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Section: Original Investigation

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A comparison of the isometric mid-thigh pull and isometric squat: intraday reliability, usefulness and the magnitude of difference between tests

Submission type: Original Investigation

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Abstract

Purpose: This investigation examined the reliability and usefulness of the isometric mid-thigh pull (IMTP) and isometric squat (ISqT) performed at the same knee and hip angles. The scores produced in each test were compared to determine the magnitude of differences between tests.

Methods: Twenty six male and female athletes (23.6±4.3 y; 1.75±0.07 m; 68.8±9.7 kg) performed 2 maximal repetitions of the IMTP and ISqT following a specific warm up. Results: Maximum force, absolute peak force (PF), relative PF, allometrically scaled PF, rate of force development (RFD) (0 – 200 and 0 – 250 ms) and impulse (0 – 300 ms) were deemed reliable (ICC ≥ 0.86 and CV ≤ 9.4%) in the IMTP and ISqT based on predetermined criteria (ICC ≥ 0.8 and CV ≤ 10%). Impulse (0 – 200 ms and 0 – 250 ms) were reliable in the ISqT (ICC ≥ 0.92 and CV ≤ 9.9%). Participants produced significantly (p < 0.05) greater PF and impulse (0 – 300 ms) during the ISqT compared with the IMTP. When split by sex, female participants produced significantly greater PF (p = 0.042) during the ISqT with no significant differences among male participants (p = 0.245). Both tests are capable of detecting changes in performance in maximum force and absolute PF. Conclusions: Both tests are reliable for non-time dependent maximal strength measures when measured at the same knee and hip angles. The ISqT may be preferred when coaches want to test an athlete’s true maximum lower limb strength, especially female athletes.

Keywords: isometric strength, force-time curve, maximum strength, explosive strength, performance testing
Introduction

Isometric tests such as the isometric mid-thigh pull (IMTP) and isometric squat (ISqT) allow the assessment of athletes’ strength qualities from a force-time curve and are used to assess skeletal muscle function. Buckner, et al. suggested that typical strength assessments such as 1RM testing are skills and that using multiple measures such as the IMTP or ISqT may be more advantageous for defining true measures and changes in strength. The IMTP is designed to replicate the body position at the beginning of the second pull position of the clean or the snatch. The second pull position (130 – 140° knee angle with an upright trunk position) is the strongest and most powerful position during weightlifting movements, generating the highest forces and velocities of any part of the lifts. From the force time curve produced in these tests, there are a number of variables that can be examined. Peak force (maximum force produced) is indicative of “maximum strength” and rate of force development (RFD) is indicative of an athletes ability to produce maximal force in minimal time. To describe different portions of the force-time curve, Zatsiorsky calculated the index of explosiveness (IES), reactivity coefficient (RC), S-gradient and A-gradient. The IES refers to the ability to exert maximal forces in minimal time and the RC expresses the IES relative to body weight. The S-gradient quantifies RFD at the beginning of muscular effort whereas the A-gradient characterises the late stages. While Haff, et al. has applied these to the force-time curve of an IMTP, they have not yet been applied to the ISqT. Impulse determines the change in momentum of an athlete and is an important performance related characteristic.

With the increased popularity of isometric tests being used to assess strength qualities, it is important that the data obtained to prescribe, monitor and alter an athletes’ training programme is reliable. Superior reliability, results in better precision of single measurements and enhanced tracking of changes in measurement in both research and practical settings. To assess test-retest reliability, it is recommended that the intraclass correlation coefficient (ICC)
and the typical error expressed as a coefficient of variation (CV) should be calculated along with 95% confidence intervals (CIs). While there are no predetermined standards set for measurements of reliability in sports science, the literature has commonly used a threshold of an ICC ≥ 0.80 and a CV ≤ 10%.

Early research on the IMTP only reported the ICC as the reliability measure and reported peak force (PF) and peak RFD (pRFD) as reliable. PF is by far the most reliable variable, with an ICC ≥ 0.92 and a CV ≤ 5% reported in the literature. Research on the reliability of the ISqT is limited compared to the IMTP, but generally results in PF being the most reliable variable, with tests performed at various knee angles (ICC ≥ 0.97). Variables including RFD and impulse have been reported as reliable in the IMTP and ISqT. There are different methods for calculating the RFD including pre-set time bands, determining the pRFD across various windows and using the slope of the curve from the initial rise to the maximum force expression (average RFD). Haff, et al. found that using selected time bands for the quantification of the RFD offers greater reliability compared with the quantification of the pRFDs. Average RFD (avgRFD) has been deemed unreliable and pRFD during a 20 ms sampling window (pRFD20) has only met the ICC criteria for acceptable reliability (ICC ≥ 0.93 and CV ≥ 12.9%). Maffiuletti, et al. noted that smaller epochs are more sensitive to changes in the slope of the curve and therefore less reliable.

Nuzzo, et al. reported that male NCAA division 1 American Football players and track and field athletes produced 12.5% more relative PF during the ISqT when compared with the IMTP, performed at the same knee angle (140°). Both tests were reported as reliable (r ≥ 0.98). There is limited research conducted among female athletes performing an ISqT. Sex differences in strength exist in the upper body with females demonstrating weakness compared to their male counterparts. The main difference between an IMTP and ISqT is the elimination of the upper limb during an ISqT and being cued to “push” rather than “pull”. In addition,
limited reliability research has been conducted in the ISqT on variables other than PF, such as RFD (sampling windows), pRFD and impulse.

Once a performance test is determined reliable, the smallest worthwhile change (SWC) should be calculated and Hopkins suggests using the typical error (TE) alongside the SWC to allow practitioners to make a well-informed decision on whether a change is both of practical significance (> SWC) and real (greater than the noise of the test, > TE). This research provides new information on the usefulness of each test looking at the TE compared to the SWC.

No previous research has compared the reliability and results obtained during the IMTP and ISqT performed at the same knee and hip angles. Therefore, the aim of the current study was to determine the intraday reliability of the IMTP and ISqT performed at the same knee and hip angle, define the usefulness of the tests and determine the magnitude of effect between the IMTP and ISqT among male and female athletes.

**Methods**

**Participants**

Sixteen male (23.0 ±4.8 y; 1.79 ±0.05m; 72.8 ±10.4 kg) and ten female athletes (24.5 ±3.1 y; 1.68 ±0.03 m; 62.5 ±3.4 kg) from track & field, boxing, modern pentathlon, canoeing, rowing, badminton and Taekwondo took part in this study. All participants had at least 6 months of resistance training experience. All participants provided written informed consent prior to participation in accordance with the ethical requirements of the Research Ethics Committee.

**Study Design**

A cross sectional study design with repeated measures was used. This study assessed the intraday reliability of the IMTP and ISqT performed at the same knee and hip angle to determine the reliability of maximum force, PF, RFD (sampling windows), pRFD, avgRFD,
impulse, IES, RC, S-gradient and A-gradient. The mean scores achieved in each test were compared. All participants took part in a familiarisation session one week prior to the testing session. The IMTP/ISqTs were randomised among participants.

**Methodology**

Participants took part in a familiarisation session that firstly included an explanation of the study and signing of the informed consent. Participants then performed a general warm up consisting of 3 minutes of cycling, 10 bodyweight squats, 10 bodyweight walking lunges and 10 glute bridges. Participants were then set in the correct position for the IMTP, which consisted of a mean knee angle of $136 \pm 3^\circ$ and a hip angle of $137 \pm 2^\circ$. Participants were required to maintain the position throughout the test. Knee angles and hip angles were measured using a hand-held goniometer, grip- and foot- width were measured and remained consistent between trials. Then each participant performed an IMTP specific warm up previously reported in the literature $^{25}$, which consisted of pulling the IMTP bar for 5 seconds at a self-directed 50%, 3 seconds at 70 – 80%, 3 seconds at 90% of maximal effort with 1 minute recovery between warm up efforts. Participants completed 3 maximal efforts lasting 5 seconds. During the IMTP, participants used lifting straps to standardise grip strength.$^{25}$ For each trial participants were instructed to “*pull as hard and as fast as you can, push the ground away, drive your feet into the ground and the bar from the floor*” to ensure maximal force was achieved.$^{26}$ Participants were then set in the position for the ISqT, which adopted the same knee and hip angles attained during the IMTP, with the bar positioned across the shoulders. The same specific warm up and instruction was given with the exception of “push” instead of “pull”.

One week later, participants completed the testing session. The order sequences of tests were randomised among participants. Participants completed the general warm up followed by the specific warm up of the first test to be completed. Participants were then given 2 minutes
rest before completing 2 maximal effort trials with 2 minutes between trials. Participants were instructed to get ready, to pre-tense, and then were given a countdown of “3, 2, 1, PULL!” Verbal encouragement was provided during each trial. They then rested for 5 minutes before completing the warm up for the second test (IMTP/ISqT) followed by 2 maximum efforts with 2 minutes rest between trials. Participants completed a third trial if they lost their position or grip.

All isometric testing was conducted on a custom-made Sorinex isometric rack (Lexington, South Carolina, USA), allowing the placement of the bar at 0.5 cm intervals permitting the desired position in each participant. The rack was anchored to the floor and placed over a Kistler (Winterthur, Switzerland) force platform sampling at 1000 Hz.

Isometric force-time curve analysis

All force-time curves were analysed with the use of a custom built spreadsheet to determine specific force-time characteristics. The collection period for each trial was set at 12 seconds and a baseline was measured during the 3 second countdown prior to the initiation of the pull. The criterion onset threshold and onset of the contraction was defined as the point where the force exceeded 5 SD from baseline.\(^{27}\) The maximum force generated during the 5 seconds was reported as the maximum force. Absolute PF was reported as the maximum force minus the participant’s body weight. Absolute PF was also reported relative to body mass (N/kg) and body weight (N/N). Additionally, absolute PF was scaled allometrically (N/kg\(^{0.67}\))

to measure muscle strength independent of body size.\(^{12}\)

RFD was analysed with methods previously reported in the literature.\(^ {9}\) Precisely, RFD was calculated (ΔForce/ΔTime) and was applied to specific time bands (0 – 30, 0 – 50, 0 – 90, 0 – 100, 0 – 150, 0 – 200, 0 – 250 ms). pRFD was then determined as the highest RFD during a 2- (pRFD 2), 5- (pRFD 5), 10- (pRFD 10), 20- (pRFD 20), 30- (pRFD 30) and 50-millisecond
(pRFD 50) sampling windows. AvgRFD was calculated from the PF achieved and the time elapsed between the initiation of the pull and the PF values. Impulse was measured by average force divided by the change in time over 100 ms, 200 ms, 250 ms and 300 ms.

The IES is calculated identical to the avgRFD. The RC was calculated using the PF and time to PF and the participants body weight [PF/ (TPF x BW)]. The S-gradient was calculated using half the PF (PF_{0.5}) and the time to achieve it (TPF_{0.5}): (PF_{0.5}/TPF_{0.5}). Finally the A-gradient was calculated by using the PF_{0.5}, TPF and TPF_{0.5}: [PF_{0.5}/ (TPF-TPF_{0.5})].

**Statistical Analyses**

All force-time data were analysed with the use of a custom spreadsheet. Normality of data was assessed by Shapiro-Wilk statistic. Reliability was calculated by determining the coefficient of variation (calculated as the typical error and expressed a CV) and the intraclass correlation coefficient (ICC) and 95% confidence interval (95% CI) using a Microsoft Excel spreadsheet. Acceptable reliability was determined at an ICC ≥ 0.8 and a CV ≤ 10%. Paired t-tests with an alpha level of \( p ≤ 0.05 \) were used to determine if differences existed between mean absolute PF, relative PF (N/kg), allometrically scaled PF, RFD (0 – 200 ms), RFD (0 – 250 ms) and impulse (0 – 300 ms) values produced in the IMTP and ISqT. Participants were then split by sex for this analysis to determine if sex differences existed. Paired t-test values were reported with a Holm’s sequential Bonferroni method in order to control for type I errors. To determine the magnitude of effect within group differences in test scores, a Hedges’ \( g \) effect size test was performed between the mean values produced in the IMTP and ISqT. The magnitude of Hedges’ \( g \) was interpreted using Cohen’s scale as trivial (\( g < 0.2 \)), small (0.2 ≤ \( g < 0.5 \)), moderate (0.5 ≤ \( g <0.8 \)) and large (\( g ≥ 0.8 \)). Typical error (TE) was calculated and the usefulness of the test was determined by comparing the TE to the smallest worthwhile change (SWC) calculated on a Microsoft Excel spreadsheet. The SWC was determine by multiplying
the between-subject SD by 0.2 (SWC_{0.2})^{31}, which is the typical small effect or 0.5 (SWC_{0.5})^{30}, which is an alternate moderate effect. If the TE was below the SWC, the test was rated as “good”, if the TE was similar to SWC it was rated as “ok” and if the TE was higher than the SWC the test was rated as “marginal”.^{31}

Results

Descriptive statistics for male and female participants for the variables that attained a criterion of an ICC ≥ 0.8 and a CV ≤ 10% are shown in Table 1 for the IMTP and Table 2 for the ISqT along with the TE, SWC_{0.2} and SWC_{0.5}. Figure 1 shows the variables that achieved a criterion of an ICC ≥ 0.8 and a CV ≤ 10% in either test. While impulse 0 – 200 ms and 0 – 250 ms were determined reliable in the ISqT, they were deemed unreliable in the IMTP (CV > 10%). RFD (0 – 30 ms, 0 – 50 ms, 0 – 90 ms, 0 – 100 ms and 0 – 150 ms), pRFD (2 ms, 5ms, 10 ms, 20 ms, 30 ms and 50 ms), avgRFD, impulse (0 – 100 ms), IES, RC, S-gradient and A-gradient were deemed unreliable in both the IMTP and ISqT (ICC < 0.8 and/or CV > 10%) (Figure 2).

Differences between mean absolute PF, relative PF (N/kg), allometrically scaled PF, RFD (0 – 200 ms), RFD (0 – 250 ms) and impulse (0 – 300 ms) produced during the IMTP and ISqT are shown in Table 3. Holm’s Sequential Bonferroni adjusted p-values show significant differences (p < 0.05) exist between absolute PF (p = 0.006), relative PF (p = 0.006), allometrically scaled PF (p = 0.006) and impulse (0 – 300 ms) (p = 0.036) values between the IMTP and ISqT with the ISqT producing significantly higher results than the IMTP (Figure 3). Figure 4 details the magnitude of effect between the IMTP and ISqT. Participants were split by sex to determine if sex differences existed between tests. Among males, no significant differences were detected between any variable (Table 4). Among females, significant differences were observed between absolute PF (p = 0.042), relative PF (N/kg) (p = 0.042) and
allometrically scaled PF (p = 0.042) with the ISqT producing significantly (p < 0.05) higher results (Table 5). Figure 5 details differences individual and group mean values of the IMTP and ISqT for male and female participants for measures of absolute peak force, allometrically scaled PF, RFD 0 – 250 ms and impulse 0 – 300 ms.

**Discussion**

The aim of this study was to determine the reliability of the IMTP and ISqT performed at the same knee and hip angles, define the usefulness of the tests and determine the magnitude of effect between the IMTP and ISqT among male and female athletes and report reference TE and SWC values. This study provides new information on the reliability and usefulness of both tests and the mean values produced at the same knee and hip angle. Variables that were reliable in both tests include, maximum force, absolute PF, relative PF (N/N) and (N/kg), allometrically scaled PF, RFD (0 – 200 ms and 0 – 250 ms) and impulse (0 – 300 ms) (ICC ≥ 0.8 and CV ≤ 10%). Impulse (0 – 200 ms) and (0 – 250 ms) were deemed reliable in the ISqT. All short sampling windows of RFD (up to 150 ms), pRFD (up to 50 ms), impulse (0 – 100 ms), IES, RC, S-gradient and A-gradient were deemed unreliable for both tests.

PF has been reported as the most reliable variable measured during an IMTP. Previous research reported ICCs ≥ 0.92 and CV ≤ 5%, which is similar to the results of this study. However, differences exist in the definition of PF with some research including body weight in the calculation and other research calculating PF as maximum force minus body weight. Beckham, et al. included body weight in their calculation whereas West, et al. calculated PF minus the participant’s body weight. Some research does not clearly state whether body weight was included leaving the interpretation of results confounding for coaches. Previous research has reported that RFD measures (0 – 200 ms and pRFD) are reliable with ICC > 0.8 even though the CV > 15%. Haff, et al. reported RFD sampling windows from 0 – 30 ms
up to $0 - 250$ ms as reliable ($ICC > 0.8$ and $CV < 10\%$), different to the results found in this study. Maffiuletti, et al.\textsuperscript{23} noted when measuring RFD, familiarisation is very important and prolonged practice procedures may be required to obtain reliable data. The participants used in the study by Haff, et al.\textsuperscript{9} had a lot of experience in producing force in the second pull position compared to the participants used in this study and this may explain the difference in results. To achieve reliable data for RFD measures additional familiarisation session may be required. Additionally, the method for detecting the onset of contraction used in the study by Haff, et al.\textsuperscript{9} was different and this may impact reliability. Haff, et al.\textsuperscript{9} visually identified the start point and in this study the point was defined at the point where the force exceeded 5 SD from baseline. Haff, et al.\textsuperscript{9} deemed pRFD sampling windows unreliable except for pRFD 20, however the CV was 12.9\%, which would be unreliable based on the criteria set in this study. All measures of pRFD were deemed unreliable in this study. Similar to the results of this study, Haff, et al.\textsuperscript{9} deemed avgRFD unreliable. Impulse at 100 ms, 200 ms and 300 ms has been reported as reliable in previous research ($ICC \geq 0.86$ and $CV \leq 8.4\%$)\textsuperscript{14-16}, in line with the results of this study, except for impulse at 100 ms which was deemed unreliable.

The TE was less than the SWC\textsubscript{0.2} for maximum force and absolute PF in both tests, and in the IMTP, the TE of relative PF (N/kg) was less than SWC\textsubscript{0.2} demonstrating that the test is useful in detecting if a “meaningful change” in performance has occurred for these variables. All other variables in both tests were rated as “marginal” or “ok”. The TE was below the SWC\textsubscript{0.5} for each variable for each test rating the usefulness as “good”. Where the TE is above the SWC\textsubscript{0.2}, coaches and practitioners can use SWC\textsubscript{0.5} to provide context of “meaningful change” to group analysis since the SWC\textsubscript{0.2} may lack the sensitivity.

Participants produced significantly greater absolute PF, relative PF (N/kg) and allometrically scaled PF in the ISqT compared to the IMTP with a moderate effect size. In addition, participants also produced significantly greater impulse ($0 - 300$ ms) with a small
effect size. However, when participants were split by sex, there were no significant results for males, also having a small effect size. By comparison, significant differences were seen for female participants for absolute PF, relative PF (N/kg) and allometrically scaled PF with a large effect size. Results are similar to Nuzzo, et al. who found that males produced an additional 12.5% relative PF (N/kg) in an ISqT. Males produced an additional 9.5% relative PF and females produced an additional 28.5% relative PF during an ISqT compared with the IMTP. This may be due to the elimination of the use of upper extremity force during the ISqT compared with the IMTP, providing a potential advantage to athletes with weakness or dysfunction in their upper extremity. Females have shown to be weaker in the upper extremity compared to their male counterparts, possibly leaving females at a disadvantage in demonstrating lower extremity strength when performing an IMTP compared to the ISqT. In addition, participants in this study had at least 6 months of resistance training experience, and not all were familiar with weightlifting movements. More recently, Beckham, et al. noted that those with less experience in weightlifting movements have spent less time overloading the power position and would not be expected to show the effect of training in this position. This lack of experience in this position may also affect the reliability results.

Results suggest that the IMTP and ISqT are reliable for comparable variables, with the IMTP appearing to be more reliable when examining pRFD and the ISqT more reliable when examining impulse. When determining the reliability the ICC and CV should be measured with the CIs giving a clearer understanding of the level of reliability. Significant differences exist between the IMTP and ISqT, and this difference is greater for female athletes compared to males.
Practical Applications

The present study demonstrated that the IMTP and ISqT are reliable for maximum force, absolute PF, relative PF, RFD (0 – 200 ms and 0 – 250 ms) and impulse (0 – 300 ms). Impulse (0 – 200 ms and 0 – 250 ms) is reliable in the ISqT. Variables of maximum force and absolute PF are useful in detecting meaningful change in both tests (SWC0.2). Where the TE is above the SWC0.2, coaches and practitioners can use SWC0.5 to provide context of “meaningful change” for all other variables in both tests. Significant differences exist between the IMTP and ISqT for measures of absolute PF, relative PF, allometrically scaled PF and impulse (0 – 300 ms). If coaches and practitioners are looking to measure an athlete’s true maximum strength, the ISqT may be the preferred test, especially among female athletes. The ISqT may be a truer reflection of the athletes maximum lower extremity strength compared with the IMTP. Future research should determine if different knee and hip angles in the ISqT produce higher forces than those used in this study.

Conclusions

Results suggest that the IMTP and ISqT are reliable for maximum force, absolute PF, relative PF, RFD (0 – 200 ms and 0 – 250 ms) and impulse (0 – 300 ms). The ISqT may be useful for measures of impulse. Both tests are useful in detecting the smallest worthwhile change for maximum force and absolute PF. The ISqT produces significantly higher absolute and relative PF among female athletes.

Acknowledgements

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References


**Figure 1:** Reliability measures of the intraclass correlation coefficient of the variables attaining an ICC > 0.8 in either the IMTP or ISqT and CV of each variable. °/° = ICC; error bars indicate 95% confidence limits. Grey shaded area = zone of acceptable reliability (ICC > 0.8). Max force = maximum force; PF = absolute peak force; RPF (N/kg) = PF relative to body weight, N/N; RFP (N/kg) = PF relative to body mass; AlloPF = allometrically scaled PF. RFP 0 – 200 = rate of force development 0 – 200 ms sampling window; RFD 0 – 250 = rate of force development 0 – 250 ms sampling window. Impulse 0 – 200 = impulse 0 – 200 ms sampling window; impulse 0 – 250 = impulse 0 – 250 ms sampling window; impulse 0 – 300 = impulse 0 – 300 ms sampling window.
Figure 2: Reliability measure of the intraclass correlation coefficient of the variables deemed unreliable in the IMTP and ISqT (ICC < 0.8 and/or CV > 10%). */* = ICC; error bars indicate 95% confidence limits. Grey shaded area = zone of acceptable reliability (ICC > 0.8). A = ICC RFD windows, B = CV%: RFD 0–150 = rate of force development 0–150 ms sampling window; RFD 0–100 = rate of force development 0–100 ms sampling window; RFD 0–90 = rate of force development 0–90 ms sampling window; RFD 0–50 = rate of force development 0–50 ms sampling window; RFD 0–30 = rate of force development 0–30 ms sampling window. C = ICC pRFD windows, D = CV%: pRFD 50 = peak rate of force development 50 ms sampling window; pRFD 30 = peak rate of force development 30 ms sampling window; pRFD 20 = peak rate of force development 20 ms sampling window; pRFD 10 = peak rate of force development 10 ms sampling window; pRFD 5 = peak rate of force development 5 ms sampling window; pRFD 2 = peak rate of force development 2 ms sampling window. E = ICC impulse and Zatsiorsky RFD measures, F = CV%: RC = reactivity coefficient; IES = index of explosiveness; avgRFD = average rate of force development; impulse 0–100 ms = impulse 0–100 ms sampling window.
Figure 3: A, B, C and D = Individual and group mean values of the IMTP and ISqT. A = absolute peak force, B = impulse 0 – 300 ms, C = RFD 0 – 200 ms, D = RFD 0 – 250 ms. Single dots represent the mean of the two trials of each participant for each test, straight line links to their corresponding score on the ISqT. *Significantly different using Holm’s Sequential Bonferroni adjusted p-value, p < 0.05.
Figure 4: Results of Hedges g with 95% CIs calculated for between tests. The shaded area detail Cohen’s scale which was interpreted as trivial ($g < 0.2$), small ($0.2 \leq g < 0.5$), moderate ($0.5 \leq g < 0.8$) and large ($g \geq 0.8$).
Table 1: Descriptive statistics for male and female participants for the IMTP and within session reliability variables attaining a criteria of an ICC > 0.8 and a CV < 10%.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
<th>ICC</th>
<th>Lower</th>
<th>Upper</th>
<th>CV%</th>
<th>Lower</th>
<th>Upper</th>
<th>TE</th>
<th>SWC (0.2)</th>
<th>Rating</th>
<th>SWC (0.5)</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Max force (N)</td>
<td>2669 ± 599</td>
<td>0.98</td>
<td>0.96</td>
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<td>3.4</td>
<td>2.6</td>
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<td>Absolute PF (N)</td>
<td>1994 ± 513</td>
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<td>0.94</td>
<td>0.99</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>89</td>
<td>103</td>
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<td>259</td>
<td>good</td>
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<td>RPF (N/N)</td>
<td>2.9 ± 0.4</td>
<td>0.93</td>
<td>0.84</td>
<td>0.97</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>0.1</td>
<td>0.1</td>
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<td>0.2</td>
<td>good</td>
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<td>RPF (N/kg)</td>
<td>28.7 ± 4.4</td>
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<td>0.84</td>
<td>0.97</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>1.3</td>
<td>0.9</td>
<td>good</td>
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<td>good</td>
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<tr>
<td>AlloPF (N/kg^{0.67})</td>
<td>116 ± 20.9</td>
<td>0.95</td>
<td>0.88</td>
<td>0.98</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>5.1</td>
<td>4.2</td>
<td>marginal</td>
<td>10.6</td>
<td>good</td>
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<tr>
<td>RFD 0 – 200 ms (N/s)</td>
<td>5623 ± 1447</td>
<td>0.89</td>
<td>0.77</td>
<td>0.95</td>
<td>9.6</td>
<td>7.4</td>
<td>13.5</td>
<td>509</td>
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<td>marginal</td>
<td>746</td>
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<td>RFD 0 – 250 ms (N/s)</td>
<td>4919 ± 1286</td>
<td>0.86</td>
<td>0.77</td>
<td>0.95</td>
<td>9.6</td>
<td>7.5</td>
<td>13.6</td>
<td>458</td>
<td>265</td>
<td>marginal</td>
<td>663</td>
<td>good</td>
</tr>
<tr>
<td>Impulse 0 – 300 ms (N.s)</td>
<td>344 ± 108</td>
<td>0.92</td>
<td>0.82</td>
<td>0.96</td>
<td>9.4</td>
<td>8.8</td>
<td>16</td>
<td>33</td>
<td>22</td>
<td>marginal</td>
<td>55</td>
<td>good</td>
</tr>
</tbody>
</table>
Table 2: Descriptive statistics for male and female participants for the ISqT and within session reliability variables attaining a criteria of an ICC > 0.8 and a CV < 10%.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
<th>ICC</th>
<th>Lower</th>
<th>Upper</th>
<th>CV%</th>
<th>Lower</th>
<th>Upper</th>
<th>TE</th>
<th>SWC (0.2)</th>
<th>Rating</th>
<th>SWC (0.5)</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max force (N)</td>
<td>2997 ± 784</td>
<td>0.98</td>
<td>0.96</td>
<td>0.99</td>
<td>3.5</td>
<td>2.7</td>
<td>4.8</td>
<td>110</td>
<td>147</td>
<td>good</td>
<td>368</td>
<td>good</td>
</tr>
<tr>
<td>Absolute PF (N)</td>
<td>2322 ± 709</td>
<td>0.97</td>
<td>0.94</td>
<td>0.99</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>110</td>
<td>131</td>
<td>good</td>
<td>327</td>
<td>good</td>
</tr>
<tr>
<td>RPF (N/N)</td>
<td>3.5 ± 0.6</td>
<td>0.95</td>
<td>0.88</td>
<td>0.98</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>0.2</td>
<td>0.1</td>
<td>marginal</td>
<td>0.3</td>
<td>good</td>
</tr>
<tr>
<td>RPF (N/kg)</td>
<td>33.3 ± 7.5</td>
<td>0.95</td>
<td>0.88</td>
<td>0.98</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>1.5</td>
<td>1.3</td>
<td>marginal</td>
<td>3.2</td>
<td>good</td>
</tr>
<tr>
<td>AlloPF (N/kg^{0.67})</td>
<td>134.9 ± 33.1</td>
<td>0.96</td>
<td>0.9</td>
<td>0.98</td>
<td>4.6</td>
<td>3.6</td>
<td>6.4</td>
<td>6.2</td>
<td>5.7</td>
<td>marginal</td>
<td>14.3</td>
<td>good</td>
</tr>
<tr>
<td>RFD 0 – 200 ms (N/s)</td>
<td>5879 ± 1891</td>
<td>0.91</td>
<td>0.8</td>
<td>0.96</td>
<td>9.9</td>
<td>7.7</td>
<td>14</td>
<td>578</td>
<td>365</td>
<td>marginal</td>
<td>911</td>
<td>good</td>
</tr>
<tr>
<td>RFD 0 – 250 ms (N/s)</td>
<td>5083 ± 1566</td>
<td>0.91</td>
<td>0.8</td>
<td>0.96</td>
<td>9.8</td>
<td>7.5</td>
<td>15.4</td>
<td>488</td>
<td>306</td>
<td>marginal</td>
<td>764</td>
<td>good</td>
</tr>
<tr>
<td>Impulse 0 – 200 ms (N.s)</td>
<td>212 ± 74</td>
<td>0.92</td>
<td>0.84</td>
<td>0.97</td>
<td>9.9</td>
<td>7.9</td>
<td>14.3</td>
<td>21</td>
<td>15</td>
<td>marginal</td>
<td>37</td>
<td>good</td>
</tr>
<tr>
<td>Impulse 0 – 250 ms (N.s)</td>
<td>294 ± 99</td>
<td>0.95</td>
<td>0.88</td>
<td>0.98</td>
<td>8.1</td>
<td>6.3</td>
<td>11.4</td>
<td>24</td>
<td>20</td>
<td>marginal</td>
<td>49</td>
<td>good</td>
</tr>
<tr>
<td>Impulse 0 – 300 ms (N.s)</td>
<td>379 ± 124</td>
<td>0.96</td>
<td>0.91</td>
<td>0.98</td>
<td>6.7</td>
<td>5.2</td>
<td>9.4</td>
<td>26</td>
<td>25</td>
<td>ok</td>
<td>62</td>
<td>good</td>
</tr>
</tbody>
</table>
Table 3: Comparison of variables deemed reliable in the IMTP and ISqT for male and female participants.

<table>
<thead>
<tr>
<th>Variables</th>
<th>All Participants</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>g</td>
</tr>
<tr>
<td>Absolute PF (N)</td>
<td>0.006*</td>
<td>0.52</td>
</tr>
<tr>
<td>RPF (N/kg)</td>
<td>0.006*</td>
<td>0.74</td>
</tr>
<tr>
<td>AlloPF (N/kg&lt;sup&gt;0.67&lt;/sup&gt;)</td>
<td>0.006*</td>
<td>0.67</td>
</tr>
<tr>
<td>RFD 0 – 200 ms (N/s)</td>
<td>0.708</td>
<td>0.15</td>
</tr>
<tr>
<td>RFD 0 – 250 ms (N/s)</td>
<td>0.708</td>
<td>0.11</td>
</tr>
<tr>
<td>Impulse 0 – 300 ms (N.s)</td>
<td>0.036*</td>
<td>0.30</td>
</tr>
</tbody>
</table>

*Statistically different using Holm’s Sequential Bonferroni adjusted p-value, g = Hedges g for magnitude of effect.

Table 4: Descriptive statistics for male participants and comparison of variables deemed reliable in the IMTP and ISqT.

<table>
<thead>
<tr>
<th>Variables</th>
<th>IMTP Mean ± SD</th>
<th>ISqT Mean ± SD</th>
<th>p</th>
<th>g</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute PF (N)</td>
<td>2225 ± 493</td>
<td>2466 ± 761</td>
<td>0.222</td>
<td>0.37</td>
<td>-0.33</td>
</tr>
<tr>
<td>RPF (N/kg)</td>
<td>30.4 ± 3.8</td>
<td>33.3 ± 7.0</td>
<td>0.245</td>
<td>0.50</td>
<td>-0.20</td>
</tr>
<tr>
<td>AlloPF (N/kg&lt;sup&gt;0.67&lt;/sup&gt;)</td>
<td>125 ± 18.5</td>
<td>137.6 ± 33</td>
<td>0.245</td>
<td>0.46</td>
<td>-0.25</td>
</tr>
<tr>
<td>RFD 0 – 200 ms (N/s)</td>
<td>6077 ± 1502</td>
<td>6044 ± 2090</td>
<td>1.000</td>
<td>-0.02</td>
<td>-0.71</td>
</tr>
<tr>
<td>RFD 0 – 250 ms (N/s)</td>
<td>5392 ± 1301</td>
<td>5297 ± 1701</td>
<td>1.000</td>
<td>-0.06</td>
<td>-0.75</td>
</tr>
<tr>
<td>Impulse 0 – 300 ms (N.s)</td>
<td>383 ± 119</td>
<td>407 ± 142</td>
<td>0.555</td>
<td>0.18</td>
<td>-0.52</td>
</tr>
</tbody>
</table>
**Table 5:** Descriptive statistics for female participants and comparison of variables deemed reliable in the IMTP and ISqT.

<table>
<thead>
<tr>
<th>Variables</th>
<th>IMTP</th>
<th>ISqT</th>
<th>p</th>
<th>g</th>
<th>lower</th>
<th>upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute PF (N)</td>
<td>1624 ± 285</td>
<td>2090 ± 578</td>
<td>0.042*</td>
<td>1.81</td>
<td>0.77</td>
<td>2.85</td>
</tr>
<tr>
<td>RPF (N/kg)</td>
<td>26 ± 4.1</td>
<td>33.4 ± 8.7</td>
<td>0.042*</td>
<td>2.06</td>
<td>0.98</td>
<td>3.15</td>
</tr>
<tr>
<td>AlloPF (N/kg^{0.67})</td>
<td>101.6 ± 16.3</td>
<td>130.6 ± 34.6</td>
<td>0.042*</td>
<td>2.07</td>
<td>0.98</td>
<td>3.15</td>
</tr>
<tr>
<td>RFD 0 – 200 ms (N/s)</td>
<td>4895 ± 1049</td>
<td>5614 ± 1589</td>
<td>0.156</td>
<td>1.10</td>
<td>0.16</td>
<td>2.04</td>
</tr>
<tr>
<td>RFD 0 – 250 ms (N/s)</td>
<td>4162 ± 857</td>
<td>4741 ± 1335</td>
<td>0.156</td>
<td>1.05</td>
<td>0.11</td>
<td>1.98</td>
</tr>
<tr>
<td>Impulse 0 – 300 ms (N.s)</td>
<td>283 ± 46</td>
<td>333 ± 75</td>
<td>0.051</td>
<td>1.28</td>
<td>0.32</td>
<td>2.25</td>
</tr>
</tbody>
</table>

*Statistically different using Holm’s Sequential Bonferroni adjusted p-value, g = Hedges g for magnitude of effect.