ISOMETRIC MID-THIGH PULL CORRELATES WITH STRENGTH, SPRINT, AND AGILITY PERFORMANCE IN COLLEGIATE RUGBY UNION PLAYERS

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ABSTRACT

Wang, R, Hoffman, JR, Tanigawa, S, Miramonti, AA, La Monica, MB, Beyer, KS, Church, DD, Fukuda, DH, and Stout, JR. Isometric mid-thigh pull correlates with strength, sprint, and agility performance in collegiate rugby union players. J Strength Cond Res 30(11): 3051–3056, 2016—The purpose of this investigation was to examine the relationships between isometric mid-thigh pull (IMTP) force and strength, sprint, and agility performance in collegiate rugby union players. Fifteen members of a champion-level university’s club rugby union team (mean ± SD: 20.67 ± 1.23 years, 1.78 ± 0.06 m, and 86.51 ± 14.18 kg) participated in this investigation. One repetition maximum (1RM) squat, IMTP, speed (40 m sprint), and agility (proagility test and T-test) were performed during 3 separate testing sessions. Rate of force development (RFD) and force output at 30, 50, 90, 100, 150, 200, and 250 milliseconds of IMTP, as well as the peak value were determined. Pearson product-moment correlation analysis was used to examine the relationships between these measures. Performance in the 1RM squat was significantly correlated to the RFD between 90 and 250 milliseconds from the start of contraction (r’s ranging from 0.595 to 0.748), and peak force (r = 0.866, p ≤ 0.05). One repetition maximum squat was also correlated to force outputs between 90 and 250 milliseconds (r’s ranging from 0.757 to 0.816, p ≤ 0.05). Sprint time over the first 5 m in the 40 m sprint was significantly correlated with peak RFD (r = −0.539) and RFD between 30 and 50 milliseconds (r’s = −0.570 and −0.527, respectively). Time for the proagility test was correlated with peak RFD (r = −0.523, p ≤ 0.05) and RFD between 30 and 100 milliseconds (r’s ranging from −0.518 to −0.528, p’s < 0.05). Results of this investigation indicate that IMTP variables are significantly associated with strength, agility, and sprint performance. Future studies should examine IMTP as a potential tool to monitor athletic performance during the daily training of rugby union players.

KEY WORDS rate of force development, acceleration, change of direction

INTRODUCTION

Rugby union is a full-contact, field-based team sport, consisting of repeated high-intensity sprints and a high frequency of physical contacts (10). Participation in rugby union seems to require a high degree of strength, power, and speed, regardless of playing position (9). Performance testing in rugby union can be valuable for a variety of reasons, including but not limited to talent identification, individualizing training programs, and monitoring both short- and long-term training adaptations. Speed, strength, and power seem to be essential characteristics needed for success in high-level rugby union players (11). Deutsch et al. (7) reported that the mean duration of sprints observed during rugby competition is approximately 3 seconds. Players are also reported to regularly achieve speeds in excess of 90% maximal velocity (12). These findings suggest that both initial acceleration and maximal speed are important for these athletes. In addition, strength and power are also reported to be qualities required for success in rugby, particularly during tackles, scrums, line-outs, rucks, and mauls (9). The relationship between strength, speed, and agility does seem to be synergistic. For instance, running velocity and ability to change direction have been demonstrated to be related to strength and power relative to body mass (12). In addition, significant correlations (r values ranging from 0.47 to 0.85) have been reported in several studies between 1 repetition maximum (1RM) squat and sprint and agility performance (5,24,25).

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The isometric mid-thigh pull (IMTP) is an assessment of whole-body skeletal muscle function with 2 primary applications. The first is to quantify the athlete’s maximal force-generating capacity, known as peak force, and the second is to assess the rate at which force can be applied during a maximal effort muscle contraction, called as the rate of force development (RFD). Peak force and RFD calculated through the force-time curve of IMTP have been reported to relate to performance variables such as vertical jump, strength, sprint, and agility in sports such as weightlifting, golfer, football, cycling, and track and field (4,19,23,26,27). West et al. (30) reported a correlation between peak RFD and 10 m sprint time \((r = -0.66)\) and countermovement jump height \((r = 0.39)\) in rugby league players. The advantages of IMTP include easy administration and minimal skill requirement (22). A recent study by Haff et al. (14) showed that the use of predetermined time zone RFD bands such as 0–30, 0–50, 0–90, 0–100, 0–150, and 0–200 milliseconds were reported to have the highest reliability.

Although investigations have examined strength, sprint, and agility abilities in rugby union players, no study to our knowledge, has investigated the relationship between performance in IMTP and these component variables in these athletes. Thus, the purpose of this study was to examine the relationship among IMTP, strength, sprint, and agility in collegiate rugby union players.

**Methods**

**Experimental Approach to the Problem**

All study participants completed 3 testing sessions on non-consecutive days separated by a minimum of 48 hours. The first 2 testing sessions were performed in the Institute’s Strength and Conditioning Laboratory, where 1RM strength and IMTP assessments were performed, respectively. During the third and final testing session, both sprint and agility assessments were performed outdoors on the rugby practice field.

**Subjects**

Fifteen members of the University’s club rugby team (mean ± SD: 20.67 ± 1.23 years, 1.78 ± 0.06 m, and 86.51 ± 14.18 kg) volunteered to participate in this investigation. This team was the defending National Champions of Collegiate Rugby. The participants comprised 4 backs and 11 forwards, and their rugby playing experience ranged from 1 to 6 years. The study was approved by the University’s Institutional Review Board. This was a retrospective analysis which included a waiver of consent, which was approved by the university IRB as a retrospective analysis in which the athletes completed testing on a volunteer basis. Testing procedures were fully explained to each participant before obtaining informed consent from each participant. In an attempt to eliminate the potential for reduced performance, the participants were asked to refrain from any strenuous physical activity for the previous 48 hours.

**Strength Testing**

Maximal strength testing was performed on the squat exercise. The 1RM squat was performed using methods previously described by Hoffman (16). Before beginning the test, each participant completed a general warm-up that included dynamic movements and 5 minutes of cycling exercise. Each participant then performed 2 warm-up sets using a resistance that was approximately 40–60% and 60–80% of

| Table 1. Descriptive statistics for IMTP, strength, agility, and sprint results. |
|-----------------|-----------------|-----------------|
| **Test**        | **Measurements** | **Results (mean ± SD)** |
| IMTP            | Peak force (N)   | 2,944.63 ± 618.32 |
|                 | Force output 30 ms (N) | 1,190.01 ± 307.59 |
|                 | Force output 50 ms (N) | 1,393.56 ± 364.45 |
|                 | Force output 90 ms (N) | 1,623.87 ± 406.84 |
|                 | Force output 100 ms (N) | 1,639.51 ± 410.01 |
|                 | Force output 150 ms (N) | 1,896.63 ± 465.81 |
|                 | Force output 200 ms (N) | 2,343.37 ± 494.05 |
|                 | Force output 250 ms (N) | 2,514.52 ± 510.65 |
|                 | Peak RFD (N·s⁻¹) | 13,145.19 ± 8,554.60 |
|                 | RFD 0–30 ms (N·s⁻¹) | 10,870.00 ± 9,417.83 |
|                 | RFD 0–50 ms (N·s⁻¹) | 10,592.93 ± 6,821.69 |
|                 | RFD 0–90 ms (N·s⁻¹) | 8,443.92 ± 3,865.55 |
|                 | RFD 0–100 ms (N·s⁻¹) | 7,755.93 ± 3,381.69 |
|                 | RFD 0–150 ms (N·s⁻¹) | 6,884.76 ± 2,576.26 |
|                 | RFD 0–200 ms (N·s⁻¹) | 7,397.30 ± 2,096.08 |
|                 | RFD 0–250 ms (N·s⁻¹) | 6,602.43 ± 1,688.76 |
| Strength        | 1RM squat (kg)   | 153.49 ± 50.62   |
| Agility         | Proagility time (s) | 5.09 ± 0.28    |
| Sprint          | T-test time (s)  | 10.80 ± 0.64     |
|                 | Sprint 0–5 m (s) | 1.24 ± 0.10      |
|                 | Sprint 0–10 m (s) | 1.90 ± 0.11     |
|                 | Sprint 0–20 m (s) | 3.06 ± 0.14     |
|                 | Sprint 0–30 m (s) | 4.15 ± 0.18     |
|                 | Sprint 0–40 m (s) | 5.22 ± 0.22     |
their estimated 1RM, respectively. The third set was the first attempt at the participant’s 1RM. If the set was successfully completed, then weight was added and another set was attempted. If the set was not successfully completed, then the weight was reduced and another set was attempted. A 3–5 minutes rest period was provided between each set. This process of adding and removing weight was continued until a 1RM was reached. Attempts that did not meet the range of motion criterion for each exercise, as determined by the researcher, were discarded. Each participant descended to the “parallel” position where the greater trochanter of the femur was aligned with the patella and ascended until full knee and hip extension. A researcher, located lateral to the participant, provided a verbal signal “up” to ensure proper range of motion.

Sprint Testing
Sprint speed was evaluated using the 40 m dash. Marker poles were positioned 5, 10, 20, 30, and 40 m from the starting point. Participants were instructed to run as quickly as possible along the 40 m distance from a standing start. All testing trials were recorded using a high-speed camera (Casio EX-FH20, Tokyo, Japan) and the video clips were analyzed using video analysis software (Kinovea 0.8.15 for Windows). The criteria used to determine the completion of the sprinting segment was the first body part to cross the marker pole. Time was measured to the nearest 0.01 seconds. Each participant performed 2 attempts. The fastest time was recorded for analysis.

Agility Testing
Agility was evaluated using both the proagility and T-test. The agility tests were performed as previously described by Hoffman (16). For the proagility test, 3 cones were placed parallel with a distance of 5 m between each other. Participants started from a straddle position in front of the middle cone. They were then instructed to pivot and accelerate as quickly as possible to a cone 5 m away and then pivot again and sprint the 10 m distance to the third cone. Participants then pivoted again and returned as quickly as possible past the middle cone. The participants were asked to touch the ground next to each cone during each change of direction. For the T-test, 4 cones were placed in a T-figure format. Participants were instructed to start at the first cone and sprint 10 m to the second cone, shuffle laterally 5 m to the third cone, shuffle 10 m in the opposite direction to the fourth cone, shuffle 5 m back to the middle cone, and then run backward 10 m to the starting cone. The participants were asked to touch the cone on each change of direction. Similar to the 40 m sprint, all trials were recorded using a high-speed camera (Casio EX-FH20) and the video clips were analyzed using video analysis software (Kinovea 0.8.15 for Windows). Times were measured to the nearest 0.01 seconds. Each participant performed 2 attempts. The fastest time was recorded for analysis.

Isometric Mid-Thigh Pull Testing and Analyses
The mid-thigh position was determined for each participant before testing by marking the mid-point distance between the knee and hip joints. Each participant was instructed to assume their preferred deadlift position by self-selecting their hip and knee angles. The height of the barbell was adjusted up or down to make sure it was in contact with the mid-thigh. The participants were allowed to use either overhand, mixed, or hook grip. The participants were instructed to pull upward on the barbell as hard and as fast as possible and to continue their maximal effort for 6 seconds. All participants were instructed to relax before the command “GO!” to avoid the precontraction. The force-time curve for each trial was recorded by a force plate (AccuPower; AMTI, Watertown, MA, USA) with a sample rate of 1,000 Hz, as suggested by Dos’ Santos et al. (8). Peak force was defined as the highest force achieved during the 6-second isometric test minus the participant’s body weight in Newtons. In addition, force outputs at 30, 50, 90, 100, 150, 200, and 250 milliseconds from the initiation of the pull were determined for each trial (4,19). The RFD was then calculated with the following equation: $RFD = \frac{\Delta \text{Force}}{\Delta \text{Time}}$. The RFD equation was applied to predetermined time bands, including 0–30, 0–50, 0–90, 0–100, 0–150, 0–200, and 0–250 milliseconds.
The peak RFD was determined as the highest rate of change in force determined across a 20 milliseconds sampling window, as recommended by Haff et al. (14).

Statistical Analyses
The Shapiro-Wilk test was conducted to test normality of each variable. Pearson product-moment correlation analysis was used for normally distributed variables. Otherwise, simple linear regression analysis was used to determine relationships between IMTP, strength, sprint, and agility performance. Data were analyzed using SPSS v22.0 software (SPSS, Inc., Chicago, IL, USA). Correlations were evaluated using the following criteria: small = 0.1–0.29, moderate = 0.30–0.49, large = 0.50–0.69, very large = 0.70–0.89, nearly perfect = 0.90–0.99, and perfect = 1.0 (17). An alpha level of $p \leq 0.05$ was considered statistically significant for all comparisons. All data are reported as mean ± SD.

Results
Descriptive statistics for IMTP, 1RM squat, agility, and sprint results are depicted in Table 1. The results of the correlational analyses between the RFD and 1RM squat, agility, and speed can be observed in Table 2, whereas the results of the analyses between force output and these performance variables are depicted in Table 3.

The Relationship Between Isometric Mid-Thigh Pull and Strength
One repetition maximum squat was positively correlated with the RFD at 90 milliseconds ($r = 0.595, p = 0.032$), 100 milliseconds ($r = 0.656, p = 0.015$), 150 milliseconds ($r = 0.679, p = 0.011$), 200 milliseconds ($r = 0.661, p = 0.014$), and 250 milliseconds ($r = 0.748, p = 0.003$). One repetition maximum squat also had positive relationships with force outputs at 90 milliseconds ($r = 0.757, p = 0.003$), 100 milliseconds ($r = 0.787, p = 0.001$), 150 milliseconds ($r = 0.782, p = 0.002$), 200 milliseconds ($r = 0.768, p = 0.002$), and 250 milliseconds ($r = 0.816, p = 0.001$), as well as peak force ($r = 0.866, p = 0.001$).

The Relationship Between Isometric Mid-Thigh Pull and Sprint
Sprint time for the first 5 m of the 40 m sprint was negatively correlated with RFD at 30 milliseconds ($r = -0.570, p = 0.027$) and 50 milliseconds ($r = -0.527, p = 0.043$), as well as peak RFD ($r = -0.539, p = 0.038$). No other significant correlations were observed between speed and peak force or the force output at any time point.

The Relationship Between Isometric Mid-Thigh Pull and Agility
Time for the proagility test was negatively correlated with the RFD at 30 milliseconds ($r = -0.518, p = 0.048$), 50 milliseconds ($r = -0.527, p = 0.044$), 90 milliseconds ($r = -0.528, p = 0.043$), and 100 milliseconds ($r = -0.518, p = 0.048$) milliseconds, as well as peak RFD ($r = -0.523, p = 0.045$). There were no significant correlations observed between peak force or the force output at any time point and proagility performance. No significant correlations were noted between IMTP and T-test performance.

Discussion
The primary purpose of this study was to investigate the relationship between IMTP force, and strength, sprint, and agility in collegiate rugby players. The results of this study indicated that RFD correlated with 1RM back squat, 5 m sprint time, and proagility time. However, no relationships were observed between peak force, force output at any time band, and agility or sprint performance.

Peak force was observed to explain 75% of the variance in 1RM squat. This was consistent with previous results indicating that isometric maximal strength can explain up to 80% of the variability in dynamic performance, including vertical jump, snatch, and the clean and jerk (13,18,22). Anderson and Aagaard (2) have suggested that the RFD can be examined as early (<100 milliseconds) and late phases (>100 milliseconds) from the onset of muscle contraction. They later showed that the early phase RFD was influenced...
by intrinsic muscle properties such as fiber-type composition, whereas late phase was related more with peripheral muscle properties such as muscle cross-sectional area and maximal strength (3). The significant relationships observed in this study between RFD and 1RM squat was seen after 90 milliseconds from the onset of muscle contraction (e.g., towards the end of early phase of the RFD). However, a comparison of correlations between different RFD time bands showed that the highest correlation was achieved at 250 milliseconds (e.g., late phase RFD). This suggests that the 1RM squat is more reliant on late phase RFD, which is associated with factors influencing maximal muscular strength. Our finding is in agreement with several training studies that reported parallel increases in both maximal muscular strength and RFD measured from 150 to 250 milliseconds (1,15,29).

The results of this investigation also indicated that only the sprint time over the first 5 m of the 40 m sprint was significantly correlated with peak RFD and RFD at 30 and 50 milliseconds. This contrasts with the results from Conlon et al. (6), who reported that both peak force and peak RFD were correlated with 5 m (r = –0.58 and r = –0.49, respectively), 10 m (r = –0.61 and r = –0.50, respectively), 20 m (r = –0.61 and r = –0.47, respectively), and 30 m (r = –0.61 and r = –0.46, respectively) sprint interval times. More recently, Thomas et al. (28) reported that both peak force and peak RFD were correlated with 5 m (r = –0.57 and r = –0.58, respectively) and 20 m (r = –0.69 and r = –0.71, respectively) sprint intervals. The discrepancy between these studies and ours may be related to the type of athletes examined. These previous 2 studies recruited athletes from various sports such as soccer, rugby, gymnastics, tennis, wrestling, whereas we examined only rugby players. In a study investigating rugby league players, West et al. (30) reported a significant inverse relationship between peak RFD and 10 m sprint time (r = –0.66). The lack of any significant correlation between peak force and sprint performance may be an indicator that maximal strength is secondary in importance to RFD for sprinting performance in rugby players. The beginning of the acceleration phase is considered the most important aspect of speed in rugby players (11). During a maximal effort sprint, the ground contact time during the concentric phase is around 50 milliseconds (21). Therefore, those athletes who are able to produce greater force during this short period may have an advantage in accelerating during competition. Our results seem to support this concept because there were no significant correlations observed between sprint performance and RFD after 50 milliseconds.

This study found that the RFD correlated only with the proagility test and not the T-test. More specifically, in addition to peak RFD, RFD at 30, 50, 90, and 100 milliseconds were all significantly correlated to proagility time, which is in part consistent with Conlon et al. (6), who reported that the proagility test correlated with both peak force (r = –0.481) and peak RFD (r = –0.314). Peak force seemed to be achieved after 250 milliseconds from the onset of muscle contraction (18). Therefore, in movements during which athletes have limited time to develop a large amount of force, peak force may not correlate with dynamic performance. McGuigan and Winchester (20), as well as Kawamori et al. (18) reported no significant relationship between peak force and mid-thigh clean pulls, which was in contrast to the findings of Haff et al. (13) and Stone et al. (27). The lack of any relationship noted between RFD, peak force, and the T-test is possibly related to the number of different movement patterns (e.g., sprint, side-shuffles, and backward run) in a relatively longer distance (40 m). The T-test seems to be a more complicated test and requires greater skill than the proagility test.

Results from this investigation demonstrate that performance in the IMTP is associated with strength, sprint, and agility performance. More specifically, early stage RFD correlates with sprint and agility performance and late stage RFD correlates with strength. The findings of this study also support the importance of enhancing RFD in collegiate rugby players. Future studies need to examine the potential of using RFD for predicting strength, sprint, and agility performance, which is considered important for rugby union players, as well as the potential role of IMTP test for monitoring athletic performance during the daily training of rugby union players.

**Practical Applications**

Our study advocates the usefulness of IMTP because it relates to various dynamic performance measures such as strength, speed, and agility, which may underlie competition success. Using traditional methods to conduct daily performance diagnosis by measuring strength, speed, and agility is not always practical because of the number of players and tight schedule of training. Therefore, sport scientists and coaches may seek to use IMTP as an appropriate tool to test and monitor athletes without worrying about the timing and disruption of regular training schedules.

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**References**

Isometric Mid-Thigh Pull and Dynamic Performance


