J. Phys. Ther. Sci. 30: 850–854, 2018

The Journal of Physical Therapy Science

Original Article

Correlation between isometric shoulder strength and racket velocity during badminton forehand smash movements: study of valid clinical assessment methods

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Abstract. [Purpose] The purpose of this study was to confirm the correlation between racket velocity during the forehand smash movements with shoulder extensor strength and internal rotator strength in the neutral and abducted positions. [Subjects and Methods] Fourteen collegiate badminton players participated in the study. Measurements were performed shoulder strength, using torque calculated from the upper extremity length and the isometric force, and racket velocity during the forehand smash movements. The shoulder extensor strength and internal rotator strength were measured in the neutral and abducted positions. [Results] The extension torque and internal rotation torque of the shoulder in the neutral position were not significantly correlated with racket velocity. Additionally, correlations between extension torque of the shoulder in the maximum abducted position and racket velocity were insignificant. However, the internal rotation torque of the shoulder in the abducted external rotated position was significantly correlated with racket velocity (r=0.652). [Conclusion] The shoulder internal rotator strength in the abducted external rotated position are suitable measurements for evaluating badminton players.

Key words: Internal rotation, Specificity, Validity

(This article was submitted Dec. 20, 2017, and was accepted Mar. 27, 2018)

INTRODUCTION

Badminton strokes include the smash, clear, drop, lob, and net shot. Karatnyk et al.[1)] reported that among the technical actions used during single games, the smash is used most often; it used for 14.82% of badminton strokes. In addition, a recent study of the Beijing Olympics showed that the smash is the most used action for finishing rallies of shots, representing 29.1 ± 8.4% of finished rallies[2)]. Lo and Stark[3)] noted that the aims of the smash are to kill, finish the rally, and win the point. The speed of the smash allows for scoring points. Badminton players are required to increase the shuttle velocity; to do so, the player must increase racket velocity. Therefore, it is necessary to improve the physical ability related to racket velocity.

Badminton strokes are divided into forehand and backhand stroke; in addition, the badminton smash is divided into the forehand and backhand smash[4)]. In general, however, “smash” is used denote the forehand smash[3)]. Additionally, because the shuttle velocity of forehand smash has been reported to be faster than that of backhand smash[4)], the forehand smash is considered important for scoring points. Therefore, this study focused on the forehand smash of badminton players.

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Tiwari et al.[5] reported that shoulder strength (r=0.693) was significantly correlated with badminton performance. They noted that shoulder strength allows the muscle to overcome resistance or act against resistance, and it is required for effective smashing[5]. During the rehabilitation process for a shoulder joint injury and during the training process to increase racket velocity, measuring shoulder strength is necessary to evaluate the rehabilitation and training outcomes. Furthermore, the shoulder strength measurement method must be reliable, simple, and relevant to the racket velocity (validity). However, the shoulder strength measurement method related to racket velocity during the forehand smash has not been clarified.

Shoulder joint movement during the impact phase during the forehand smash combines shoulder extension and internal rotation in the abducted position[3]. Therefore, several studies have reported a relationship between performance and shoulder strength and measured the 90-degree shoulder abducted position[6–10]. Baiget et al.[10] reported a significant correlation (r=0.67) between the velocity of the ball during the tennis serve and isometric shoulder internal rotator strength on the dominant side using simple equipment that measures isometric muscle strength. However, in the clinical setting, the neutral position (NP) is also measured; therefore, the difference in the shoulder position has not been clarified. Moreover, the relationship between isometric shoulder strength and racket velocity for badminton forehand smash movements has not been clarified.

The knowledge of shoulder muscle strength related to racket velocity helps to assess muscle strength during the rehabilitation process and to create a specific training program for increasing the racket velocity. Therefore, the purpose of the present study was to confirm the correlation between racket velocity during the forehand smash, shoulder extensor strength, and internal rotator strength in the NP and shoulder abducted position.

SUBJECTS AND METHODS

The study had a sample size of 11, which was calculated using an effect size of 0.693, a statistical power of 0.8, and a significance level of 5%, with reference to the results of Tiwari et al.[5] (r=0.693) using the G*Power 3.1.9.2 statistical software.

Fourteen collegiate badminton players (5 men, 9 women; mean ± standard deviation [SD]: age, 19.6 ± 1.1 years; height, 164.4 ± 8.9 cm; and body weight, 58.1 ± 6.7 kg) participated in the study. The participants did not experienced shoulder pain within the past 6 months and had no history of shoulder surgery. This study was approved by the Research Ethics Committee of Kyushu Kyoritsu University (approval no. 2015-10). The participants provided informed consent for participating in the study. Muscle strength and racket velocity measurements were performed by experienced examiners.

The smash velocity measurement was performed after the muscle strength was measured. Thirty minutes of rest was allowed between the smash movements and strength measurements.

Muscle strength was measured as the maximum isometric force using a hand-held dynamometer (HHD) (Mobie MM100C; Minato Medical Science Co., Ltd., Japan), calculated as the torque, which was calculated using isometric force and extremity length. The torque was calculated using the extremity length and isometric force. Participants performed shoulder warm-up movements before the trial was started. The extension force of the shoulder in the maximum abducted position (EF-MAP) was measured with the upper extremity positioned with maximum shoulder abduction, elbow extension, and neutral forearm (Fig. 1-a)[11]. The internal rotation force of the shoulder in the abducted external rotated position (IF-AEP) was measured with the upper extremity positioned with 90 degrees of shoulder abduction, 90 degrees of external rotation, 90 degrees of elbow flexion, and neutral forearm (Fig. 1-b)[11]. The extension force of the shoulder in the NP (EF-NP) was measured with the upper extremity positioned with the shoulder neutral, elbow extension, and forearm pronation (Fig. 1-c). The internal rotation force of the shoulder in the NP (IF-NP) was measured with the upper extremity positioned with the shoulder neutral, 90 degrees of elbow flexion, and neutral forearm (Fig 1-d). During the EF-MAP measurement, the participants were in the prone position with their toes, abdomen, chest, and mentum touching the ground[11]. During the IF-AEP measurement, the participants were in the prone position with their toes, abdomen, chest, elbow, and mentum touching the ground[11]. During the EF-NP measurement, the participants were in the supine position with their heels, buttocks, back, and head touching the ground. During the IF-NP measurement, the participants knelt with their toes and knees touching the ground. During the EF-MAP, IF-AEP, and EF-NP measurements, the opposite shoulder was positioned in contact with the side of the body. During the IF-NP measurement, the opposite hand was positioned in contact with the wall. For all measurements, the HHD was placed on the ground or wall and against the heads of the metacarpal bones on the palm side, and it was held in place manually to prevent any improper movement during measurements[11]. Maximum isometric contractions lasting 3 seconds were measured during each session; each session comprised three trials. Five minutes of rest was allowed between sessions. The examiner observed the participants to ensure they maintained the proper measurement position. Measurements were repeated when the position was changed or when an error occurred. The average value of the three trials was calculated for each measurement. Participants and measurement positions were assigned randomly by a computer system. The upper extremity length and forearm length were measured using a tape measure. The upper extremity length was determined by measuring the acromial process to the distal head of the third metacarpal bone on the dorsal side. The forearm length was measured from the lateral joint line of the elbow to the distal head of the third metacarpal bone on the dorsal side. The extension torque of the shoulder in the maximum abducted position (ET-MAP) was determined by measuring the upper extremity length and EF-MAP. The extension torque of the shoulder in the NP (ET-NP) was measured from the upper extremity length and EF-NP. The internal rotation torque of the shoulder in the abducted external rotated position (IT-AEP) was determined by measuring the forearm length and IF-AEP. The internal rotation torque of the shoulder in the NP (IT-NP) was measured from the forearm length and IF-NP.

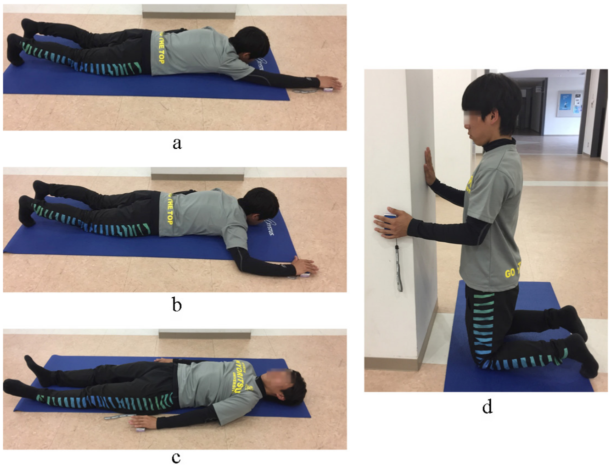

Fig. 1. Muscle strength measurement using a hand-held dynamometer.
a: The extension force of the shoulder in the maximum shoulder abducted position (EF-MAP); b: The internal rotation force of the shoulder in the abducted and external rotated position (IF-AEP); c: The extension force of the shoulder in the neutral position (EF-NP); d: The internal rotation force of the shoulder in the neutral position (IF-AEP).

Table 1. The participants characteristics

	Mean (SD)
Hight (cm)	164.4 (8.9)
Weight (kg)	58.1 (6.7)
Upper extremity length (cm)	59.7 (4.8)
Forearm length (cm)	31.4 (2.5)
Muscle strength	
EF-MAP (N)	96.1 (41.6)
ET-MAP (Nm)	58.5 (28.1)
EF-NP (N)	66.3 (14.4)
ET-NP (Nm)	40.0 (11.1)
IF-AEP (N)	83.3 (30.3)
IT-AEP (Nm)	26.8 (11.9)
IF-NP (N)	117.7 (25.5)
IT-NP (Nm)	37.2 (9.4)
Racket velocity (km/h)	156.2 (18.3)

SD: Standard deviation; EF-MAP: The extension force of the shoulder in the maximum shoulder abducted position; IF-AEP: The internal rotation force of the shoulder in the abducted and external rotated position; EF-NP: The extension force of the shoulder in the neutral position; IF-NP: The internal rotation force of the shoulder in the neutral position; ET-MAP: The extension torque of the shoulder in the maximum shoulder abducted position; ET-NP: The extension torque of the shoulder in a neutral position; IT-AEP: The internal rotation torque of the shoulder in the abducted and external rotated position; IT-NP: The internal rotation torque of the shoulder in a neutral position.

Participants were instructed to perform the forehand smash shot seven times. A skilled badminton coach with more than 20 years of experience served each participant a lob shot to stabilize the forehand smash shot as much as possible. In addition, the participants performed sufficient warm-up exercises before the trial. They were given sufficient breaks between trials so that they would not get tired. The smash motion was recorded from the racket side by a digital video camera (Exilim HS EX-ZR1600; CASIO, Tokyo, Japan) at 240 fps. The digital video camera was installed 15 m away from participants. In addition, the angle of view was set so that it was in line with the badminton court to calculate a two-dimensional (2D) coordinate. The 2D coordinate data in the center of the racket were obtained using digital motion analysis software (Frame Dias 5; DKH, Tokyo, Japan). Racket velocity was calculated using five frames before the shuttle impact. In addition, the average value of five out of seven trials for each participant was used as that participant's value.

Mean and SD values and 95% confidence intervals (95% CIs) were calculated as descriptive data for each measurement. The correlation between racket velocity and shoulder strength was examined using Pearson's product-moment correlation coefficient. The correlation between shoulder extensor strength and shoulder internal rotator strength was examined using the same statistical analysis. Statistical analysis was conducted using R2.8.1, and a p-value<0.05 was considered statistically significant. The significant p-values were adjusted using the Holm-Bonferroni correction[12, 13]. Torque was used as muscle strength in the statistical analysis. Correlation values were evaluated according to the criteria of Hinkle et al.[14]: negligible, 0.00 to 0.30; low, 0.30 to 0.50; moderate, 0.50 to 0.70; high, 0.70 to 0.90; and very high, 0.90 to 1.00.

RESULTS

Participant characteristics are shown in Table 1. The results of statistical analysis are shown in Table 2. Regarding extensor strength, the correlation between the ET-MAP and ET-NP were significant (r=0.862; 95% CI, 0.611 to 0.956; p<0.001; high). The correlation between the ET-MAP and racket velocity of the badminton forehand smash was not statistically significant (r=0.612; 95% CI, 0.121 to 0.863; p=0.06). The correlation between the ET-NP and racket velocity for the badminton forehand smash was not significant (r=0.411; 95% CI, −0.153 to 0.773; p=0.145).

Regarding internal rotator strength measurements, the correlation between the IT-AEP and IT-NP was significant (r=0.729; 95% CI, 0.324 to 0.908; p=0.009; high). The correlation between the IT-AEP and racket velocity for the badminton forehand smash was significant (r=0.652; 95% CI, 0.186 to 0.879; p=0.046; moderate). The correlation between the IT-NP and racket velocity for the badminton forehand smash was not statistically significant (r=0.23; 95% CI, −0.342 to 0.678; p=0.429).

Table 2. The results of the Pearson's product-moment correlation coefficient

	ET-NP	IT-AEP	IT-NP	Racket velocity
ET-MAP	0.862** (0.611 to 0.956)	0.909** (0.731 to 0.971)	0.698* (0.266 to 0.897)	0.611 (0.119 to 0.862)
ET-NP		0.839** (0.556 to 0.948)	0.54* (0.013 to 0.832)	0.411 (−0.153 to 0.773)
IT-AEP			0.729** (0.324 to 0.908)	0.651* (0.184 to 0.878)
IT-NP				0.23 (−0.342 to 0.678)

(95% Confidence Interval)

The p-values were adjusted using the Holm-Bonferroni correction. *p<0.05, **p<0.01.

ET-MAP: The extension torque of the shoulder in the maximum shoulder abducted position; ET-NP: The extension torque of the shoulder in a neutral position; IT-AEP: The internal rotation torque of the shoulder in the abducted and external rotated position; IT-NP: The internal rotation torque of the shoulder in a neutral position.

DISCUSSION

The present study measured shoulder extensor strength and internal rotator strength in the NP and abducted position to confirm the relationship between these factors and racket velocity during the forehand smash. The IT-AEP was significantly correlated with racket velocity.

Shoulder joint movement during the impact phase during the smash involves the combination of shoulder extension and internal rotation in the abducted position[3]. Therefore, studies[6–10] have reported the relationship between performance and shoulder strength, and they measured the 90-degree abducted position of the shoulder. However, a player with high muscular strength in the abducted position of the shoulder may also have high muscular strength in the NP of the shoulder, which is often clinically used to evaluate shoulder injury. However, the relationship between racket velocity and shoulder strength may be different between the NP and abducted position of the shoulder. Therefore, the present study examined the relationships between racket velocity and shoulder extensor strength and between internal rotator strength in the shoulder NP and abducted position. The correlation coefficients between racket velocity and IT-AEP were 0.652. The sample size of this study was valid, because it was calculated with a level of significance of 5%, a detection power of 0.8, and an effect size of 0.652 was 13.

Regarding the relationship between velocity and shoulder extensor strength[10], reported that shoulder extension with the shoulder flexed 90 degrees was not significant for the serving velocity while playing tennis. Similar to the findings of Baiget et al.[10], the ET-MAP and ET-NP measurements were not significantly correlated with the racket velocity of the badminton smash in the present study. However, because the ET-MAP measurement in the present study showed a moderate correlation with racket velocity (r=0.612) by the p-value before the adjustment, further study, is necessary.

A previous study[10] of the relationship between performance and shoulder internal rotator strength reported a significant correlation (r=0.63) between ball velocity during a tennis serve and isometric shoulder internal rotator strength when the shoulder was in the 90-degree abducted position. Furthermore, Forthomme et al.[7] reported a significant correlation between the spike velocity and isokinetic concentric values of 60 degrees/sec (r=0.63), 240 degrees/sec (r=0.54), and 400 degrees/sec (r=0.47) for volleyball players whose shoulder internal rotator strength was assessed in the 90-degree abducted position. Similar to the results of previous studies of tennis[10] and volleyball[7], the IT-AEP measurement in the present study was moderately correlated (r=0.652, p<0.05) with the racket velocity of the badminton smash, but the IT-NP measurement showed no significant correlation with racket velocity. Additionally, internal rotator strength of the shoulder showed a high correlation (r=0.729, p<0.01) between the IT-AEP and IT-NP. Therefore, it is necessary to measure internal rotator strength in the shoulder abducted position.

The results of the present study suggest that angular specificity exists in shoulder internal rotator strength, and its specificity should be considered in the measurement. The internal rotator strength of AEP is valid measurements for assessing badminton players because they have a relationship with racket velocity. In addition, the internal rotator strength of AEP measurement was reported to have high reliability, and they are easy to obtain because the examiner is not involved in holding the HHD[11]. Therefore, this measurement is valid, reliable, and simple, suggesting that this is suitable for measuring badminton players' shoulder joint muscle strength. In other words, the internal rotator strength of AEP can be used to assess muscle strength during practical situations such as during specific training and rehabilitation.

The present study was limited because the only participants were athletes with limited competition levels. Furthermore, the characteristics of smash motions were not analyzed. Therefore, differences regarding the type of swing were not clear.

These findings suggest that the internal rotator strength of AEP are suitable measurements for evaluating badminton players. These results will help therapists and trainers to assess muscle strength during rehabilitation and training and to create a specific training program for increasing racket velocity during the forehand smash.

ACKNOWLEDGEMENTS

The authors thank the athletes who participated in this study. The authors also thank Editage (www.editage.jp) for English language editing.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

None.

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