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Physical and performance measures of university cricket players

R.V. November and L.L. Leach

Abstract

The ability to throw a ball at high velocity and with great accuracy is critical for successful performance in many ball sports. This study examines the physical characteristics and performance measurements amongst university cricketers. A convenient sample of 40 male cricketers from four teams at the University of the Western Cape was tested. Physical characteristics comprised stature, body mass, skinfold thickness, girth circumferences and limb lengths. Isokinetic strength was measured at 60º•sec^{-1} and 90º•sec^{-1}using the Biodex Pro System 4 isokinetic dynamometer. Throwing velocity was measured using a calibrated Speed Gun. The fourth team had a significantly shorter arm length than the other teams. Player experience also differed significantly between the first team and the other three teams. Age and body fat percentage correlated significantly with throwing velocity, but in the first team only. Significant correlations were found for the following variables, i.e., between age and strength ratio in the first team; between hip circumference and peak torque during internal rotation at 90º•sec^{-1} in the second team; between body mass and peak torque during internal rotation at 60º•sec^{-1} in the third team; between total arm length and peak torque during internal rotation at 60º•sec^{-1} in the fourth team. In conclusion, this study found that various physical characteristics such as age and body fat percentage significantly influenced throwing velocity, while body mass, hip circumference and total arm length had a significant influence on peak torque.

Introduction

Various physical and anthropometric characteristics of athletes play an important role in determining success in sport (Koley et al., 2012). It has been reported in the literature that specific physical characteristics indicate whether a player would be suitable for high level competition in a specific sport (Gutnik et al., 2015; Bennur, 2016).

The isokinetic dynamometer is useful in characterizing an athlete's muscular status, since it provides information about strength, power, endurance, and strength ratios. Isokinetic evaluation is an extensively used tool for studying the shoulder muscle performance of both healthy and injured athletes (Steulcken et al., 2008; Stickley et al., 2008; Saccol et al., 2010).

Cricketers are exposed to many sport-specific demands characterized be long duration training and practice (Koley, 2011). The sport of cricket requires repetitive bouts of high velocity upper limb movement, which involves high velocity throwing. Considering that high velocities are reached during the throw, the greatest velocities available in isokinetic dynamometers are used to evaluate internal and external rotation of the shoulder (Carter et al., 2007; Andrade et al., 2010).

Current literature explores the isokinetic strength of the shoulder in overhead sport, namely, in baseball (Clement et al., 2001a; Clement et al., 2001b; Carter et al., 2007; Byram et al., 2010).There is limited research on isokinetic strength in cricketers.

For success in cricket, it is essential that players are skilled at throwing the ball with power and accuracy across the field during play (Derbyshire, 2007). An effective throw in cricket is the result of a combination of good technique and the correct anthropometric measurements (Van den Tillar & Ettema, 2003). The increments in workload, if not properly regulated, can result in predisposing factors that can lead to sport-related injuries (Gabbett & Domrow, 2007; Gabbett, 2016). In an attempt to address these issues, the aim of this study focused on examining the physical characteristics, inclusive of age, stature, body weight, body fat percentage, limb lengths and girth circumferences, and the effects on performance measurements, specifically throwing velocity, peak torque and strength ratios, amongst university cricketers.

Methodology

A cross-sectional quantitative experimental study design was used in this study.

Participants

A convenient sample of forty (40) male cricketers ranging in age from 18 to 32 years from the first to the fourth team at the cricket club of the University of the Western Cape gave their written informed consent to participate in the study. The method of recruiting the cricketers was by convenient sampling.

Exclusion criteria

Participants were excluded if they were younger than 18 years or older than 32 years or presented with acute or chronic shoulder pathology within the previous three (3) months.

Data collection

Each cricketer filled out a general purpose questionnaire consisting of personal information, years of participating in cricket and current level of competitive participation. The testing procedures included each participant’s physical profile, throwing velocity and isokinetic strength. Physical profile comprised testing stature, body mass, subcutaneous skinfold thickness, girth circumferences and limb lengths according to the International Society for the Advancement of Kinanthropometry (ISAK) guidelines (Marfell-Jones et al., 2006). Throwing velocity entailed measuring maximal and average throwing velocities of the dominant arm using the Bushnell velocity speed gun (Bushnell®

Velocity™, Overland Park, Kansas, USA). Lastly, isokinetic strength, peak torque during external and internal rotation at the isokinetic angular velocities of $60^{o} \bullet sec^{-1}$ and $90^{o} \bullet sec^{-1}$, and the muscular strength ratios were measured using the Biodex Pro System 4 isokinetic dynamometer (Biodex Medical Systems, Inc., Biodex Corp., Shirley, New York, USA).

Testing Procedures

Physical measures

The physical measures comprised stature, body mass, subcutaneous skinfold thickness, girth circumferences and limb lengths using the following anthropometric equipment, namely, a combination stadiometer and balance beam scale (Seca model 700, Gmbh & Co., Germany), a Harpenden skinfold caliper (Harpenden, UK), a Harpenden sliding caliper (Harpenden, UK), a metal tape measure (Sanny Medical, HK) and a Harpenden anthropometer (Harpenden, UK). All instruments were previously calibrated by the suppliers.

Throwing velocity

Testing of throwing velocity was conducted at the University of the Western Cape's cricket oval. Before participating in the throwing velocity test, participants performed a general warm-up for 5 to 10 minutes, consisting of light-to-moderate intensity jogging around the cricket oval. This was followed by general stretching (static and dynamic stretches) of the major muscle groups (upper limb stretches predominantly), and 10 to 15 minutes of progressive light- to-vigorous intensity overhead throwing with a standard cricket ball. Regulation, four-piece leather cricket balls weighing 156 g were thrown into a net with no specific target.

The participants performed maximal throws from behind a marked throwing line at a distance of 20.12 m from the target. This distance was equal to the length of a standard cricket pitch. A cordless Bushnell Velocity Speed Gun was positioned behind the net and used to measure maximal throwing velocity. The participants were instructed to "throw as hard as possible towards the radar gun". The participants performed five throws at maximal intensity with an overarm throwing technique simulating the cricket throw. The 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 outside factors on throwing performance, such as approach speed, approach angle, and ball pick-up. The highest speed measured was recorded as the participant's maximal throwing velocity, and the average of the five throws as the average throwing velocity (Freeston et al., 2007).

Isokinetic strength

Before the start of isokinetic testing, participants warmed up using an arm ergometer, pedalling at a moderate intensity (60% HRR) for approximately 5 minutes followed by static (chest, shoulder and triceps) stretches held for 10 - 15 seconds per stretch. An isokinetic contraction test was done to measure maximal muscular strength and to examine the ratio of the internal to external rotator muscular strength in the dominant throwing shoulder. For isokinetic testing, participants were positioned in a seated position and stabilized for testing internal and external rotation with the shoulder positioned in 45° of abduction (Davies et al., 2000; Dvir, 2004; Edouard et al., 2013). The humerus was aligned with the rotational axis of the dynamometer head. The elbow was supported in 90° flexion, and the forearm and wrist were in neutral pronation/supination.

Prior to testing, each participant received concise testing instructions how to complete testing on the Biodex isokinetic dynamometer. Each participant was allowed three (3) trials for familiarization with the equipment. Thereafter, participants performed the maximal isokinetic strength tests at the two testing speeds. The participants were assessed for concentric/concentric isokinetic shoulder contractions for five maximal repetitions performed for both internal and external rotation at the two speeds, namely, $60^{o}{\bullet}sec^{-1}$ and $90^{o}{\bullet}sec^{-1}$. Participants were verbally encouraged to move the arm "as hard and as fast as possible" during concentric testing. A rest period of approximately 5 minutes was given between tests for full recovery of the participants.

Data analysis

Data was captured by double entry for correctness using Microsoft Office Excel. It was then exported to the Statistical Package for the Social Sciences (SPSS), version 22 (IBM, New York, USA) for data analysis. 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. Pearson correlation was used to assess the relationship between the two principle variables, namely, physical characteristics and performance measurements (isokinetic strength and throwing velocity). Kruskal-Wallis H test was used to examine if there were statistically significant differences between the four groups. 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 and permission to conduct the study was granted by the Senate Research and Ethics Committee of the University of the Western Cape. Permission was also granted by the management committee of the cricket club of the University of the Western Cape for the players to participate voluntarily in the study (Ethics clearance number 13/9/27). During the recruitment phase of the study, an information letter, including the background and purpose of the study, was given to all the cricket players and their consent to participate was requested in writing.

Participants were informed that participation in the study was voluntary and that they could refuse to perform the tests or withdraw from the study at any stage without any negative consequences. Participant confidentiality and privacy, as well as data protection were assured at all times. Each participant was allocated an identity code to protect their identity when capturing the data either on data sheets or on computer. Once the data was collected, only the researcher had access to the participants' files and database. All participant files were stored in a locked cabinet. The computer database containing the participants' information was protected by a password to which only the researcher had access.

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 age of the first, second, third and fourth team participants was 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 follow up this finding. A Bonferroni correction was applied to the post hoc analysis to minimise 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 stature of the first, second, third and fourth team participants was 1.76 ± 0.06, 1.78 ± 0.09, 1.76 ± 0.04 and 1.73 ± 0.06 m, respectively, with no significant differences between groups [H(3) = 2.258, p = 0.521]. Similarly, for mean body mass, the results were 78.59 ± 10.78, 72.70 ± 7.29, 76.52 ± 9.09 and 69.89 ± 9.06 kg for the first, second, third and fourth teams, respecti ely, with no significant differences between groups [H(3) = 3.423, p = 0.331].

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 mean lean body mass of the first, second, third and fourth team cricket participants was 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 for lean body mass 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 mass of the first, second, third and fourth teams was 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] . The mean body fat percentage of the first, second, third and fourth teams was12.72 ± 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 circumference of the first, second, third and fourth teams was 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 circumference of the first, second, third and fourth teams was 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 length displayed by the first, second, third and fourth teams was 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 for total arm length 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 team (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 of experience playing cricket between the four teams [H(3) = 15.012, p = 0.002]. Post hoc analysis for number of years of experience playing cricket 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).

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

The mean maximal throwing velocity for the first, second, third and fourth teams was 108.90 ± 6.17, 105.80 ± 3.19, 97.70 ± 8.41 and 95.70 ± 8.85 $km\bullet h^{-1}$, respectively. There was a significant difference for maximal throwing velocity between the four teams [H(3) = 22.006, p = 0.000]. Post hoc analysis for maximal throwing velocity 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 team (U = 6.0, r = −0.75).

The average throwing velocity for the first, second, third and fourth teams was 106.64 ± 5.48, 104.32 ± 3.00, 96.50 ± 8.23 and 94.18 ± 8.94 km•h^{-1}, respectively. There was a significant difference for maximal throwing velocities between the four teams [H(3) = 19.559, p = 0.000]. Post hoc analysis for average throwing velocity 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 mean peak torque during external rotation at 60^{o}•sec^{-1} for the first, second, third and fourth teams was 35.70 ± 3.84, 33.99 ± 2.69, 31.16 ± 2.20 and 30.71 ± 2.33 Nm, respectively. There was a significant difference for peak torque during external rotation at 60 ^{o}•sec^{-1} between the four teams [H(3) = 12.724, p = 0.005]. Post hoc analysis for peak torque during external rotation at 60^{o}•sec^{-1} showed significant differences between teams, i.e., second and third teams (U = 14.0, r = −0.61).

The mean peak torque during internal rotation at 60^{o}•sec^{-1} for the first, second, third and fourth teams was 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 mean strength (agonist/antagonist) ratio at 60^{o}•sec^{-1} for the first, second, third and fourth teams was 79.03 ± 2.35, 78.34 ± 2.20, 75.40 ± 1.55, and 75.25 ± 1.12 %, respectively. There was a significant difference for strength ratio at 60 ^{o}•sec^{-1} between the four teams [H(3) = 18.535, p = 0.000]. Post hoc analysis for strength ratio at 60 ^{o}•sec^{-1} 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 mean peak torque during external rotation at 90^{o}•sec^{-1} for the first, second, third and fourth teams was 33.84 ± 3.92, 33.13 ± 3.27, 31.77 ± 3.68 and 29.96 ± 2.45 Nm, respectively, with no significant differences between groups [H(3) = 5.931, p = 0.115].

The mean peak torque during internal rotation at 90^{o}•sec^{-1} of the first, second, third and fourth teams was 38.85 ± 5.12, 39.96 ± 3.38, 35.76 ± 4.70 and 33.31 ± 3.24 Nm, respectively. There was a significant difference for mean peak torque during internal rotation at 90^{o}•sec^{-1} between the four teams [H(3) = 11.976, p = 0.007]. Post hoc analysis for peak torque during internal rotation at 90°•sec^{-1} showed significant differences between teams, i.e., second and fourth teams (U = 8.0, r = −0.71).

The mean strength ratio at 90°•sec^{-1} for the first, second, third and fourth teams was 82.81 ± 1.65, 82.40 ± 1.47, 81.63 ± 1.47, and 81.17 ± 0.92 %, respectively, with a significant difference between groups [H(3) = 10.600, p = 0.014]. Post hoc analysis for mean strength ratio at 90 °•sec^{-1} showed no significant difference between groups, i.e., first and second teams (U = 43.0, r = -0.12), first and third teams (U = 33.5, r = -0.47), first and fourth teams (U = 16.5, r = -0.57), second and third teams (U = 28.0, r = -0.37), second and fourth teams (U = 17.5, r = - third and fourth teams (U = 39.5, r = -0.18).

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 60°•sec^{-1} (Nm)	35.70 ± 3.84	33.99 ± 2.69	31.16 ± 2.20	30.71 ± 2.33	0.005*
PT-IR at 60°•sec^{-1} (Nm)	42.59 ± 2.88	42.87 ± 2.70	41.30 ± 3.11	40.23 ± 2.67	0.160
SR at 60°•sec^{-1} (%)	79.03 ± 2.35	78.34 ± 2.20	75.40 ± 1.55	75.25 ± 1.12	0.000*
PT-ER at 90°•sec^{-1} (Nm)	33.84 ± 3.92	33.13 ± 3.27	31.77 ± 3.68	29.96 ± 2.45	0.115
PT-IR at 90°•sec^{-1} (Nm)	38.85 ± 5.12	39.96 ± 3.38	35.76 ± 4.70	33.31 ± 3.24	0.007*
SR at 90°•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 relationship between the participants' physical characteristics and maximal throwing velocity indicated that age correlated significantly with maximal throwing velocity (r = 0. 69, p = 0.03) in the first team (Table 3). Body fat percentage also correlated significantly with maximal throwing velocity (r = 0.66, p = 0.04) in the first team.

Table 3: Relationship between the physical characteristics of the participants per team and maximal throwing velocity

Variables	First team	Second team	Third team	Fourth team
	Maximal throwing velocity			
Age	0.69*	-0.41	-0.45	-0.02
Lean body mass	0.02	-0.39	-0.18	-0.15
Stature	-0.24	-0.24	-0.05	0.39
Body mass	0.29	-0.39	-0.09	0.03
Body fat mass	0.58	-0.27	0.04	0.08
Body fat percentage	0.66*	-0.20	0.06	0.61
Total arm length	0.63	0.55	0.03	0.63
Hip circumference	0.35	-0.31	0.10	0.28
Waist circumference	0.44	-0.22	-0.07	0.49

* indicates significant correlation (p<0.05).

The relationship between the participants' physical characteristics and average throwing velocity indicated age correlated significantly with average throwing velocity (r = 0.70, p = 0.03) in the first team (Table 4). Body fat percentage correlated significantly with average throwing velocity (r = 0.66, p = 0.04), and total arm length correlated significantly with average throwing velocity (r = 0.69, p = 0.03), both in the first team. Waist circumference correlated significantly with average throwing velocity, but in the fourth team only (r = 0.64, p = 0.05).

Table 4: Relationship between physical characteristics and average throwing velocity per team

Variables	First team	Second team	Third team	Fourth team
	Average throwing velocity			
Age	0.70*	-0.41	-0.43	-0.16
Lean body mass	0.03	-0.42	-0.16	-0.15
Stature	-0.20	-0.28	-0.05	0.39
Body mass	0.29	-0.41	-0.08	0.05
Body fat mass	0.59	-0.27	0.04	-0.04
Body fat percentage	0.66*	-0.20	0.06	0.09
Total arm length	0.69*	0.50	-0.00	0.61
Hip circumference	0.34	-0.29	0.12	0.23
Waist circumference	0.41	-0.24	-0.05	0.64*

* indicates significant correlation (p<0.05).

The relationship between the physical characteristics, isokinetic peak torque and strength ratios indicated that age correlated significantly with strength ratio at $60^{o}\bullet sec^{-1}$ (r = 0.67, p = 0.03) and age and strength ratio at $90^{o}\bullet sec^{-1}$ (r = 0.67, p = 0.03), both in the first team (Table 5).

Lean body mass correlated significantly with peak torque during external rotation at 60^{o}•sec^{-1} (r = -0.64, p = 0.05) in the second team. Lean body mass correlated significantly with strength ratio at 90^{o}•sec^{-1} (r = 0.68, p = 0.03) in the third team. Body mass correlated significantly with peak torque during internal rotation at 60^{o}•sec^{-1} (r = -0.65, p = 0.04) in the third team. Body fat mass correlated significantly with peak torque during external rotation at 90^{o}•sec^{-1} (r = 0.72, p = 0.02), and body fat percentage correlated significantly with peak torque during external rotation at 90^{o}•sec^{-1} (r = 0.74, p = 0.01), both in the first team.

Total arm length correlated significantly with strength ratio at 60^{o}•sec^{-1} in both the first (r = 0.69, p = 0.03) and second (r = 0.81, p = 0.00) teams. Total arm length correlated significantly with peak torque during internal rotation at 60^{o}•sec^{-1} (r = 0.67, p = 0.03), and total arm length also correlated significantly with strength ratio at 90^{o}•sec^{-1} (r = 0.64, p = 0.04), both in the fourth team. Hip circumference correlated significantly with peak torque during internal rotation at 90^{o}•sec^{-1} (r = -0.74, p = 0.01) in the second team. Waist circumference correlated significantly with peak torque during external rotation at 90^{o}•sec^{-1} (r = p = 0.01) in the first team.

Table 5: Relationship between the physical characteristics and isokinetic peak torque per team, and between the physical characteristics and strength ratios per team

Variables	Team	Isokinetic peak torque				Strength ratio	
		ER@ 60°•sec^{-1}	IR@ 60°•sec^{-1}	ER@ 90°•sec^{-1}	IR@ 90°•sec^{-1}	IR:ER 60°•sec^{-1}	IR:ER 90°•sec^{-1}
Age	First	0.53	0.46	0.41	0,57	0.67*	0.67*
	Second	-0.57	-0.51	0.02	-0.52	-0.45	-0.28
	Third	-0.08	-0.33	-0.31	-0.25	-0.17	-0.40
	Fourth	0.31	-0.17	-0.34	0.42	-0.14	0.43
Lean body mass	First	-0.23	-0.08	0.28	0.15	0.24	-0.19
	Second	-0.64*	-0.48	-0.51	-0.34	-0.06	-0.05
	Third	-0.19	-0.46	-0.26	-0.45	-0.16	0.68*
	Fourth	-0.13	-0.13	-0.11	-0.36	-0.14	0.26
Stature	First	-0.32	-0.13	-0.22	-0.18	-0.08	-0.09
	Second	-0.27	-0.21	-0.47	0.04	0.04	0.14
	Third	0.03	-0.34	0.09	-0.01	-0.08	-0.31
	Fourth	-0.22	0.39	-0.10	0.05	0.53	0.24
Body mass	First	-0.13	0.12	0.52	0.27	0.34	-0.10
	Second	-0.58	-0.39	-0.47	-0.43	-0.06	-0.17
	Third	-0.15	-0.65*	-0.09	-0.03	0.01	-0.39
	Fourth	-0.09	-0.26	-0.30	-0.07	0.01	0.16
Body fat mass	First	0.04	0.37	0.72*	0.38	0.41	0.05
	Second	-0.18	0.04	-0.14	-0.55	-0.12	-0.52
	Third	-0.06	-0.56	0.10	0.38	0.17	0.04
	Fourth	0.21	-0.08	-0.03	-0.30	-0.20	-0.06
Body fat percentage	First	0.12	0.47	0.74*	0.37	0.39	0.09
	Second	-0.03	0.14	-0.03	-0.53	-0.12	-0.56
	Third	-0.03	-0.51	0.11	0.44	0.18	0.10
	Fourth	0.30	0.05	0.06	-0.21	-0.08	-0.01
Total arm length	First	0.43	0.34	0.47	0.54	0.69*	0.53
	Second	-0.01	0.29	0.07	0.44	0.81*	0.59
	Third	-0.05	0.08	0.27	-0.09	-0.39	0.03
	Fourth	0.48	0.67*	0.47	0.29	0.57	0.64*
Hip circumference	First	-0.27	0.07	0.62	0.38	0.38	-0.12
	Second	-0.46	0.02	0.00	-0.74*	-0.01	-0.47
	Third	-0.09	-0.46	-0.02	0.30	0.28	-0.03
	Fourth	0.25	0.21	0.11	0.06	0.21	0.07
Waist circumference	First	-0.24	0.15	0.76*	0.44	0.33	-0.15
	Second	-0.37	0.05	-0.20	-0.47	-0.08	-0.35
	Third	-0.28	-0.33	-0.29	0.04	0.15	-0.15
	Fourth	0.34	0.49	0.17	0.23	0.58	0.40

ER= external rotation; IR= internal rotation; * indicates significant correlation ($p < 0.05$).

Discussion

The study examined the physical and performance measurements in university cricketers. The primary findings of the study indicates that the physical and performance measures, i.e., total arm limb length displayed a significant difference between the groups, similar to a previous study by Sahu 2015 who showed that there was a significant difference in arm length in male college level cricketers. The concept that arm length influences bowling speed and throwing velocity is supported by Stuelcken et al. (2007). They found that the length of the bowling arm influenced the bowling speed, because for any given angular velocity, the linear speed of a segment's endpoint is proportional to the length of its radius (Pyne et al., 2006).

Performance measures for maximal and average throwing velocity showed that there was a significant difference between groups. Both the first and second teams displayed a greater throwing velocity than the third and fourth teams. The greatest throwing velocity was achieved by the first team, the team also shown to have more playing experience. It is considered that playing experience (years of participation and level of participation) has a significant influence on maximal throwing velocity in cricket (Freeston et al., 2007). Freeston et al. (2007) examined the throwing performance of 110 cricket players from six different populations and found that gender, training volume (training time per week) and, to a lesser extent, experience (playing training experience) had a significant influence on maximal throwing velocity in cricketers. Their results indicated that gender, playing experience, and training volume (muscle strength) may all contribute to throwing performance in cricket players.

Muscle strength and endurance of the shoulder rotators are essential physical characteristics for success in overhead throwing performance and dynamic glenohumeral stability (Dale et al., 2007).

The results obtained for peak torque during external rotation at $60^{o} \bullet sec^{-1}$ were significantly different between the teams. In a study exploring the strength of the internal and external shoulder rotators in cricket bowlers, the concentric external rotator strength of the dominant shoulder showed no significant difference in mean torque values (Mabasa et al., 2002). Hurd et al. (2011) reported significant weakness in the external rotator muscles the infraspinatus and teres minor, and that throwing activity imposed tremendous demands on the external rotators which could lead to overuse and weakness (Hurd et al., 2011).

Several researchers used isokinetic devices which calculated the ratio of the external to internal rotator muscle strength for concentric muscular action in an attempt to assess muscular strength imbalances of the shoulder complex (Dale et al., 2007; Batalha et al., 2013; Andrade et al., 2013; Edouard et al., 2013; Pontaga & Ziden, 2014; Cha et al., 2014).

In the current study, the strength ratio of the internal rotators compared to the external rotators at $60^{o} \bullet sec^{-1}$ showed significant differences between the teams. Peak torque during internal rotation at $90^{o} \bullet sec^{-1}$ showed statistically significant tween the teams. Pontaga and Ziden (2014) showed that the power tween the teams. Pontaga and Ziden (2014) showed that the power produced by the internal rotator muscles during concentric contraction after eccentric contraction of the external rotator muscles was significantly greater in the dominant shoulder. A previous study on concentric internal rotator muscle strength showed no significant differences in mean torque in the dominant shoulder for cricket bowlers (Mabasa et al., 2002).

Mabasa et al. (2002) reported a decreased strength ratio at speeds of $60^{o} \bullet sec^{-1}$ and $90^{o} \bullet sec^{-1}$. They further suggest that this could have been due to an increase in internal rotational peak torque and a decrease in external rotational peak torque.

Sports that involve overhead throwing (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 one of these factors became impaired, functional instability would occur and performance is likely to deteriorate (Dale et al., 2007; Cha et al., 2014). In the current study, the strength ratio of the internal rotators compared to the external rotators at $90^{o} \bullet sec^{-1}$ shows a significant difference between groups, but post hoc analysis indicates no significant difference between the group.

In the current study, maximal throwing velocity correlated significantly with age and body fat percentage, while average throwing velocity correlated significantly with age, body fat percentage and total arm length. Similarly, Bayios (2001) reported ball velocity to be positively correlated with body size, as well as with the length of the upper and lower extremities'.

Shedlarski (2011) aimed to determine how strength characteristics associated with jumping were affected by percent body fat, lean body mass and free fat mass.The findings of that study displayed a significant relationship between body fat percentage and muscular strength measured by a countermovement jump. Similarly, the findings in the current study showed that certain physical characteristics, namely, age, lean body mass, weight, fat mass, body fat percentage, total arm length, hip circumference and waist circumference all correlated significantly with the muscular strength measurements.

In the study by Pyne et al. (2006), the mean stature of the club cricket players was shorter than that reported in senior cricketers, but was not statistically significant (Pyne et al., 2006). In a similar study, which profiled the anthropometric characteristics of Indian interuniversity male cricketers, no significant difference was found between the height and body composition among batsmen, bowlers and all-rounders (Koley, 2011).

In addition, the results from this study showed that mean body mass in novice cricket players was greater than that of inter-university cricketers (Koley, 2011), but less than that of senior cricketers (Pyne et al., 2006).

The results for height, body mass, arm length, and body composition in this study are consistent with the results reported by Choudhary (2011) which indicated that morphological differences exist between cricketers playing in different competition levels (Choudhary et al., 2011). Portus et al. (2000) investigating cricket fast bowling performance and technique and the influence of selected physical factors, found that selected girth and skinfold measures, as opposed to upper body strength alone, played a role in ball speed. Analysis of these characteristics provides useful references for investigations focusing on player selection and athlete development (Stuelcken et al., 2007).

The strength of this study lies in the fact that it investigated an area of scarce research concerning the physical and performance characteristics in university cricket players. More especially, it highlights the importance of physical measurements, such as age and body composition on performance measures such as maximal and average throwing velocity, as well as the influence of total arm length, hip and waist circumference on peak torque and muscular strength ratios.

Conclusion

In conclusion, various physical characteristics such as age and body fat percentage play an important role in the execution of a powerful throw in university cricketers. Furthermore, body mass, hip circumference and total arm length play an important role in isokinetic peak torque and shoulder strength ratios.

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