Original Article

Relationship between shoulder complex strength and throwing velocity in club cricketers

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ABSTRACT

Cricket is a game of immense physical prowess requiring high levels of fitness and skill. Purpose: The aim of this study focused on examining the relationship between shoulder concentric strength and throwing velocity amongst club cricketers. Method: The study used a quantitative, cross-sectional design. A convenient sample of 40 male university cricketers was tested. Shoulder concentric strength was measured at 60º•sec^{-1} and 90º•sec^{-1} using an isokinetic dynamometer. Throwing velocity was measured using a Speed Gun. Results: Significant correlations were found between peak torque during concentric internal rotation at 60º•sec^{-1} and maximal throwing velocity for the first team ($r = 0.72$; $p = 0.01$), second team ($r = 0.67$; $p = 0.03$), third team ($r = 0.73$; $p = 0.01$) and fourth team ($r = 0.69$; $p = 0.02$). The correlation between strength ratio at 60º•sec^{-1} and maximal throwing velocity was also significant for the first team ($r = 0.76$; $p = 0.01$), second team ($r = 0.83$; $p = 0.002$), third team ($r = 0.70$; $p = 0.02$) and fourth team ($r = 0.94$; $p = 0.0001$). Conclusion: The shoulder concentric internal rotators play a significant role in throwing velocity of club cricketers. **Keywords:** Cricket; Arm speed; Muscle force.

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INTRODUCTION

The capacity to throw a ball at high speed and with precision is of utmost importance for successful performance in numerous ball sports, including cricket (Freeston et al., 2016). In cricket, the fielder must be able to throw the ball with precision and speed, during the attacking format of the game (Freeston et al., 2007). This relies heavily on throwing technique, and the kinetic chain is most valuable (Elliott & Anderson, 1990).

This mechanism involves neuromuscular co-ordination that transfers energy sequentially from lower body to the upper body (Seroyer et al., 2010). The more the body segments contribute to the sequential movement, the greater the potential velocity. The shoulder plays a crucial role in this (kinetic) chain, and the muscular forces developed in the shoulder are major factors in the overall throwing performance (Seroyer et al., 2010).

Previous research on throwing, focused primarily on strength testing of the shoulder and the ratio of the external to internal shoulder rotators (Marques et al., 2007; Andrade et al., 2010). One such study investigated throwing skill in adolescents to determine the physical adaptations that take place with repetitive throwing (Clements et al., 2001a). No significant differences were found in either the shoulder or elbow joint. However, maximum throwing speeds were attained in well-trained adolescent players without modifications in their isokinetic muscle strength (Clements et al., 2001b).

During throwing, balanced and coordinated action of the rotator cuff muscles of the shoulder are paramount in providing glenohumeral joint motion and stability (Reinold & Curtis, 2013). Thus, in order to prevent injuries, the muscular stabilizers of the shoulder complex (rotator cuff muscles) play a significant role (Paine &Voight, 2013). However, despite an increase in the amount of research on the area of isokinetic strength and sport performance (Cools et al., 2007; Cerrah et al., 2012), there is still a scarcity of studies on cricket (Derbyshire, 2007; Freeston et al., 2007; Freeston et al., 2016).

The application of isokinetic testing of the upper extremity is particularly valuable due to the demanding muscular work required in various sport-specific activities. Therefore, the aim of this study was to examine the relationship between isokinetic muscular strength of the shoulder complex and throwing velocity amongst university cricketers.

MATERIALS AND METHODS

A quantitative, cross-sectional study design was used.

Participants

Forty male cricketers, aged 18 to 32 years, were conveniently sampled from four teams at the cricket club at the University of the Western Cape. All participants were asymptomatic and injury-free for 3 months prior to testing.

Data Collection

Participants filled out a self-administered questionnaire which consisted of personal information and participation in cricket. The participants also completed physical profile evaluation as well as and cricket performance tests.

Physical profiling comprised measuring stature, body mass, subcutaneous skinfold thickness, girth circumferences and limb lengths. Throwing velocity of the dominant arm was measured using the Bushnell speed gun (Bushnell® Velocity™). Peak torque during concentric external and internal rotation and muscular strength ratios (i.e., concentric external to concentric internal shoulder rotation) at the isokinetic angular velocities of 60º•sec^{-1} and 90º•sec^{-1} was measured using the Biodex Pro System 4 isokinetic dynamometer (Biodex Medical Systems, Inc., Biodex Corp., Shirley, NY, USA).

Testing Procedures

Throwing Velocity

Before participating in the throwing velocity test, participants performed a warm-up for 5 to 10 minutes, consisting of a moderate-intensity jog followed by general stretching (static and dynamic stretches) of the major muscle groups (upper arms, shoulders, chest, upper and lower back and legs). The participants then performed progressive light-to-heavy intensity overhead throwing with standard cricket balls.

Next, participants performed maximal throws from behind a marked throwing line at a distance of 20.12 m from the target (wicket), equivalent to the length of a standard cricket pitch. A Bushnell Speed Gun was positioned behind a cricket net and used to measure throwing velocity. Participants were instructed to, "Throw the ball as hard as possible at the target." Participants performed five throws at maximal intensity with an overarm throwing technique. Participants were permitted one stride forward with the front leg while maintaining the front foot behind the throwing line until ball release. This relatively stationary starting position was adopted to minimize the influence of extrinsic factors on throwing performance, such as approach speed, approach angle, and ball pick-up. The highest speed measured was recorded as maximal throwing velocity, and the average of the five throws as the average throwing velocity (Freeston et al., 2007).

Isokinetic Strength

Isokinetic shoulder strength was measured on a different day to throwing velocity. Participants warmed up by pedalling on an arm ergometer at a moderate intensity for approximately 5 minutes, followed by stretching.

Next, the participants were seated for testing concentric internal and concentric external rotator peak torque of the shoulder joint at the isokinetic angular velocities of 60º•sec^{-1} and 90º•sec^{-1} with the arm positioned in 45º of shoulder abduction (Edouard et al., 2013). Each participant was allowed three (3) trials for familiarization and thereafter, performed the isokinetic tests. The strength ratio was expressed as a percentage of peak torque (ER ÷ IR x 100).

Statistical Analysis

Data was analysed the Statistical Package for the Social Sciences (SPSS), version 22 (IBM, New York, USA). Descriptive statistics (mean and standard deviation) and inferential statistics (Pearson product-moment correlation coefficient and the Kruskal-Wallis H test) were generated. A p value <0.05 indicated statistical significance. Mann Whitney test was applied post hoc with a Bonferroni correction, so all effects are reported at a 0.0083 (0.05 ÷ 6 comparative groups) critical level of significance (Field, 2009).

Ethical Considerations

Ethical clearance to conduct the study was obtained from the Senate Biomedical Research Ethics Committee of the University of the Western Cape (Ethical clearance number 13/9/27). During the recruitment phase of the study, an information letter was given to all the cricket players and their consent to participate in the study was requested in writing.

RESULTS

A total of 40 participants from four university cricket teams participated in the study. The results for age, stature, body mass, lean body mass, body fat mass, body fat percentage, waist circumference, hip circumference and arm limb lengths of the participants in the four teams are presented in Table 1 as mean (±SD). The mean ages of the first, second, third and fourth team participants were 24.40±2.91, 21.60±2.79, 20.80±3.55 and 21.50±3.24 years, respectively. There was a significant difference for age between the four teams [H(3) = 9.159, p = 0.027]. The post-hoc Mann–Whitney test was then used to test this finding. A Bonferroni correction was applied to the post hoc analysis to minimize the type I error so that all effects are reported at a 0.0083 level of significance. Post hoc analysis for age showed no significant differences between teams, i.e., first and second teams (U = 23.5, r = −0.45), first and third teams (U = 15.5, r =- 0.59), first and fourth teams (U = 21.5, r = −0.49), second and third teams (U = 34.5, r = −0.27), second and fourth teams (U = 46.5, r = −0.06) and third and fourth teams (U = 38.5, r = −0.19).

The mean lean body masses of the first, second, third and fourth teams were 68.26±6.91, 65.81±6.01, 65.62±5.60 and 57.64±8.99 kg, respectively. There was a significant difference for lean body mass between the four teams [H(3) = 8.343, p = 0.039]. Post hoc analysis showed no significant differences between teams, i.e., first and second teams (U = 40.5, r = −0.16), first and third teams (U = 40.5, r = -0.16), first and fourth teams (U = 18.0, r = −0.54), second and third teams (U = 46, r = −0.07), second and fourth teams (U = 20.5, r = −0.49), and third and fourth teams (U = 22.0, r = −0.47).

The mean body fat masses of the first, second, third and fourth teams were 10.30±5.03, 6.80±2.13, 10.90±5.88 and 10.70±5.18 kg, respectively, with no significant differences between groups [H(3) = 4.168, p = 0.244]. Similarly, the mean body fat percentages of the first, second, third and fourth teams were 12.72±4.80, 9.28±2.29, 13.69±6.64 and 14.28±6.38 %, respectively, with no significant differences between groups [H(3) = 4.804, p = 0.187].

The mean waist circumferences of the first, second, third and fourth teams were 82.34±7.54, 81.66±3.94, 82.39±5.65 and 81.79±5.77 cm, respectively, with no significant differences between groups [H(3) = 0.487, p = 0.922]. Similarly, the mean hip circumferences of the first, second, third and fourth teams were 99.75±8.25, 98.74±4.47, 100.21±5.19 and 100.52±8.25 cm, respectively, with no significant differences between groups [H(3) = 2.583, p = 0.461].

The mean total arm lengths displayed by the first, second, third and fourth teams were 79.52±2.29, 80.14±3.64, 76.59±2.22 and 71.60±1.77 cm, respectively. There was a significant difference for total arm length between the four teams [H(3) = 25.006, p = 0.000]. Post hoc analysis showed significant differences between teams, i.e., first and fourth teams (U = 0.00, r = −0.85), second and fourth teams (U = 4.00, r = −0.78), and third and fourth teams (U = 1.50, r = −0.82).

The mean number of years of experience playing cricket in the first, second, third and fourth teams was 14.00±3.40, 10.00±1.30, 10.00±2.40, and 10.00±1.30 years, respectively. There was a significant difference for number of years playing cricket between the four teams [H(3) = 15.012, p = 0.002]. Post hoc analysis showed significant differences between teams, i.e., first and second teams (U = 9.0, r = −0.71), first and third teams (U = 9.0, r = −0.71), and first and fourth teams (U = 12.5, r = −0.64).

Table 1. Physical characteristics of the participants per team

Variable	First team (n = 10) (X±SD)	Second team (n = 10) (X±SD)	Third team (n = 10) (X±SD)	Fourth team (n = 10) (X±SD)	p value
Age (years)	24.40±2.91	21.60±2.76	20.80±3.55	21.50±3.24	0.027*
Stature (m)	1.76±0.06	1.78±0.09	1.76±0.04	1.73±0.06	0.521
Body mass (kg)	78.59±10.78	72.70±7.29	76.52±9.09	69.89±9.06	0.331
Lean body mass (kg)	68.26±6.91	65.81±6.01	65.62±5.60	57.46±8.99	0.039*
Body fat mass (kg)	10.30±5.03	6.81±2.13	10.88±5.88	10.67±5.18	0.244
Body fat (%)	12.72±4.80	9.28±2.29	13.69±6.64	14.28±6.38	0.187
Waist circumference (cm)	82.34±7.54	81.66±3.94	82.39±5.65	81.79±5.77	0.922
Hip circumference (cm)	99.75±8.25	98.74±4.47	100.21±5.19	100.52±8.25	0.461
Total arm length (cm)	79.52±2.29	80.14±3.64	76.59±2.22	71.60±1.77	0.000*
Players experience (years)	14.00±3.40	10.00±1.33	10.00±2.40	10.00±1.33	0.002*

** indicates statistically significant difference between groups (p<0.05).*

The results of the isokinetic performance measurements of the participants per team for throwing velocity, peak torque (PT) during concentric external rotation (ER) and concentric internal rotation (IR) at $60^{o}\cdot sec^{-1}$ and $90^{o}\cdot sec^{-1}$, and the concentric strength ratios of the internal to external rotators at $60^{o}\cdot sec^{-1}$ and $90^{o}\cdot sec^{-1}$ are presented in Table 2 as mean (±SD).

The maximal throwing velocities for the first, second, third and fourth teams were 108.90±6.17, 105.80±3.19, 97.70±8.41 and 95.70±8.85 $km\cdot h^{-1}$, respectively. There was a significant difference in maximal throwing velocity between the four teams [H(3) = 22.006, p = 0.000]. Post hoc analysis showed significant differences between teams, i.e., first and third teams (U = 8.0, r = −0.71), first and fourth teams (U = 5.5, r = −0.75), second and third teams (U = 10.5, r = −0.67), and second and fourth teams (U = 6.0, r = −0.75).

The average throwing velocities for the first, second, third and fourth teams were 106.64±5.48, 104.32±3.00, 96.50±8.23 and 94.18±8.94 $km\cdot h^{-1}$, respectively. There was a significant difference in average throwing velocity between the four teams [H(3) = 19.559, p = 0.000]. Post hoc analysis showed significant differences between teams, i.e., first and third teams (U = 12.0, r = −0.64), first and fourth teams (U = 8.0, r = −0.71), second and third teams (U = 12.5, r = −0.64), and second and fourth teams (U = 6.5, r = −0.74).

The peak torques during concentric external rotation at $60^{o}\cdot sec^{-1}$ for the first, second, third and fourth teams were 35.70±3.84, 33.99±2.69, 31.16±2.20 and 30.71±2.33 Nm, respectively. There was a significant difference in peak torque during external rotation at 60 $^{o}\cdot sec^{-1}$ between the four teams [H(3) = 12.724, p = 0.005]. Post hoc analysis showed significant differences between second and third teams (U = 14.0, r = −0.61).

The peak torques during concentric internal rotation at $60^{o}\cdot sec^{-1}$ for the first, second, third and fourth teams were 42.59±2.88, 42.87±2.70, 41.30±3.11 and 40.23±2.67 Nm, respectively, with no significant differences between groups [H(3) = 5.161, p = 0.160].

The peak torque to body weight (PT ÷ BW x 100) ratios during concentric external rotation at $60^{o}\cdot sec^{-1}$ for the first, second, third and fourth teams were 46.21±7.85, 47.44±8.52, 41.30±6.15 and 44.63±6.49 %, respectively, with no significant differences between teams [H(3) = 3.601, p = 0.308].

The peak torque to body weight (PT ÷ BW x 100) ratios during concentric internal rotation at 60º•sec^{-1} for the first, second, third and fourth teams were 55.00±7.42, 59.70±9.06, 54.98±9.99 and 58.53±8.90 %, respectively, with no significant differences between teams [H(3) = 2.226, p = 0.527].

The strength ratios during concentric external to concentric internal rotation at 60º•sec^{-1} for the first, second, third and fourth teams were 79.03±2.35, 78.34±2.20, 75.40±1.55, and 75.25±1.12 %, respectively. There was a significant difference in strength ratio at 60 º•sec^{-1} between the four teams [H(3) = 18.535, p = 0.000]. Post hoc analysis showed significant differences between teams, i.e., first and third teams (U = 12.0, r = −0.65), first and fourth teams (U = 7.0, r = −0.73), second and third teams (U = 14.5, r = −0.60), and second and fourth teams (U = 10.0, r = −0.68).

The peak torques during concentric external rotation at 90º•sec^{-1} for the first, second, third and fourth teams were 33.84±3.92, 33.13±3.27, 31.77±3.68 and 29.96±2.45 Nm, respectively, with no significant differences between teams [H(3) = 5.931, p = 0.115]. The peak torques during concentric internal rotation at 90º•sec^{-1} of the first, second, third and fourth teams were 38.85±5.12, 39.96±3.38, 35.76±4.70 and 33.31±3.24 Nm, respectively. There was a significant difference in peak torque during internal rotation at 90º•sec^{-1} between the four teams [H(3) = 11.976, p = 0.007]. Post hoc analysis showed significant differences between second and fourth teams (U = 8.0, r = −0.71).

The peak torque to body weight (PT ÷ BW x 100) ratios during concentric external rotation at 90º•sec^{-1} for the first, second, third and fourth teams were 43.47±5.62, 46.25±8.74, 42.13±7.65 and 43.63±7.19 %, respectively, with no significant differences between teams [H(3) = 1.275, p = 0.735].

The peak torque to body weight (PT ÷ BW x 100) ratios during concentric internal rotation at 90º•sec^{-1} for the first, second, third and fourth teams was 50.07±8.74, 55.72±9.57, 47.36±8.41 and 48.39±7.44 %, respectively, with significant differences between groups [H(3) = 8.775, p = 0.032]. Post hoc showed significant differences between second and fourth teams (U = 14.00, r = -0.61).

Table 2. Throwing velocity, isokinetic peak torque and strength ratio measurements per team

Variables	First team (n = 10) (X±SD)	Second team (n = 10) (X±SD)	Third team (n = 10) (X±SD)	Fourth team (n = 10) (X±SD)	p value
Maximal throwing velocity (km•h^{-1})	108.90 ± 6.17	105.80 ± 3.19	97.70 ± 8.41	95.70 ± 8.85	0.000*
Average throwing velocity (km•h^{-1})	106.64 ± 5.48	104.32 ± 3.00	96.50 ± 8.23	94.18 ± 8.94	0.000*
PT-ER at 60º•sec^{-1} (Nm)	35.70 ± 3.84	33.99 ± 2.69	31.16 ± 2.20	30.71 ± 2.33	0.005*
PT-IR at 60º•sec^{-1} (Nm)	42.59 ± 2.88	42.87 ± 2.70	41.30 ± 3.11	40.23 ± 2.67	0.160
Peak TQ/BW (%) ER at 60º•sec^{-1}	46.21 ± 7.85	47.44 ± 8.52	41.30 ± 6.15	44.63 ± 6.49	0.308
Peak TQ/BW (%) IR at 60º•sec^{-1}	55.00 ± 7.42	59.70 ± 9.06	54.98 ± 9.99	58.53 ± 8.80	0.527
SR at 60º•sec^{-1} (%)	79.03 ± 2.35	78.34 ± 2.20	75.40 ± 1.55	75.25 ± 1.12	0.000*
PT-ER at 90º•sec^{-1} (Nm)	33.84 ± 3.92	33.13 ± 3.27	31.77 ± 3.68	29.96 ± 2.45	0.115
PT-IR at 90º•sec^{-1} (Nm)	38.85 ± 5.12	39.96 ± 3.38	35.76 ± 4.70	33.31 ± 3.24	0.007*
Peak TQ/BW (%) ER at 90º•sec^{-1}	43.47 ± 5.62	46.25 ± 8.74	42.13 ± 7.65	43.63 ± 7.19	0.735
Peak TQ/BW (%) IR at 90º•sec^{-1}	50.07 ± 8.74	55.72 ± 9.57	47.36 ± 8.41	48.39 ± 7.44	0.032*
SR at 90º•sec^{-1} (%)	82.81 ± 1.65	82.40 ± 1.47	81.63 ± 1.39	81.17 ± 0.92	0.014*

*PT-ER= Peak torque of external rotation; PT-IR= Peak torque of internal rotation; SR= Strength ratio. * indicates significant difference between groups (p<0.05).*

The strength ratios during concentric external to concentric internal rotation at 90º•sec^{-1} for the first, second, third and fourth teams were 82.81±1.65, 82.40±1.47, 81.63±1.47, and 81.17±0.92 %, respectively, with significant differences between teams [H(3) = 10.600, p = 0.014]. However, post hoc analysis showed no significant differences between teams.

Significant results were found for the relationship between peak torque during concentric internal rotation at 60º•sec^{-1} and maximal throwing velocity, and between strength ratio during concentric external to concentric internal rotation at 60º•sec^{-1} and maximal throwing velocity in all four teams (Table 3). The strength ratio during concentric external to concentric internal rotation at 90º•sec^{-1} and maximal throwing velocity also displayed significant correlations, but in the first and second teams only. Furthermore, there was a statistically significant correlation between maximal throwing velocity and peak torque to body weight ratio for internal rotation at 60º•sec^{-1} in the second team. Additionally, there was a strong correlation between maximal throwing velocity and peak torque to body weight ratio for external and internal at 90º•sec^{-1} in the second team.

Table 3. Relationship between isokinetic peak torque, strength ratios and maximal throwing velocity per team

Variables	Maximal throwing velocity			
	First team	Second team	Third team	Fourth team
Isokinetic peak torque				
PT-ER @ 60˚•sec^{-1}	0.60	0.61	0.60	0.47
PT-IR @ 60˚•sec^{-1}	0.72*	0.67*	0.73*	0.69*
Peak TQ/BW (%) ER at 60º•sec^{-1}	0.19	0.61	0.36	0.01
Peak TQ/BW (%) IR at 60º•sec^{-1}	0.13	0.66*	0.35	0.17
PT-ER @ 90˚•sec^{-1}	0.63	0.60	0.62	0.61
PT-IR @ 90˚•sec^{-1}	0.63	0.62	0.61	0.61
Peak TQ/BW (%) ER at 90º•sec^{-1}	0.31	0.65*	0.45	0.16
Peak TQ/BW (%) IR at 90º•sec^{-1}	0.28	0.64*	0.49	0.26
ER/IR Ratio				
SR @ 60˚•sec^{-1}	0.76*	0.83*	0.70*	0.94*
SR @ 90˚•sec^{-1}	0.72*	0.75*	0.39	0.57

*PT-ER = Peak torque of external rotation; PT-IR = Peak torque of internal rotation; Peak TQ/BW (%) ER = Peak torque to Body weight in external rotation; Peak TQ/BW (%) IR = Peak torque to Body weight in internal rotation; SR = Strength ratio of internal to external rotator peak torque. * indicates significant correlation (p<0.05).*

Significant correlations were found between peak torque during concentric external rotation at 60º•sec^{-1} and average throwing velocity, but in the first and second teams only (Table 4). The correlation between peak torque during internal rotation at 60º•sec^{-1} and average throwing velocity was also significant, but in the first team only. Also, the correlation between peak torque during external rotation at 90º•sec^{-1} and average throwing velocity was significant, but in the second team only. Finally, the correlation between strength ratio during concentric external to concentric internal rotation and average throwing velocity was statistically significant in all four teams both at 60º•sec^{-1} and 90º•sec^{-1}. Furthermore, there was a statistically significant correlation between average throwing velocity and peak torque to body weight ratio for internal rotation at 60º•sec^{-1} in the second team. Additionally, there was a strong correlation between average throwing velocity and peak torque to body weight ratio for external at 90º•sec^{-1} in the second team.

Table 4. Relationship between isokinetic peak torque, strength ratios and average throwing velocity per team

Variables	Average throwing velocity			
	First team	Second team	Third team	Fourth team
Isokinetic peak torque				
PT-ER @ 60˚•sec-1	0.76*	0.73*	0.38	0.55
PT-IR @ 60˚•sec-1	0.64*	0.60	0.60	0.45
Peak TQ/BW (%) ER at 60º•sec-1	0.19	0.62	0.34	0.07
Peak TQ/BW (%) IR at 60º•sec-1	0.12	0.69*	0.34	0.13
PT-ER @ 90˚•sec-1	0.59	0.65*	0.60	0.61
PT-IR @ 90˚•sec-1	0.59	0.58	0.60	0.61
Peak TQ/BW (%) ER at 90º•sec-1	0.26	0.69*	0.43	0.14
Peak TQ/BW (%) IR at 90º•sec-1	0.26	0.63	0.47	0.23
ER/IR Ratio				
SR @ 60˚•sec-1	0.77*	0.85*	0.71*	0.94*
SR @ 90˚•sec-1	0.77*	0.72*	0.73*	0.66*

*PT-ER = Peak torque of external rotation; PT-IR = Peak torque of internal rotation; Peak TQ/BW (%) ER = Peak torque to Body weight in external rotation; Peak TQ/BW (%) IR = Peak torque to Body weight in internal rotation; SR = Strength ratio of internal to external rotator peak torque. * indicates significant correlation (p<0.05).*

DISCUSSION

The aim of this study was to examine the relationship between isokinetic muscular strength of the shoulder complex and throwing velocity amongst club cricketers. Sports that involve overhead throwing (such as baseball, cricket, tennis, volleyball and handball) require a delicate balance between shoulder strength, mobility and stability in order to meet the functional demands of performance and competition (Dale et al., 2007; Borsa et al., 2008; Cha et al., 2014). Such integration involves muscular strength, endurance, flexibility and neuromuscular control (Cha et al., 2014). If any of these factors become impaired, functional instability might occur and performance may deteriorate (Dale et al., 2007; Cha et al., 2014).

Generating high throwing speed in cricket is essential for an effective throw, and plays a crucial role in the players' attacking performance, especially if the throwing speed can be enhanced and applied effectively within a team's offensive play (DeRenne et al., 2001). Throwing a cricket ball at maximum velocity is arguably one of the most dynamic skills in cricket, with many repetitions of the throwing action performed in a game. The glenohumeral internal rotators (i.e., subscapularis, pectoralis major and latissimus dorsi) contract concentrically to generate peak internal rotation angular velocities approximating 6500˚•sec^{-1} at ball release (Escamilla & Andrews, 2009). Since throwing requires specific muscle actions, muscle strength may arguably be considered essential for optimal throwing performance.

In the present study, concentric shoulder strength correlated significantly with throwing velocity. Specifically, the measurements were peak torque of concentric external rotation, peak torque of concentric internal rotation, peak torque to body weight ratio in concentric external rotation, peak torque to body weight ratio in concentric internal rotation and strength ratio of concentric external to concentric internal rotator peak torque. Clements et al. (2001a) demonstrated that isometric shoulder internal rotation peak torque to body weight ratio correlated significantly with throwing speed in elite adolescent baseball players. In addition, they also reported that concentric shoulder internal rotation peak torque to body weight correlated moderately, but not significantly, with throwing speed. Isometric shoulder internal rotation (and concentric elbow extension) peak torque to body weight ratios together accounted for 71% of the variation in throwing speed (Clements et al., 2001a).

In the current study, the relationship between concentric external rotation at an isokinetic angular velocity of 60º•sec^{-1} and maximal throwing velocity showed a positive correlation in all teams, but none were statistically significant. In contrast, Bayios et al. (2001) showed that the peak torques of the internal and external rotators of the shoulder were not related to ball velocity. They concluded that the peak torques of the internal and external rotators were not good indicators of throwing velocity. Other studies also reported a poor correlation between maximal shoulder muscle strength and throwing velocity (Goharpey et al., 2007; Jones & Bampouras, 2010; Çetin & Balcı, 2015).

The present study showed statistically significant correlations between concentric internal rotator strength at 60º•sec^{-1} and maximal throwing velocity in all four teams. In contrast to these results, concentric shoulder internal rotation peak torque was reported previously to only contribute minimally (6-10%) to throwing speed in baseball players (Pedegana et al. 1982). Bartlett et al. (1989) reported that concentric shoulder adduction peak torque accounted for 55% of throwing speed. However, the shoulder adductors, such as pectoralis major, latissimus dorsi and teres major, also contribute to internal rotation. Therefore, a clear distinction between the contribution ascribed to shoulder adduction and internal rotation remains unclear.

The relationship between peak torque during concentric external rotation at 90º•sec^{-1} and maximal throwing velocity showed a moderately positive correlation in all four teams, but none were statistically significant. Similarly, the relationship between peak torque during internal rotation at 90º•sec^{-1} and maximal throwing velocity also displayed a moderately positive correlation that was also statistically not significant. Similarly, Derbyshire (2007) reported that peak torque during concentric external rotation at 90º•sec^{-1}, and the peak torque during concentric internal rotation at 90º•sec^{-1} correlated positively with throwing velocity, but neither were statistically significant.

In the present study, statistically significant positive relationships were found between strength ratio during concentric external to concentric internal rotation at 60º•sec^{-1} and average and maximal throwing velocities in all four teams. This finding indicates that the peak torques of the external and internal rotator muscles are important in achieving high ball speeds when throwing. Pontaga and Ziden (2014) who compared shoulder external to internal rotator muscle peak torques, average power and strength ratios in the dominant and non-dominant arms showed positive correlations between the isokinetic characteristics of the shoulder rotator muscles and ball throwing speed.

The relationship between the strength ratio during concentric external to concentric internal rotation and maximal throwing velocity at 90º•sec^{-1} showed statistically significant correlations in both the first and second teams. In addition, the relationship between the strength ratios during concentric external to concentric internal rotation at 60º•sec^{-1} and 90º•sec^{-1} and average throwing velocity showed statistically significant correlations in all teams. In contrast, Derbyshire (2007) reported a very weak correlation between strength ratio and throwing velocity at 90º•sec^{-1}. In the latter study, the researcher concluded that in cricket players, energy is generated in the torso, and not merely due to the torque generated in the shoulder joint. This emphasised the kinetic chain involved in throwing and the energy that is transferred from one link to the next in throwing. Because of the substantial contribution of the lower extremity in the cricket throwing action (Kreighbaum & Barthels, 1990), differences in kinetic chain (sequential lower and upper limb involvement) and muscle strength between players in the various teams may account for differences in throwing speed.

What does this article add?

The results of this study support the important role of the shoulder internal rotators in increasing the force on the ball, which partially determines the ultimate ball velocity during the acceleration phase of throwing in cricket players. The study provides evidence that shoulder concentric internal rotator strength is a good measure of throwing velocity in club cricket players. In certain playing situations, fast throwing arms can help produce run-outs and thereby limit the loss of unnecessary wickets. Therefore, it may be recommended that training programs focus on the development of shoulder concentric internal rotator muscle strength to increase throwing velocity. Additionally, cricket players must learn to coordinate the muscle activity within the throwing arm, as well as the motion of the throwing arm with the rest of the body in order to increase throwing speed. Ultimate throwing speed is not dependent on throwing arm muscle strength entirely.

CONCLUSION

This study showed a significant correlation between isokinetic peak torque for concentric internal rotation at 60º•sec^{-1} and throwing velocity. Also, the strength ratio during concentric external to concentric internal rotation at 60º•sec^{-1} and throwing velocity correlated significantly Consequently, shoulder concentric internal rotator strength plays a significant role in throwing velocity and should be considered as part of a well-planned sport conditioning programs for players involved in sports such as cricket that incorporate a sizeable component of throwing in competitive sport performance. Furthermore, there is strong evidence in the literature of kinetic chain involvement in the cricket throw, so that as more body segments are used sequentially, this generates greater ball velocity at release.

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