ES ranging from 0.1 to 0.4.

Table 3 shows baseline side-to-side differences in the different shoulder ROMs analysed (IR, ER and TAM) as well as the number of players with side-to-side differences in the IR, ER and TAM. The results showed significant differences ($p < 0.05$) in the three variables analysed, with a higher ER in the dominant side and higher IR and TAM in the non-dominant side. Regarding side-to-side differences, 35.4% of the players showed differences in the IR, 22.5% in ER and 77.4% in the TAM.

Table 1
Pre- and post-competition differences in shoulder ROMs and isometric strength in boys.

Protocols and variables	Baseline(pre-test)	Post-test	ES	% Dif	Chances that the true effects were positive/trivial/negative	Inference[a]
Shoulder Strength test (N)						
Internal Rotation D	131.0 ± 15.3	126.0 ± 17.5	0.3	−4.0	2/25/73	Possibly
Internal Rotation ND	111.8 ± 17.2	118.5 ± 15.1	−0.5	5.7	82/17/1	Likely
External Rotation D	97.4 ± 16.4	95.2 ± 12.6	0.2	−2.4	6/66/28	Unclear
External Rotation ND	87.0 ± 13.5	93.0 ± 11.3	−0.5	6.4	83/16/1	Likely
Internal Rotation D norm	2.0 ± 0.2	1.9 ± 0.2	0.3	−3.8	3/18/79	Likely
Internal Rotation ND norm	1.7 ± 0.2	1.8 ± 0.2	−0.5	6.0	87/13/0	Likely
External Rotation D norm	1.5 ± 0.2	1.5 ± 0.2	0.2	−2.2	7/60/33	Unclear
External Rotation ND norm	1.3 ± 0.2	1.4 ± 0.4	−0.5	6.8	87/12/1	Likely
Shoulder Range of motion (°)						
Internal Rotation D	62.9 ± 13.4	61.5 ± 11.6	0.1	−2.2	42/40/18	Unclear
Internal Rotation ND	76.2 ± 14.2	73 ± 14.6	0.3	−4.4	6/50/44	Unclear
External Rotation D	151.4 ± 15.1	143.0 ± 13.2*	0.7	−5.8	0/6/94	Likely
External Rotation ND	142.6 ± 13.1	136.1 ± 8.5*	0.7	−4.8	0/3/97	Very Likely
TAM D	214.3 ± 23.4	205.5 ± 16.8*	0.6	−4.1	0/12/88	Likely
TAM ND	218.8 ± 22.8	209.1 ± 18.8*	0.8	−4.4	3/46/51	Possibly

*$p < 0.05$. TAM: Total arc of motion; D; dominant; ND: Non-dominant; norm: normalised.
[a] If chance of benefit and harm both >5%, true effect was assessed as unclear (could be beneficial or harmful). Otherwise, chances of benefit or harm were assessed as follows: <1%, almost certainly not; 1–5%, very unlikely; >5–25%, unlikely; >25–75%, possibly; >75–95%, likely; >95–99%, very likely; >99%, almost certain.

Table 2
Pre- and post-competition differences in shoulder ROMs and isometric strength in girls.

Protocols and variables	Baseline (pre-test)	Post-test	ES	% Dif	Chances that the true effects were positive/trivial/negative	Inference[a]
Shoulder Strength test (N)						
Internal Rotation D	92.6 ± 6.1	95.5 ± 13.2	−0.2	3.0	56/19/25	Unclear
Internal Rotation ND	79.5 ± 5.9	80.8 ± 10.3	−0.1	1.6	45/26/29	Unclear
External Rotation D	75.4 ± 10.0	79.1 ± 7.3	−0.3	4.7	70/25/5	Possibly
External Rotation ND	69.3 ± 4.1	74.5 ± 12.8*	−0.4	7.0	79/10/11	Likely
Internal Rotation D norm	1.5 ± 0.2	1.6 ± 0.3	−0.2	2.6	42/43/15	Possibly
Internal Rotation ND norm	1.3 ± 0.2	1.3 ± 0.2	−0.1	1.1	34/42/24	Possibly
External Rotation D norm	1.2 ± 0.2	1.3 ± 0.1	−0.4	4.9	70/25/5	Possibly
External Rotation ND norm	1.1 ± 0.1	1.2 ± 0.2	−0.4	7.0	74/18/8	Possibly
Shoulder Range of motion (°)						
Internal Rotation D	64.8 ± 16.9	66.5 ± 13.3	−0.2	2.5	33/64/3	Possibly
Internal Rotation ND	82.9 ± 12.1	81.6 ± 7.2	0.1	−1.6	12/63/25	Unclear
External Rotation D	152.5 ± 10.2	144.6 ± 14.4	0.5	−5.4	2/8/90	Likely
External Rotation ND	141.0 ± 11.5	128.3 ± 11.9*	1.1	−9.1	0/1/99	Very Likely
TAM D	217.3 ± 13.7	211.1 ± 19.4	0.3	−2.9	7/20/73	Unclear
TAM ND	223.9 ± 17.4	209.9 ± 13.4*	0.9	−6.3	0/3/97	Very Likely

*$p < 0.05$. TAM: Total arc of motion; D; dominant; ND: Non-dominant; norm: normalised.
[a] If chance of benefit and harm both >5%, true effect was assessed as unclear (could be beneficial or harmful). Otherwise, chances of benefit or harm were assessed as follows: <1%, almost certainly not; 1–5%, very unlikely; >5–25%, unlikely; >25–75%, possibly; >75–95%, likely; >95–99%, very likely; >99%, almost certain.

4. Discussion

We described for the first time the effects of playing two badminton matches on the same day on the shoulder profile (i.e., ROM and strength) of young elite badminton players. Results showed gender-specific adaptations after a real badminton competition, with significant decreases in the shoulder ROM (i.e., dominant and non-dominant ER ROMs as well as in the dominant and non-dominant TAMs) in boys. In girls, significant increases were found in the non-dominant ER absolute strength, while significant decreases were found in the non-dominant ER ROM and the non-dominant TAM. Moreover, side-to-side measures obtained before competition showed significant bilateral differences, including higher ER in the dominant side and higher IR and TAM in the non-dominant side.

Shoulder strength is an important performance factor in badminton players, as they must perform a great number of over-shoulder strokes (i.e., ~30%) over concentrated periods of time (~40% of the whole match time) (Fahlström et al., 2006; Fernandez-Fernandez et al., 2013). Descriptive values of the players analysed here showed that boys were stronger than girls in both IR and ER, not only when analysing absolute values, but also relative after adjustment for body weight. To the best of our knowledge, only a single previous study had analysed the shoulder (i.e., ROM and IR/

Table 3
Statistics (mean ± SD) of the different glenohumeral rotation measurements collected and inference about side-to-side difference for shoulder (internal, external rotation and total arc of motion) ranges of motions (n = 31).

Range of motion (°)	Dominant	Non-dominant	Difference in degrees (%)	Bilateral differences >18° and >5° TAM differences	P value	Inference
Internal Rotation	63.6 ± 14.6	78.8 ± 13.6	15.2 ± 13.5 (19.3)	11	0.02	Most likely positive (100/0/0)
External Rotation	151.8 ± 13.2	142.0 ± 12.3	−9.8 ± 15.4 (6.9)	7	0.02	Likely negative (2/8/91)
TAM	215.4 ± 19.9	220.8 ± 20.6	5.4 ± 17.8 (2.4)	24	<0.05	Possibly positive (70/27/3)

TAM: total arc of motion; °: degrees.

ER strength) of a similar age-range of national badminton players (Couppe et al., 2014), showing absolute and relative values lower than those in the present study. However, it is necessary to conduct more badminton-specific research in order to compare not only boys and girls, but also different performance levels.

When analysing the effects of playing two matches in the same day, shoulder strength values showed different results for boys and girls. In boys, the IR and ER strength of the dominant side decreased by 4% and 2.4%, respectively, while values for the non-dominant side surprisingly increased (i.e., +5–6%). In the case of girls, data are more surprising, with increases in all measures ranging from 1.1 to 7%. It is difficult to compare data with previous studies, as there is no information available regarding badminton players. Several previous studies, conducted with tennis players and analysing IR/ER maximal strength production of the shoulder after consecutive matches or days of prolonged match play, reported reductions in the dominant shoulder rotation levels ranging from 6 to 8% (Gallo-Salazar et al., 2017; Gescheit, Cormack, Reid, & Duffield, 2015). In accordance with the common definitions of fatigue (Gandevia, 2001), we can state that, in boys, upper-body strength was affected by fatigue; although these reductions are trivial (ES < 0.2), values are in agreement with previous research conducted in other racket sports, such as tennis, showing decreases in serve velocity either as training and matches progress or subsequent to their completion (Mendez-Villanueva, Fernandez-Fernandez, & Bishop, 2007). In badminton, this could lead to a less effective use of the stretch shortening cycle in the shoulder rotators during the cocking and acceleration phases and consequently to a decrease in smash performance.

In girls, results are the opposite of those in boys, excluding the non-dominant values, with increases in all of the measures (small ES: 0.3 to 0.5), although non-significant. In general, differences can be related to strength levels in girls, which are significantly lower than in boys. Moreover, these results could be related to the different game style in girls, with fewer shots per game, as well as a lower percent of over-shoulder strokes than boys (Fahlström et al., 2006). Although speculative, these shoulder strength increases in girls could be also related to the post-activation potentiation phenomenon, acknowledged as a short-term enhancement in muscle strength and power after performing not only a high-intensity conditioning activity (Hodgson, Docherty, & Robbins, 2005), but also after different running exercises in endurance athletes (Boullosa, del Rosso, Behm, & Foster, 2018). The possible increased muscle temperature has been documented to increase the following power output, and is likely attributed to increased muscle temperature-related factors (i.e., increases in Adenosine Triphosphate turnover rate (Gray, De Vito, Nimmo, Farina, & Ferguson, 2006), positive shifts in the force velocity curve and/or increased nerve conduction velocity (McGowan, Pyne, Thompson, & Rattray, 2015). Although the time-window in which badminton players performed the post-tests is in agreement with the recommendations in the literature (i.e., 10 min post-exercise) (Boullosa et al., 2018), muscle temperature could be a confounding factor. In this regard, although players performed a supervised warm-up protocol before pre-tests, it was obvious that body temperature before performing the post-tests was significantly higher. Thus, positive acute adaptations of activity, such as the elevation of muscle temperature and increased metabolic responses, should be differentiated from the potentiation of contractile capacity *per se* (Boullosa et al., 2018). However, this is based on simple observations, because we did not measure the players' internal temperature. In the case of increases obtained for the non-dominant side, for both boys and girls, results could also be related to the potentiation factor, which could be more evident in this side, as high fatigue levels are not expected. However, the high muscular activity of this side while playing is evident, as players are continuously required to balance their body and generate powerful strokes and movements, in which the non-dominant side is fundamental (Phomsoupha & Laffaye, 2015). More research is definitely needed in order to elucidate these changes and establish conclusions.

In terms of overall bilateral differences in shoulder strength, data showed most likely differences of 13.9% (Moderate ES = 0.8) and 9.7% (Moderate ES = 0.6) in the IR and ER, respectively, favouring the dominant side. When analysing boys and girls separately, differences were also found. In boys, IR and ER were most likely higher in the dominant compared to the non-dominant side, with 13.9% and 9.7% differences for the IR and ER, respectively (moderate ES (1.5–1.9)). In girls, similar values were obtained, with 12.8% and 7.5% differences in the IR and ER, respectively (moderate to large ES (1.1–2.0)).

In general, with respect to cut-off values distinguishing a healthy shoulder from an at risk shoulder, an isometric ER/IR ratio of 75% is advised, with a general rotator cuff strength increase of 10% of the dominant throwing side compared to the non-dominant side (Cools, De Wilde et al., 2014). Our results showed an ER/IR ratio of 78% and 81% for the dominant and non-dominant sides, respectively, suggesting that in terms of injury risk, these sample of junior badminton players show “safe” values of shoulder IR/ER strength. However, as players are still young and will be submitted to great training loads, caution should be taken in this regard, as analysing individual data showed ratios exceeding 90% or even more (i.e., two cases were over 100%). Therefore, based on the individual reports, the inclusion of training programs aimed at rotator cuff strengthening should be recommended.

Excessive or limited shoulder ROM may contribute to shoulder pathologies such as instability and impingement (Martin, Kulpa, Ezanno, Delamarche, & Bideau, 2016). However, the information on shoulder ROM in badminton is very scarce. Only a single previous study analysed the rotational profile of healthy young players, with lower ROM values than in the present study, which, together with the strength measures, highlight the increased level of the present sample of players. The results showed that ROM values decreased for both boys and girls, in the dominant and non-dominant IR and ER, after two matches, except for the IR ROM of the girls' dominant side. Deficits in the IR values of the dominant side averaged by 2% in boys, while in girls the values increased by 2.4%. Deficits in the boys were lower than previous values reported in tennis- or baseball-specific research after a “normal” baseball throwing game (50–72 throws) or after a prolonged tennis match (3 h), with deficits ranging from 4 to 20% (Gallo-Salazar et al., 2017; Martin et al., 2016; Reinold et al., 2008). Differences between boys and girls could be related to the previously mentioned strength differences. Interestingly, ER values for both the dominant and non-dominant side, and for both boys and girls, decreased significantly, with values ranging from 5.4 to 10.4%. This can be related to the high number of powerful strokes which are performed overhead, but with a shoulder ER (i.e., defensive clear under pressure).

From a pathological point of view, although the present results showed important decreases in the dominant side IR, values are already at the limit (bilateral differences of 19° for girls and 13° for boys), as shoulder IR problems are identified when there is a loss of rotation greater than 18° to 20°, with a corresponding loss of total ROM greater than 5° when compared bilaterally (Cools et al., 2017). Moreover, caution should be taken, as the individual values in the current study can be considered dangerous, with bilateral differences exceeding more than 30° in some cases. Regarding TAM values, in the present study, these were less than 10° for both boys and girls. However, as in the case of IR ROMs, individual cases should be analysed, as we reported individual total ROM values higher than 40°. Based on these results, it appears necessary, especially at young ages, to restore the "normal" shoulder ROM before having to play the next match, as well as to improve general flexibility. Although there is not enough evidence to support that a stretching program reduces the incidence of recurrent shoulder injury (Cools et al., 2017), the use of active, passive or manual therapy forms of stretching, it is recommended to improve posterior shoulder tightness and GIRD in the short-term for asymptomatic young overhead athletes. In this regard we can suggest that upper body stretching routines should be performed a minimum of three times a week for a total of 15–30 min per session (Mine, Nakayama, Milanese, & Grimmer, 2017). Although these are general recommendations, it seems that monitoring changes in the shoulder profile of the badminton players is recommended in order to avoid overuse injuries, as players are usually submitted to very demanding training and competitive schedules. The measures conducted in the present study (i.e., ROM and manual strength testing) show excellent relative reliability for several for the evaluation of the shoulder/hip, and also show clinically acceptable absolute reliability values (Cools et al., 2014). Thus, they should be included in the regular testing programs of badminton players.

It seems also important to highlight several limitations of the present study. First, because of the real tournament demands, individual differences were important, as, for example, match duration was not balanced, and neither was the level of the opponents, which depended on the tournament draw. Moreover, adding more measurements could have provided further information about the real impact of every match on performance, thereby enhancing the value of the research. However, due to the real tournament conditions, the present study offers a unique insight into the competitive demands on elite junior badminton players, and data can be used to design sport-specific routines in terms of performance and injury prevention.

In conclusion, playing two badminton matches on the same day led to gender-specific changes on the shoulder profile (i.e., ROM and strength) of young elite badminton players, with more impact on the shoulder profile of boys compared to girls. Thus, it appears necessary to identify players exhibiting "at risk" shoulders and include training programs aimed at rotator cuff strengthening when needed, and/or restore the "normal" shoulder ROM's in competitions that include several matches in the same day. Is therefore suggested that, given the concern regarding the possible impact of changes in shoulder strength and ROM on injury risk in other overhead athletes, it would be important to include mid-term preventative or regenerative training programs aimed at maintaining or restore the normal ROM and developing ER strength.

Disclosures

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