Short Communication

Relationship between isometric mid-thigh pull variables and sprint and change of direction performance in collegiate athletes

Christopher Thomas, Paul Comfort, Chieh-Ying Chiang, Paul A. Jones

Objectives: The aim of this investigation was to assess the use of isometric strength testing as a determinant of sprint and change of direction performance in collegiate athletes.

Design and Methods: Fourteen male collegiate athletes (mean ± *SD*; age = 21 ± 2.4 years; height =176 ± 9.0 cm; body mass = 72.8 ± 9.4 kg) participated in the study. Maximal strength was assessed via an isometric mid-thigh pull (IMTP). Isometric mid-thigh pull testing involved trials with peak force (IPF), maximum rate of force development (mRFD), impulse at 100 ms (IP 100) and 300 ms (IP 300) determined. Sprint and COD performance was measured using 5- and 20-m sprint performance, and a modified 505 test. Relationships between variables (IMTP, sprint and COD) were analysed using Pearson's product – moment correlation.

Results: Results suggest that IP 300 displayed the strongest relationships with 5- and 20-m sprint performance ($r = -0.51$ and -0.54, respectively). The results demonstrate maximum force production measures during IMTP correlate to sprint and COD ability in collegiate athletes.

Conclusion: Isometric mid-thigh pull force-time measures are related to athletic performance (acceleration and sprinting), and thus are recommended for use in athlete monitoring and assessment.

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Key words: peak isometric force ■ impulse ■ dynamic performance ■ sprinting

INTRODUCTION

Sprint performance is of great importance in many sports, including soccer, rugby league, basketball, and netball. The number of sprinting activities is dependent upon the sport, training experience, fitness, and position of play. For instance, professional netballers execute on average 5-81 sprints per game, whilst professional basketball athletes perform 55-105 sprints per game.[1,2] Sprint performance is considered to be important in soccer and rugby league, with athletes performing on average 17-81 and 31-39 sprinting activities, respectively, during play.[3] Although periods of play may require maximum sprinting velocity to be attained, the aforementioned sports are characterised by sprints between 10-15 m (dependent upon sports and playing position), so a maximum velocity will not be attained. Therefore, the ability to accelerate is important and may strongly influence periods of play, whereby athletes are making a break from an opponent, tackling, or intercepting.[4]

Sprinting performance can be divided into three stages; acceleration, maximum velocity, and the ability to maintain velocity against fatigue.[5] Sprint acceleration is dependent upon three external forces; gravity, wind, and ground reaction force (GRF), the latter of which is controlled by the individual.[6,7] Further, being a vector quantity, GRF has a magnitude (measure), and directional (horizontal and vertical) component, with the goal of maximum velocity sprinting to minimize impact vertical GRF and increase active vertical GRF. According to Kawamori *et al.*[8], GRF can be determined via kinetic (peaks, means, impulses) and temporal (duration of phase) characteristics, in relation to sprint acceleration performance. Research has found net horizontal impulse (IP) to strongly relate to sprint acceleration performance ($r = -0.52$), while maximum velocity sprinting requires athletes to produce vertical GRF to propel the body upward to create flight time, thus creating flight time long enough to reposition the limbs.[8,9] However, athletes do not have ample time to produce maximum force; therefore sprinting ability may be limited by an athlete's ability to generate IP, with faster sprint performances displaying greater GRF applied during shorter ground contact times (GCT).[6]

Mero[7], found velocity at first ground contact during a sprint from block starts to strongly correlate with horizontal GRF ($r = 0.62$ to 0.71), and vertical GRF ($r = 0.41$ to 0.50). These findings are consistent to work by Hunter *et al.*[6] who found velocity at 16 m to observe a strong relationship with net horizontal IP ($r^2 = 0.61$), compared to a weaker relationship with net vertical IP ($r^2 = 0.17$). The aforementioned studies used track and field subjects as part of their investigations; therefore it is questionable whether the results of these studies can be applicable to team sport athletes due to differences in running technique, playing surface, footwear, and running posture.[10] Early research by Wilson *et al.*[11] found no relationship ($r = -0.46$ to 0.17; $p > 0.05$) between single joint isometric strength

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From the Directorate of Sport, Exercise and Physiotherapy, University of Salford, Salford, Greater Manchester, UK (C.T., P.C., P.A.J.), and the College of Athletics, National Taiwan Sports University, Taoyuan City, Taiwan (C-Y.C.).

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Correspondence to Mr. Christopher Thomas, Directorate of Sport, Exercise and Physiotherapy, University of Salford, Salford, Greater Manchester, UK. Email: C.Thomas2@edu.salford.ac.uk

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and 30 m sprint performance. In agreement with these findings, Requena *et al.*[12] observed no relationship ($r = -0.35$; $p > 0.05$) between isometric strength with subjects sat in a custom-made dynamometric chair, and 15 m sprint performance. However, West *et al.*[13] found significant correlations between isometric mid-thigh pull (IMTP) RFD, absolute and relative PF at 100 ms, and 10 m sprint performance ($r = 0.66$, 0.54, and 0.68, respectively). Tillin *et al.*[14] found normalized PF at 100 ms during an isometric back squat to correlate to 5- and 20-m sprint performance in rugby players. In addition, Spiteri *et al.*[15] found a significant correlation ($r = 0.79$) between IPF during the IMTP and 505 COD performance in female basketball athletes.

The relationship between leg strength qualities and change of direction (COD) performance also remains unclear.[16-18] Young *et al.*[19] reported non-significant correlations ($r = 0.10$ to 0.54) between isokinetic concentric squat power, straight sprinting, and COD protocols of various magnitudes. Nimphius *et al.*[17] found significant relationships between relative PF and PP ($r = -0.74$ and -0.73, respectively), as measured by a bodyweight jump squat and 505 COD performance. In contrast, significant correlations were observed between maximal strength as measured by a 3 repetition maximum (3RM) back squat and 505 COD performance. In addition, Hori *et al.*[16] found that absolute strength, as measured by 1RM in the hang power clean and front squat, both observed significant correlations with modified 505 COD performance ($r = -0.41$ and -0.51, respectively). The discrepancy between many of these studies may be due to different COD protocols utilized, or the transferability of measured strength level (isokinetic, concentric, and dynamic) to COD performance. The execution of efficient COD requires linear acceleration, force absorption, isometric strength during the foot plant, and concentric strength to position the body appropriately to rapidly decelerate and re-accelerate in a new direction.[15] Stronger athletes have also shown to adopt more efficient lower body positions while producing faster COD performances.[20] Increased strength levels have found to contribute to increased storage of elastic energy during the eccentric phase of stretch-shortening cycle activities.[6] Further, increased strength levels may improve the acceleration out of the plant phase (COD propulsive phase), due to increased peak GRF and IP.[20]

What is not yet clear is the association between isometric force-time variables to measures of sports performance, such as sprint and COD. Further observations are warranted to determine the role key isometric force-time performance measures play in sprint performance assessment. Therefore, the aim of this study was to examine the relationship between IMTP (IPF, maximum RFD [mRFD], and IP 100 and IP 300) test variables with sprint and COD performance measures in collegiate athletes from various sporting disciplines.

METHODS

Subjects

Fourteen male collegiate athletes (mean ± SD; age = 21 ± 2.4 years; height =176 ± 9.0 cm; body mass = 72.8 ± 9.4 kg), active in soccer and rugby league, participated in this study. All individuals volunteered for the testing as part of their normal training and monitoring regime. Ethical approval was provided by the Institutional Review Board, and all athletes provided written informed consent. All procedures conformed to the Declaration of Helsinki. All individuals were familiar with testing protocols.

Design

This study was designed to investigate the relationships between IMTP strength, sprint performance (times over 5 and 20 m), and COD performance (modified 505 COD) in collegiate athletes. Isometric mid-thigh pull was chosen as a common method to assess maximal force production capabilities.[21] Sprint performances over 5 and 20 m were selected because these are representative of sprint distances covered during team field sports,[22,23] whereas the COD protocol was selected as a modified version of a test commonly used to assess such performance outcomes[17,24]. After data collection was complete, associations between variables were analyzed via Pearson's correlations.

Procedures

Athletes attended the human performance laboratory on two separate days, with anthropometric measurements taken (height and body mass), followed by IMTP testing on day 1, and sprint and COD performance measures completed on day 2. Athletes were required to abstain from training for 48 hours before testing and asked to maintain a consistent fluid and dietary intake on each day of testing. Before the start of testing, participants were instructed to perform a standardised warm up, as directed by the investigator.

Isometric Strength Assessment

Isometric mid-thigh pull testing was performed using a portable force plate sampling at 600 Hz (400 Series Performance Force Plate, Fitness Technology, Adelaide, Australia). The force plate was interfaced with computer software [Ballistic Measurement System (BMS)] that allows for direct measurement of force-time characteristics, and then analysed using the BMS software. Data was filtered using a fourth order Butterworth filter with a 16 Hz cut-off frequency. For the IMTP, athletes obtained self-selected knee and hip angles based on the reports of previous research.[25] For this test, an immovable bar (Werksan Olympic Bar, Werksan, Moorsetown, NJ, USA) was positioned at mid-thigh position. The bar height could be fixed at various heights above the force platform to accommodate different sized athletes, and the rack was anchored to the floor. Once the bar height was established, the athletes stood on the force platform, and their hands were strapped to the bar in accordance with previously established methods.[26,27] Each athlete was provided two warm-up pulls, one at 50%, and one at 75% of the athletes perceived maximum effort, separated by 1 minute of rest. Once body position was stabilised (verified by watching the subject and force trace), the subject was given a countdown of “3, 2, 1, Pull”. Minimal pre-tension was allowed to ensure there was no slack in the subject's body prior to initiation of the pull. Athletes performed 3 maximal IMTP trials, with the instruction to pull against the bar with maximal effort as quickly as possible, and push the feet down into the force plate; this instruction has been previously found to produce optimal testing results.[21,27] Each maximal isometric trial was performed for 5 seconds, and all athletes were given strong verbal encouragement during each trial. Two minutes of rest was given between the maximal effort pulls. The best of three trials was used for correlation analysis. The maximum force recorded from the force-time curve during the 5-second IMTP trial was reported as the PF. Maximum RFD was calculated by dividing the difference in consecutive vertical force readings by the time interval (0.0017 seconds) between readings.[28] Impulse at 100 and IP 300 were also calculated. The time intervals were selected based on typical GCT for the various sprint, jump, and COD activities that would be experienced by the athletes used in the investigation.[9,29,30]

Sprint Assessment

Standardized progressive warm-ups were applied to control potential variables and improve the reliability of all tests. Warm-up included 10 minutes of non-fatiguing activation and mobilization exercises, including various bodyweight lunges and squats, interspersed with footwork and sprint mechanics drills, followed by some low-level plyometric drills, replicating the athlete's standardized warm-ups before training. The 20-m sprint test was administered as a test of acceleration and sprint ability. All athletes performed 3 trials, with 2-minutes rest between trials, on a third-generation artificial rubber crumb surface using "Brower photocell timing Gates" (model number BRO001; Brower, Draper, UT, USA) setup at 0, 5, and 20 m. Timing gates were placed at the approximate hip height for all athletes as previously recommended,[31] to ensure that only one body part, such as the lower torso, breaks the beam. Athletes started 0.3 m behind the first gate, to prevent any early triggering of the initial start gate, from a 2-point staggered start. Testing was conducted after a standardized warm-up protocol. The best performance from each of the 3 trials was used for correlation analysis.

Change of Direction Speed Assessment

Change of direction speed was assessed utilising a modified 505 test on the same surface as the sprint trials. All athletes performed 3 trials, with a 2-minute rest between trials. Athletes started 0.3 m behind the photocell gates, to prevent any early triggering of the initial start gate, from a 2-point staggered start. Timing gates were again placed at the approximate hip height for all athletes. Athletes were instructed to sprint to a line marked 5 m from the start line, placing preferred foot on the line, turn 180° and sprint back 5 m through the finish.[22] The best performance from each of the 3 trials was used for correlation analysis.

Statistical Analysis

Intraclass correlation coefficients (ICC), coefficient of variation (%CV), typical error (TE), and percentage change in the mean were used to assess the repeatability of performances between trials for IMTP, sprint and COD.[32] Normality of data was assessed by Shapiro–Wilk statistic and Q–Q plot analysis. Relationships between variables (isometric strength, and sprint and COD performances) were analysed using Pearson's product – moment correlation using SPSS software (version 17.0, SPSS, Inc., IL, USA). Correlations were evaluated as follows: small (0.10 - 0.29), moderate (0.30 - 0.49), large (0.50 - 0.69), very large (0.70 - 0.89), nearly perfect (0.90 to 0.99), and perfect (1.0).[32] The criterion for statistical significance of the correlation was set at $p \leq 0.05$.

RESULTS

Descriptive statistics and between-session reliability for IMTP, sprint, and COD performances are presented in Table 1.

Pearson correlation coefficients between IMTP variables and sprint and COD performances are presented in Table 2. Isometric strength demonstrated significant large-to-very large

Table 1. Descriptive statistics and between-session reliability for performance tests (n = 14).

Variable	Mean ± SD	ICC (90% CI)	%CV (90% CI)	TE	Change in mean (%)
IMTP PF (N)	2752 ± 546	0.96 (0.91-0.99)	4.3 (3.3-6.5)	113.7	−1.0
IMTP mRFD ($N \cdot s^{-1}$)	11780 ± 4920	0.93 (0.83-0.97)	11.1 (8.4-17.0)	1531.6	0.8
IMTP IP 100 ($N \cdot s^{-1}$)	77.06 ± 11.29	0.97 (0.91-0.99)	3.2 (2.4-4.7)	2.4	0.2
IMTP IP 300 ($N \cdot s^{-1}$)	229.67 ± 33.34	0.96 (0.91-0.99)	3.1 (2.4-4.7)	7.2	−0.2
5 m Sprint (s)	1.06 ± 0.05	0.92 (0.83-0.97)	1.4 (1.1-2.1)	0.01	0.5
20 m Sprint (s)	3.12 ± 0.20	0.98 (0.96-0.99)	0.5 (0.4-0.7)	0.01	−0.1
Modified 505 COD (s)	2.73 ± 0.17	0.89 (0.71-0.96)	1.7 (1.3-2.7)	0.05	−0.3

IMTP = isometric mid-thigh pull; mRFD = maximum rate of force development.
COD = change of direction; PF =peak force; IP = impulse.

Table 2. Correlation coefficients between IMTP, sprint, and COD performance ($n = 14$).

Variable	Sprint Intervals		Modified 505 COD
	5 m	20 m	
IMTP PF (N)	−0.57 *	−0.69 **	−0.57*
IMTP mRFD ($N{\cdot}s^{-1}$)	−0.58 *	−0.71 **	−0.57*
IMTP IP 100 ($N{\cdot}s^{-1}$)	−0.71 **	−0.75 **	−0.58*
IMTP IP 300 ($N{\cdot}s^{-1}$)	−0.74 **	−0.78 **	−0.62*

* $p \leq 0.05$; ** $p \leq 0.01$.
IMTP = isometric mid-thigh pull; COD = change of direction.
mRFD = maximum rate of force development; PF =peak force; IP = impulse.

inverse relationships with sprint performances ($r = -0.57$ to -0.78). Further, IMTP performance showed significantly large inverse relationships with COD performance ($r = -0.57$ to -0.62).

DISCUSSION

The aim of this study was to examine the relationships between IMTP test variables with sprint and COD performance measures in collegiate athletes from various sporting disciplines. Our results suggest that absolute measures of IMTP force production, specifically IP generated in ≤ 300 ms, demonstrated very strong inverse correlations with sprint performance ($r = -0.71$ to -0.78).

In this study IPF was related to 5- and 20-m sprint performance which is in agreement with work by Mero *et al.*[33], and Cunha *et al.*[34], but in contrast to West *et al.*[13]. Sprint acceleration is heavily reliant on the acceleration of body mass; therefore, based on findings by West *et al.*[13], absolute measures of IPF are secondary to relative measures, potentially explaining differences to previous findings. This was confirmed by significant relationships ($r = -0.37$ to -0.68) between relative IPF and relative IPF at 100 ms during IMTP testing, and 10 m sprint performance. The authors acknowledge that relative strength variables were not assessed in the current study; therefore it is suggested further study to investigate the relationships of relative IMTP variables to sprint performance in athletes of similar competition to that of previous research.

Our findings demonstrate isometric IP 100 and IP 300 showed significant correlations with 5- and 20-m sprint performances. These findings are similar to West *et al.*[13], who found PF at 100 ms to significantly correlate to 10 m sprint performance in rugby players. Harris *et al.*[35] has previously found IP relative to body mass to be an important factor in 30- and 40-m sprint performance, therefore it could be assumed IP to be an important factor in sprint performance. During elite sprinting, GCT is <100 ms,[36] therefore athletes who produce large GRF in a short time may exhibit better sprint performance. This may potentially explain reasons for IP 100 and IP 300 observing slightly stronger relationships to sprint performance compared to IPF in the current study. Further IP 300 may have observed slightly higher correlation values to sprint performance than IP 100 due to training status of the subject cohort, as it is likely GCT are closer to 300 ms than 100 ms.

The relationship of isometric strength to COD performance found in the current study is in agreement with previous research highlighting the importance of maximal isometric strength for COD performance.[20] Spiteri *et al.*[20] found stronger athletes to produce higher levels of force and IP during braking (deceleration) and propulsive (re-acceleration) phases of a COD protocol. Greater IPF generated in short time periods will increase IP, which has shown to contribute to sprint acceleration.[8] This may suggest being able to apply large braking forces in <300 ms during the braking phase of the COD movement is highly important to further enable a rapid re-acceleration during the propulsive phase.[37]

Our data show significant relationships between modified 505 COD performance and IPF ($r = -0.57$). Absolute strength has also been reported to strongly correlate with COD in collegiate athletes ($r = 0.78$).[38] These findings are consistent with Hori *et al.*[16] who found significant negative correlations between 1RM front squat and modified 505 performance. In addition, our findings are consistent with the work of Spiteri *et al.*[15], in that IPF during the IMTP showed significant relationships to COD performance. Sprinting and COD requires acceleration of body mass, and is highly dependent upon absolute strength levels, with research showing transfer effects from long-term periodized strength training to positively improve COD performance.[39]

CONCLUSION

Results of this study demonstrate that force-time variables (IPF, mRFD, IP 100, and IP 300), assessed via IMTP, are related to sprint and COD performance in male collegiate athletes. In addition, reliability data show the IMTP may be advantageous in monitoring time-force adaptations in order to identify which components of force production warrant development through training. The findings of this study suggest the importance of developing high levels of lower body strength; specifically IP to enhance sprint and COD performance in male collegiate athletes. Coaches and strength and conditioning coaches should ensure athletes develop lower body strength, and more specifically the ability to exert high forces over short periods of time, which are essential to sprint and COD performance. Lower body strength should be improved as part of a periodized training program, initially focusing on the ability to produce force, before developing the contributing mechanisms to express the developed force (IP, RFD, and PP).

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