Short Communication

Relationships between speed, change of direction and jump performance with cricket specific speed tests in male academy cricketers

Matthew Foden, Sam Astley, Paul Comfort, John J. McMahon, Martyn J. Matthews, Paul A. Jones

Objectives: The aim of this study was to investigate the relationships between general speed and change of direction speed and 'cricket specific' speed tests and the relationships between jump performance and speed and change of direction ability in male academy cricketers.

Design and Methods : Sixteen academy male cricketers (age: 17 ± 0.7 years; height: 176.9 ± 6.2 cm; mass: 72.2 ± 13.2 kg) performed tests of 20 m sprint, 505 change of direction (COD) on both left and right legs, "quick single" with bat (WB) (17.68m), running-a-two WB, running-a-three WB, countermovement jump (CMJ), and drop jump (DJ).

Results: Intra-class correlation coefficients (ICC's) revealed high within-session reliability for all tests (ICC ≥ 0.92; $p \leq 0.001$), except 0-5 m (ICC = 0.642; $p \leq 0.001$) and 0-10 m (ICC = 0.708; $p \leq 0.001$) tests. General speed tests showed strong relationships to 'cricket specific' speed tests (20 m sprint - running-a-two; $r = 0.951$; $p \leq 0.01$; 20 m sprint - running-a-three; $r = 0.937$; $p \leq 0.01$; 'quick single'; $r = 0.951$; $p \leq 0.01$). Strong relationships were also observed between the 505 right foot COD times and all cricket specific tests (r = 0.909- 0.934; $p \leq 0.01$). CMJ height showed the strongest correlations with: 20 m ($r = -0.668$; $p \leq 0.01$); 505 left ($r = -0.789$; $p \leq 0.01$); 505 right ($r = -0.807$; $p \leq 0.01$); "quick single" WB ($r = -0.739$; $p \leq 0.01$); running-a-two WB ($r = -0.742$; $p \leq 0.01$); running-a-three (WB) ($r = -0.733$; $p \leq 0.01$).

Conclusions: The findings suggest that general speed and COD tests are highly appropriate to assess cricket specific qualities in youth cricketers.

(*Journal of Trainology* 2015;4:37-42)

Key words: acceleration ■ stretch shorten cycle ■ change of direction

INTRODUCTION

Short sprint performance is important in many sports, often determining success in key periods of play. In cricket, sprinting is an important quality in order to move quickly between the wickets for a quick single run, intercepting the ball when fielding, and creating high run up velocities when bowling, all of which are key instances that can decide the outcome of a game.[1,2,3]

In recent years cricket has become ever more athletically and physically challenging due to the development of shorter game formats, namely Twenty-20 and one day, which have altered some of the vital characteristics of the game. Shorter formats are more physically intensive in relation to match duration and are comprised of a greater number of maximal sprints.[4,5,6] As a result, improved short sprint performance has become an essential athletic quality for cricketers'.[7] In order to direct appropriate and specific conditioning programmes, and aid coaches with talent / ability indicators and physical development monitoring such physical qualities need to be assessed appropriately in relation to cricket.

Assessments of speed in other sports typically occur over distances of 5, 10, and 20 m.[8,9,10] These short sprint distances are also appropriate for cricketers, with mean sprint distances of 13-18 m in all game formats when fielding,[6] and maximal sprint efforts when batting occurring over a distance of 17.68 m between the wickets. Subsequently this shows that linear sprinting in cricket primarily consists of the acceleration phases of maximal sprinting. Hence, linear sprint tests for cricketers should be conducted over distances of ≤ 30 m for all players and 17.68 m when exclusively assessing sprint performance in relation to batting.

Effective running between the wickets increases a batter's run scoring potential,[4] making it essential to correctly assess a cricketer's sprint ability between the wickets. Smith, Harley and Stockhill[11] previously suggested measuring sprint time over the distance between the wickets (17.68 m), from a standing start without a bat, however this does not take into account the effective length of the sprint being reduced by reaching with the bat or any effects that holding a bat may have on running technique. Additional considerations into how the bat is held also needs to be made, with faster singles being recorded when carrying the bat in the dominant hand, compared to using 2 hands or the non-dominant hand.[12] Not all sprints between the wickets are linear, with a 180° change of direction (COD) occurring between linear sprints when more than one run is taken. This action replicates movement patterns occurring within a 505 COD test, which may therefore provide an

Received September 12, 2015; accepted November 2, 2015
From the Directorate of Sport, Exercise and Physiotherapy, University of Salford, Salford, Greater Manchester, United Kingdom (M.F., S.A., P.C., J. J.M., M.J.M., P.A.J.)
Communicated by Takashi Abe, PhD
Correspondence to Dr. Paul A. Jones. Directorate of Sport, Exercise and Physiotherapy, University of Salford, Allerton Building, Frederick Road Campus, Salford, Greater Manchester, United Kingdom, M6 6PU. Email: P.A.Jones@salford.ac.uk
***Journal of Trainology* 2015;4:37-42 ©2012 The Active Aging Research Center http://trainology.org/**

appropriate and reliable mode of assessing COD performance in cricketers. Previous research has used the 505 test in field based sports[13,14] and has been recommended for cricket.[11] Despite this there is limited research indicating if the 505 is an appropriate COD speed test for cricketers, with only Lockie et al.[2] showing significant ($p \leq 0.01$) correlations between the 505 test and components of a cricket specific COD task, namely running-a-three (r = 0.66 to 0.83). Other researchers have deemed running-a-three with a bat a more appropriate COD test for cricketers.[3,7,12] Running-a-three, includes three maximal linear sprints repeated with two 180º COD's between each sprint, with a bat used to reach for the crease between the first two runs and slide across the crease at the end of the third run. Even though cricket-specific speed tests have been utilised within the literature, it is unknown whether general speed tests assess different physical capacities.

Within the acceleration phase of a sprint, prevalent in cricket specific sprints (≤ 30 m), it is essential to produce high amounts of force during each foot contact in order for athletes to overcome inertia, with the ability to accelerate at greater rates relying predominantly on an athlete's strength and force production abilities.[15,16,17]

Further consideration into the utilisation of the stretch shortening cycle (SSC) and other strength qualities, occurring at each ground contact, within the phases of a sprint and COD also needs to be considered. During the acceleration and propulsion phases, ground contact times (GCT) are ≥ 250 ms and large angular displacement takes place at the joints, hence the long SSC is utilised.[18] Whereas at maximum sprint speeds GCT shortens (≤ 250 ms) and joint angular displacement decreases, thus utilising the short SSC.[18,19]

Additional research has examined the association between jump tests and sprint performance over various distances.[20,21,22] CMJ height correlates most with sprints over shorter distances, where strong inverse correlations of r = -0.97 were reported between CMJ height and 30 m sprint times.[20] Similarly, Hennessey and Kilty[21] showed moderate to high inverse correlations between CMJ height and 30-, 100- and 300 m sprint times (r = -0.55 to -0.64), while Lopez-Sigoria et al.[22] found CMJ also had a moderate inverse correlation with 20 m sprint times (r = -0.54). Jumps utilising the short SSC (≤ 250 ms) had stronger correlations with longer distance sprints, with drop jump reactive index correlating (r = -0.79 to -0.75) to 30 and 100 m sprint times.[21]

The aim of this study is to investigate the relationship between general speed tests and cricket specific speed tests in academy aged male cricketers. Furthermore, the relationships between various muscle strength qualities assessed through jump tests and sprint performance is investigated. It is hypothesised that cricket specific speed tests correlate with general speed tests. It is further hypothesised that CMJ height is strongly related to sprint times with drop jump reactive strength index (DJ - RSI) having weaker correlations, as a result of cricket specific sprint tests primarily focusing on the propulsion and acceleration phases of a sprint.

METHODS

Subjects

Sixteen academy male cricketers (age = 17 ± 0.7 years; height = 176.9 ± 6.2 cm; mass = 72.2 ± 13.2 kg) participated in the study. The procedures and methods used within the study were approved by the institution's ethics committee. Written informed consent was provided before any testing took place.

Procedures

All testing was conducted at the same time of day over 3 separate sessions during the pre-season training phase. All sprint testing was conducted on an indoor rubber surface. All participants conducted a familiar self-instructed dynamic warm up before any testing took place.

Each subject attended one testing session where they completed three trials each of CMJ and DJ, 20 m sprint; flying 505 COD (turning with left and right legs). For each sprint, COD and jump test, three trials were performed with two minutes rest allocated between each trial. An intermittent break was then given to allow recovery before the cricket specific speed assessments. These tests were conducted in the order of; running a single; running-a-two; running-a-three (all with a bat), with 3 trials each performed. Three trials of each test were performed with three minutes rest given between each trial due to a greater utilisation and strain on energy systems.[23]

Linear Sprint Tests

20-Metre Sprint

A 20 m sprint test recording 0-5 m, 0-10 m, and 0-20 m split times was used to replicate distances previously used within other field based sports[8,9,10] and mean sprint distances in cricket.[6] Three trial runs at moderate-high intensity were allocated to facilitate the warm up and familiarise subjects with the test.

Split times were recorded using Brower timing gates (Draper, UT) set at 0-, 5-, 10- and 20 m. The height of the timing cells was set at approximate hip height for all subjects in accordance with previous recommendations.[24] Each subject used a 2 point standing start 0.3 m behind the first timing cells. Trials were disregarded if subjects had been deemed to decelerate prematurely within the sprint or rocked backward and forward to initiate the sprint.

Running a Quick Single (17.68 m Sprint)

To replicate a "quick single" (QS) between the wickets subjects sprinted over a distance of 17.68 m (the length of the pitch), with a bat (WB) to simulate the effects that carrying a bat may have on sprint time, through adjustments in technique.[2,7,11] Timing gates were positioned at 0 and 17.68 m, at approximate hip height for all subjects[24] to measure the 17.68 m sprint time. Subjects initiated the sprint using a two point standing start 0.3 m behind the first timing gate whilst holding the bat below hip height. Despite this starting position being a somewhat atypical representation of a "quick single" during match play, it was required to eradicate any premature initiation of the timing gates caused by the bat. Each subject sprinted maximally over the full 17.68 m. To ensure that the bat was positioned below the height of the timing cells at both the start and end points of the sprint and eradicate the possibility of braking the beam prematurely with the protruding bat, each subject was required to slide the bat through the crease at the end timing gate.

Trials were disregarded when the subjects were deemed to; rock backward or forward when initiating the sprint; decelerate before the 17.68 m and not slide their bat in through the crease at the end of the sprint trial. If necessary, the trials were repeated after the allotted rest period of two minutes. For the test a standard-sized willow cricket bat (0.85 m × 0.11 m, mass = 2.8 lbs) was held in the subject's preferred/ dominant hand, due to it resulting in quicker singles.[12]

Change-of-Direction Speed Tests

505 Change-of-Direction speed test

The 505 test has been recommended and used to assess COD speed in cricketers[2,11] due to it simulating the same 180° turn and linear sprints associated with running between the wickets. The set-up of the test was in accordance with pre-established methods.[25] The test was initiated with the same two point standing start used in the previous sprint tests, with the toes of the front foot behind the start line. Subjects then sprinted maximally to the turning line (15 m) that was marked with tape on the laboratory running track, running through the timing gates set 5 m from the turning point. At the turning point the subjects planted their left or right foot (depending on the trial) on or behind the turning line before turning 180° and sprinting back through the timing gate 5 m from the turning line. The time to complete the 5 m to the turning point and return 5 m was recorded.

Subjects performed 3 trials with the left and right leg acting as the turning leg. In any trials where the subject was deemed to turn before the marked turning line, the trial was disregarded and performed again after the allotted rest period.

Running-a-Two and Running-a-Three

Both running-a two (R2) and running-a-three (R3) require repeated linear sprints combined with COD based on previously established methods.[2,7,12] For both tests the protocols were the same as those used with the QS but with subjects being able to utilise the bat to reach for the crease at each COD. For this test researchers were placed at each COD point to ensure subjects slid the bat over the crease. If this was not achieved the trial was disregarded and repeated in accordance to the previous protocol used with the QS. Three minutes rest was allocated before repeating the trial.

Jump Assessments

All force data from the jumps was recorded using a Kistler force plate (Type 9286AA) linked with Bioware software (sampling at 1000 Hz for 6 seconds) and analysed using Microsoft Excel using a bespoke analysis spreadsheet. Both tests were standardised by ensuring hands were kept on hips, to eliminate arm swing, and any trials where subjects flexed the knees whilst in flight were disregarded. All disregarded trials were performed again after the allocated rest time.

DJ height was set at 30 cm. Any jumps observed to have long contact times (≥ 250 ms) were disregarded. Flight time was then divided by contact time to calculate DJ RSI. Jump height for the CMJ was calculated using the formula; $JH = 9.81 \times FT^2/8$, where *JH = jump height* and *FT = flight time*. For both jumps, take-off and landing was identified as the point when the vertical ground reaction force descended and ascended past 20 N, respectively.

Statistical Analysis

Within session reliability between trials was assessed using intraclass correlation coefficients (ICC) and interpreted based on previous recommendations.[26] Standard error of measurement was also calculated using the equation[27]:

$$SEM = (SD_{pooled} \times \sqrt{(1\text{-}ICC)}).$$

A Shapiro-Wilk test confirmed normality of all data, thus Pearson's correlation was used to determine relationships between variables. All statistical tests were conducted using SPSS for windows v20 (Chicago, IL). Correlation coefficients were interpreted as weak (0.1-0.3), moderate (0.4-0.6) or strong (≥ 0.70) in accordance with previous recommendations.[26]

RESULTS

ICC's showed a very high reliability for most tests between trials (Table 1), however 0-5 m and 0-10 m tests showed only moderate to high reliability between trials (Table 1). A one-way ANOVA revealed that no significant differences ($p > 0.05$) were observed between trials suggesting the absence of systematic bias (Table 1).

The best performance from the three trials of each test was used for further statistical analysis. Pearson's correlation coefficients (Table 2) demonstrated that all general speed tests positively correlated with all cricket specific speed tests. Five metre times showed a moderate relationship to the three cricket specific tests; whereas all other general speed tests (10 & 20 m) displayed high to very high correlations to these tests (Table 2). Strongest relationships were observed between 20 m sprint times and the three cricket specific tests (Table 2). Strong relationships were also observed between the 505 COD times (turning with both feet) and all cricket specific tests (Table 2).

Moderate to strong inverse relationships ($p < 0.05$) were demonstrated between CMJ height and all speed tests (Table 3), whereas DJ-RSI observed weak non-significant ($p > 0.05$) inverse relationships with all speed tests (Table 3).

Table 1 Reliability for general and cricket specific speed tests, and jump performance.

Variable	MEAN ± SD				MIN	MAX	ICC	95% Confidence Interval		SEM	p value
	T1	**T2**	**T3**	**All Trials**				**Lower bound**	**Upper bound**		
0-5m (s)	1.17 ± 0.05	1.14 ± 0.07	1.14 ± 0.07	1.11 ± 0.15	1.02	1.21	0.642	0.219	0.861	0.038	0.064
0-10m(s)	1.96 ± 0.1	1.93 ± 0.11	1.90 ± 0.25	1.91 ± 0.11	1.77	2.16	0.708	0.338	0.889	0.089	0.332
0-20m(s)	3.38 ± 0.18	3.34 ± 0.21	3.35 ± 0.21	3.31 ± 0.19	3.06	3.78	0.978	0.948	0.992	0.029	0.106
505 L (s)	2.50 ± 0.15	2.50 ± 0.17	2.51 ± 0.17	2.45 ± 0.14	2.24	2.75	0.921	0.817	0.970	0.045	0.860
505 R (s)	2.53 ± 0.15	2.54 ± 0.17	2.53 ± 0.16	2.49 ± 0.15	2.28	2.80	0.947	0.877	0.980	0.035	0.805
QS (s)	3.12 ± 0.2	3.13 ± 0.21	3.14 ± 0.23	3.09 ± 0.20	2.80	3.55	0.981	0.957	0.993	0.029	0.799
R2(s)	6.97 ± 0.46	6.97 ± 0.5	6.98 ± 0.5	6.91 ± 0.47	6.29	8.09	0.990	0.977	0.996	0.048	0.941
R3 (s)	10.73 ± 0.72	10.73 ± 0.76	10.70 ± 0.69	10.63 ± 0.72	9.79	12.42	0.991	0.980	0.997	0.067	0.586
CMJ (cm)	24.4 ± 6.0	23.6 ± 6.5	24.1 ± 5.9	25.5 ± 5.7	15	37	0.960	0.907	0.985	1.204	0.951
DJ-RSI	0.94 ± 0.29	1.00 ± 0.31	0.95 ± 0.24	1.04 ± 0.30	0.66	1.81	0.935	0.853	0.975	0.071	0.347

CMJ = counter movement jump; DJ-RSI = drop jump reactive strength index; ICC = Intraclass correlation coefficient; MAX = maximum; MIN = Minimum; QS = Quick Single, R2 = Running a two, R3 = Running a three; SD = Standard Deviation; SEM = standard error of measurement

Table 2 Relationships between general and cricket specific speed tests.

	0-5m	**0-10m**	**0-20m**	**505(L)**	**505 (R)**
QS	0.603*	0.891**	0.915**	0.804**	0.909**
R2	0.581*	0.881**	0.951**	0.857**	0.923**
R3	0.548*	0.847**	0.937**	0.867**	0.934**

*$p < 0.05$, **$p < 0.01$
L = Left; R =Right; QS = Quick Single; R2 = Running a two; R3 = Running a three.

Table 3 Relationships between jump and speed test performance

	0-5m	**0-10m**	**0-20m**	**505 (L)**	**505 (R)**	**QS**	**R2**	**R3**
CMJ Height	-0.425	-0.595*	-0.668**	-0.789**	-0.807**	-0.739**	-0.742**	-0.733**
DJ RSI	-0.002	-0.203	-0.199	0.125	-0.140	-0.160	-0.160	-0.169

*$p < 0.05$ ** $p < 0.01$
CMJ = counter movement jump; DJ RSI= drop jump reactive strength index; QS = Quick Single, R2 = Running a two, R3 = Running a three.

DISCUSSION

The aim of this study was to investigate relationships between general speed and COD tests and cricket specific speed test performance, and the relationships between jump performance and speed and change of direction ability in male academy cricketers. In conjunction with our first hypothesis, this study found mainly strong-very strong ($r = 0.804$; $p \leq 0.01$ – $r = 0.951$; $p \leq 0.01$) relationships between general and all cricket specific speed tests, in regards to 0-10 m; 20 m; 505 left foot; 505 right foot times. However, in contrast, the general 0-5 m sprint times only demonstrated moderate correlations ($r = 0.548$; $p \leq 0.05$ – $r = 0.603$; $p \leq 0.05$). Additionally, strongest correlations were seen between CMJ height and all speed tests rather than DJ-RSI ($r = -0.002$ – $r = -0.203$), supporting the study's further hypothesis.

Only one other study, to the researcher's knowledge, has analysed the relationships between general and cricket specific testing. Lockie et al.[2] reported similar findings to the present study. They found that the 30 m sprint correlated strongly with the 17.68 m (WB) QS sprint ($r = 0.78$; $p \leq 0.01$) due to both tests being linear sprints. They also found strong relationships between the cricket specific COD speed test, R3, and the general 505 left ($r = 0.71$; $p \leq 0.01$) and 505 right ($r = 0.80$; $p \leq 0.01$). Both the 30 m and QS with bat linear sprint tests also possessed strong relationships with R3 ($r = 0.81$; $r = 0.89$). Hence, linear sprint speed is a major component within cricket specific speed test performance.

Despite the current study having similar findings, it should be noted that all correlations within this study demonstrated stronger relationships between general and cricket specific tests (Table 2), especially in regards to relationships between linear sprint tests, with the current study showing very strong ($r = 0.915$) relationship with 20 m and QS sprint times ($r^2 = 0.84$) compared to the relationship between 30 m sprint and

QS (r^2 = 0.66) reported previously.[2] Additionally the same was seen between general and cricket specific COD speed tests, with this study showing stronger (r = 0.934) relationships between 505 right foot and R3 tests compared to Lockie et al.[2] Subsequently these comparisons contradict previous findings[2] which supported the need for cricket specific testing, in regards to physiological testing and talent identification purposes for cricketers. However, this may have been a result of the 20 m sprint used within this study better resembling the shorter distance (17.68 m) covered to complete a single than the 30 m sprint used in the previous study. Another contributing factor to discrepancies in findings may have been a result of the height of the timing gates within the Lockie et al.[2] study being changed between general and cricket specific speed tests. This meant that for the 30 m sprint and 505 tests the subject's torso would break the beam, with cells set at approximate hip height. Whereas within the cricket specific tests the cells were lowered so that the bat would break the beam when reaching for the crease. Within this study the cells remained at hip height for all speed testing to make sure the same measurements of speed were being assessed across all tests and to prevent inaccurate double breaking of the beams caused by the bat. This may also account for further stronger relationships found between the 0-5 m, 0-10 m, 505 left, and all cricket specific testing than observed by Lockie et al.[2]

Another similar finding between the studies was that the 0-5 m interval of the general linear sprint test had the worst correlation with cricket specific testing compared to weak correlations found previously.[2] This may be due to 0-5 m sprint intervals not being shown to differ between faster and slower groups of cricketers[2] as well as the lower reliability for this test observed in the present study.

The relationship between linear sprint and jump performance support previous findings by Carr et al.[18] and Hori et al.[28], who discovered strong to moderate inverse relationships between CMJ height and 20 m sprint performance (r = -0.741, p = 0.006; r = -0.69, $p \leq 0.001$, respectively). In this study the QS and CMJ height best resembled the strong relationship found by Carr et al.[18] Whilst 20 m sprint times showed slightly weaker relationships than Carr et al.,[18] they were similar to the moderate correlations found by Hori et al.[28] All relationships with linear sprint tests were notably weaker than the very strong inverse relationships (r = -0.93; $p \leq 0.01$) reported between CMJ height and 30 m sprint times.[20] Differences in the strength of correlations between studies may be due to the training status and anthropometric measurements of the subjects used. Carr et al.[18] assessed professional players playing and competing at a higher level with larger anthropometric measurements than the young players assessed within this study. The professional players also had greater experience with performing jump tests, for monitoring purposes.

This study further supports previous findings[18] where DJ-RSI was observed to have weaker correlations with all speed and COD tests that have greater emphasis on the acceleration phases of a sprint. These findings are in line and support the suggestion that DJ-RSI best relates to maximum velocity sprinting, as it better resembles the use of the short SSC prominent when running at higher velocities.[19] Furthermore, these differences were also demonstrated within all COD tasks, both general and cricket specific, suggesting that slow reactive strength, utilising the long SSC, is of greater importance and has greater influence on COD and cricket specific speed performance.

CONCLUSION

Due to the rapid ongoing development of cricket in regards to the shorter formats, namely Twenty20 and one-day, running and COD speed has become a fundamental physiological characteristic of the modern-day player. As a result it is essential that tests used for monitoring and talent identification purposes need to replicate the demands of the sport as closely as possible. The results of the present study suggest that general speed and COD tests can be deemed as appropriate methods for talent identification and monitoring training in young cricketers. In addition, CMJ tests, utilizing the long SSC would be an appropriate test to include to best reflect the speed and COD demands of cricket players.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Phil Graham-Smith (Aspire Academy) for providing bespoke spreadsheets for analysis of jump data.

REFERENCES

1. Bartlett RM. The science and medicine of cricket: an overview and update. *J Sports Sci* 2003; 21: 733-752.
2. Lockie RG, Callaghan SJ, Jeffriess, MD (2013). Analysis of specific speed testing for cricketers. *J Strength Cond Res* 2013; 27: 2981-2988.
3. Loock N, Du Toit DE, Ventner DJL, et al. Effect of different types of cricket batting pads on the running and turning speed in cricket batting. *Sports Biomechanics* 2006;5:15-22.
4. Duffield R, Drinkwater EJ. (2008). Time-motion analysis of Test and One-Day international cricket centuries. *J Sports Sci* 2008;26:457-464.
5. Petersen CJ, Pyne DB, Portus MR, et al. Comparison of player movement patterns between 1-day and test cricket. *J Strength Cond Res* 2011;25: 1368-1373.
6. Petersen CJ, Pyne D, Dawson B, et al. Movement patterns in cricket vary by both position and game format. *J Sports Sci* 2010;28:45-52.
7. Johnstone JA, Ford PA. Physiologic profile of professional cricketers. *J Strength Cond Res* 2010;24:2900-2907.
8. Lockie RG, Murphy AJ, Knight TJ, et al. (2011). Factors that differentiate acceleration ability in field sport athletes. *J Strength Cond Res* 2011;25: 2704-2714.
9. Duthie GM, Pyne DB, Marsh DJ, et al. Sprint patterns in rugby union players during competition. *J Strength Cond Res* 2006;20:208-214.
10. Gabbett TJ. Physiological characteristics of junior and senior rugby league players. *Brit J Sports Med* 2002;6:334-339.
11. Smith RG, Harley RA, Stockill NP. Cricket, chapter 29 in *Sport and Exercise Physiology Testing Guidelines: The British Association of Sport and Exercise Sciences Guide*. Eds. Winter EM, Jones, AM, Davison RCR, Bromley PD, Mercer TH. London, Routledge, 2007.
12. Houghton LA. Running between the wickets in cricket: What is the fastest technique? *Int J Sports Sci Coaching* 2010;5:101-108.
13. Alves JMVM, Rebelo AN, Abrantes C, et al. Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. *J Strength Cond Res* 2010;24:936-941.
14. Nimphius S, McGuigan MR, Newton RU. Relationship between strength, power, speed, and change of direction performance of female softball

players. *J Strength Cond Res* 2010;24:885-895.

15. Comfort P, Haigh A, Matthews MJ. Are changes in maximal squat strength during preseason training reflected in changes in sprint performance in rugby league players? *J Strength Cond Res* 2012;26:772-776.
16. Comfort P, Stewart A, Bloom, L, et al. Relationships between strength, sprint, and jump performance in well-trained youth soccer players. *J Strength Cond Res* 2014;28:173-177.
17. Wisløff U, Castagna C, Helgerud J, et al. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Brit J Sports Med* 2004;38:285-288.
18. Carr C, McMahon JJ, Comfort P. Relationships between jump and sprint performance in first-class county cricketers. *J Trainology* 2015;4:1-5.
19. Young W, McLean B, Ardagna J. Relationship between strength qualities and sprinting performance. *J Sports Med Phys Fitness* 1995;35:13-19.
20. Bosco C, Belli A, Astrua M, et al. A dynamometer for evaluation of dynamic muscle work. *Eur J Appl Physiol Occupational Physiol* 1995;70:379-386.
21. Hennessy L, Kilty J. Relationship of the stretch-shortening cycle to sprint performance in trained female athletes. *J Strength Cond Res* 2001;15:326-331.
22. López-Segovia M, Marques M, van den Tillaar R, et al. Relationships between vertical jump and full squat power outputs with sprint times in U21 soccer players. *J Hum Kinetics* 2011;30:135-144.
23. Noakes, T, Durandt J. Physiological requirements of cricket. *J Sports Sci* 2000;18:919-929.
24. Yeadon MR, Kato T, Kerwin, DG. (1999). Measuring running speed using photocells. *J Sports Sci* 1999;17:249-257.
25. Draper JA, Lancaster MG. The 505 test: A test for agility in the horizontal plane. *Aus J Sci Med Sport* 1985;17:15-18.
26. Baumgartner TA, Chung, H. Confidence limits for intraclass reliability coefficients. *Measurement in Physical Education Exer Sci* 2001;5:179-188.
27. Thomas JR, Nelson JK, Silverman SJ. Measuring Research Variables, chapter 11, in *Research Methods in Physical Activity*. Champaign, IL, Human Kinetics, 2005.
28. Hori N, Newton RU, Andrews WA, et al. Does performance of the hang power clean differentiate performance of jumping, sprinting and changing of direction? *J Strength Cond Res* 2008;22:412-418.