COMPARISON OF THE RELIABILITY OF PEAK FORCE MEASURED DURING AN ISOMETRIC MID-THIGH PULL AND ISOMETRIC SQUAT.

Claire J. Brady, Andrew J. Harrison, Eamonn P. Flanagan, and Thomas M. Comyns.

Biomechanics Research Unit, University of Limerick, Limerick, Ireland and Sport Ireland Institute, IIS Building, National Sports Campus, Abbotstown, Dublin 15, Ireland.

The purpose of this study was to compare peak force produced during the isometric mid-thigh pull (IMTP) and isometric squat (IsoSquat), performed at the same knee and hip angles (135 – 140°) and determine the reliability of both tests. Following a specific warm-up, 22 international athletes from different sports performed 2 maximal effort tests of both the IMTP and IsoSquat. Peak force achieved during the IsoSquat was significantly greater ($p = 0.01$) than peak force achieved during the IMTP. Both tests were highly reliable for peak force (ICC ≥ 0.97; CV ≤ 5%). Therefore, strength and conditioning coaches can select either test when examining lower extremity maximum strength. However, the IsoSquat produces higher peak force values and this may be a more accurate reflection of the athlete's maximum strength.

KEYWORDS: Isometric strength, maximum strength, performance testing

INTRODUCTION: Maximal force generating capabilities are commonly monitored in athletes. According to Juneja, Verma, and Khanna (2010) the isometric mid-thigh pull (IMTP) appears to be the most commonly used isometric assessment when attempting to evaluate the force-time curves of athletic populations. Nuzzo, McBride, Cormie, and McCaulley (2008) reported that NCAA division I American footballers and track and field athletes produced 12% more peak force (PF) during an isometric squat (IsoSquat) compared with an IMTP performed at the same knee and hip angle (140°). This difference may be due to the elimination of the use of the upper extremity during the IsoSquat compared with the IMTP. This may be a potential advantage to athletes with weakness or dysfunction in their upper extremity. In particular, females may be at a greater disadvantage, as previous studies have established gender differences, especially of the upper body (Yanovich et al., 2008). This may leave females at a disadvantage in demonstrating lower extremity strength when performing an IMTP compared to an IsoSquat.

When reporting the reliability of PF, the majority of studies have only reported the intraclass correlation coefficient (ICC) as the reliability measure. To determine the reliability of a test, the intraclass correlation (ICC), coefficient of variation (CV) and 90% confidence intervals (90% CI) should be determined (Hopkins, 2000). Therefore, the level of reliability reported some studies remains questionable. Additionally, the joint positions assumed for these tests differ across studies, with the knee angle for the IMTP ranging from 120 – 150° (Comfort, Jones, McMahon, & Newton, 2015; West et al., 2011) and the IsoSquat ranging from 90 – 150° (Blazevich, Gill, & Newton, 2002; Wilson, Lyttle, Ostrowski, & Murphy, 1995). This lack of consistency may adversely impact on the reliability of the measures. The purpose of this study was to compare peak forces achieved during the IMTP and IsoSquat performed at the same knee and hip angles and assess the reliability of both tests.

METHODS: Following ethical approval by the local University Research Ethics Committee, twenty two international athletes (Track and Field, Taekwondo, Canoeing, Rowing, Modern Pentathlon, Boxing and Badminton) were recruited for this study. This consisted of sixteen male participants, age: 22.8 ± 2.9 years; height: 179 ± 5.8 cm; body mass: 72.8 ± 10.4 kg and six female participants, age: 25.0 ± 2.0 years; height: 168.9 ± 3.3 cm; body mass: 62.9 ± 3.9 kg.

All isometric testing was conducted on a custom-made isometric Sorinex rack (Lexington, USA) anchored to the floor and placed over a Kistler force platform (Winterthur, Switzerland) sampling at 1000 Hz. The rack has small increments (0.5 cm) to allow for the desired position. Participants completed a familiarisation session. Firstly they were set in the correct position for the IMTP, i.e. a clean "2nd pull" position, which consisted of a mean knee angle of 137 ± 2° and a near vertical trunk with a hip angle of 138 ± 2°. This position was selected for assessment because it corresponds to the portion of the clean where the highest forces and velocities are generated (Garhammer, 1993). This position had to be maintained throughout the test. Each participant performed an IMTP-specific warm up, which consisted of pulling the IMTP bar for 5 seconds at a self-directed 50%, 3 seconds at 70 – 80% and 3 seconds at 90% of maximal effort. A 1 minute recovery was provided between warm-up efforts. Following this, participants completed 3 – 4 submaximal efforts of an IMTP lasting 5 seconds where the participant was instructed to pre-tense and then given a countdown of "3, 2, 1, Pull". Participants were then set in the IsoSquat position. The knee and hip angles and distance between feet used in the IMTP were also used for the IsoSquat (mean knee angle of 137 ± 2° and a near vertical trunk with a hip angle of 138 ± 3°). They completed the same specific warm up, pushing the bar instead of pulling and also completed 3 – 4 submaximal efforts of the IsoSquat lasting 5 seconds, with a similar instruction given. The instruction given was "focus on pushing the ground as hard and as fast as you possibly can" to ensure maximal force was achieved (Halperin, Williams, Martin, & Chapman, 2015). The testing session was completed 1 week after the familiarisation session. Participants performed a standardised warm-up consisting of 3 minutes cycling at a self-selected, comfortable pace followed by one set of dynamic exercises, 10 repetitions of each (bodyweight squat, forward lunge and glute-bridge). Participants then completed the IMTP specific warm up or IsoSquat specific warm up (counterbalanced among participants). Following this, each participant rested for 2 minutes before their two maximal-effort trials, lasting 5 seconds, with two minutes rest between trials. To standardise grip strength, participants used lifting straps. Participants rested for 5 minutes before completing the specific warm up for the second test (IMTP/IsoSquat) and then performed two maximal trials with the same recovery between trials.

The vertical force-time curve (FZ) was analysed from the output from the force plate. The onset of contraction was identified as 5 SD of BW onset threshold (Dos'Santos, Jones, Comfort, & Thomas, 2016). The maximum force generated during the 5 second IMTP and IsoSquat trial minus the participant's body weight was reported as the absolute peak force (PF) (N). Relative PF was calculated to take into account the participant's body mass (absolute PF ÷ participants body mass; $N \cdot kg^{-1}$). Additionally, to measure muscle strength independent of muscle size, PF was measured allometrically (Allo) (absolute PF ÷ participant's body mass 0.67; $N \cdot kg^{-0.67}$). All statistical analyses of the data were carried out in Excel (Hopkins, 2015). A threshold of an ICC ≥ 0.80 and a CV ≤ 10% was set to determine reliability Hopkins (2000). Paired t-tests with a significance set at ($p \leq 0.05$) were used to determine whether differences existed between the mean PF values produced during the IMTP and IsoSquat. Effect sizes were also calculated using Cohen's dz = (M1 – M2)/SDdifferences, where M1 and M2 are the means for the 1st and 2nd samples and the SD differences is the SD calculated from the differences between each pair. Effect sizes (ES) were modified as trivial (ES < 0.2), small (0.2 ≤ ES < 0.5), moderate (0.5 ≤ ES <0.8) and large (ES ≥ 0.8) (Cohen, 1988).

RESULTS: Mean ± SD of absolute PF, relative PF and allometrically scaled PF for both the IMTP and IsoSquat are shown in Table 1.

Table 1. Mean ± SD of absolute PF, relative PF and Allo PF for the IMTP and IsoSquat

Variable	All participants	Females	Males
IMTP Absolute PF (N)	2045 ± 554	1533 ± 316	2237 ± 503
IsoSquat Absolute PF (N)	2297 ± 754	1936 ± 717	2433 ± 743

IMTP Relative PF (N/kg)	28.8 ± 4.8	24.3 ± 4.4	30.5 ± 3.9
IsoSquat Relative PF (N/kg)	32.2 ± 7.7	30.6 ± 10.3	32.9 ± 6.9
IMTP Allo PF (N/kg$^{0.67}$)	117.4 ± 22.9	95.5 ± 17.8	125.6 ± 19.2
IsoSquat Allo PF (N/kg$^{0.67}$)	131.5 ± 34.7	120.1 ± 41.6	135.8 ± 32.2

Participants produced significantly greater PF (p = 0.01) during the IsoSquat, which was 11% greater than the IMTP PF with a moderate effect size (dz = 0.6). When participants are separated by sex, there was no significant difference between IsoSquat and IMTP PF (p > 0.05). Females produced 20.8% greater PF (dz = 0.8) and males produced 8.1% greater PF (dz = 0.5) during the IsoSquat compared to the IMTP (Table 2).

Table 2. Comparison of the mean ± SD absolute PF values

Participants	n	IMTP (N)	IsoSquat (N)	p	dz
All participants	22	2045 ± 554	2297 ± 754	0.01	0.6
Female	6	1533 ± 316	1936 ± 717	0.11	0.8
Male	16	2237 ± 503	2433 ± 743	0.07	0.5

The reliability analysis conducted for both tests demonstrated excellent reliability for absolute PF during the IMTP (ICC = 0.97; CV = 5%) and IsoSquat (ICC = 0.98; CV = 4.3%). Additionally, the lower limit of the CI falls above an ICC of 0.94 and the upper limit of the CV falls below 6.7%. When separated by sex the tests were equally reliable for females and males. All reliability measures for absolute PF are shown in Table 3 along with typical error measurement (TE) and change in the mean from trial 1 to trial 2 (%).

Table 3. Reliability measures for absolute PF

Test	Participants	%CV (90% CI)	ICC (90% CI)	TE	Change in mean (%)
IMTP	Male and female	5.0 (4 – 6.7)	0.97 (0.94 – 0.99)	94.6	3.5
IMTP	Females	2.8 (1.8 – 5.8)	0.99 (0.96 – 1.00)	46.3	10.3
IMTP	Males	4.3 (2.9 – 9.2)	0.97 (0.92 – 0.99)	98.4	3.3
IsoSquat	Male and female	4.3 (3.4 – 5.8)	0.98 (0.96 – 0.99)	106.4	4.3
IsoSquat	Females	3.1 (2.1 – 6.7)	1.00 (0.98 – 1.00)	84.1	6.3
IsoSquat	Males	4.6 (3.1 – 9.9)	0.98 (0.95 – 0.99)	115.1	6.8

DISCUSSION: The purpose of this study was to compare PF achieved during the IMTP and IsoSquat performed at the same knee and hip angles and the reliability of both tests. The reliability data indicates that both tests are reliable for PF (ICC ≥ 0.97, CV ≤ 5%). When determining the reliability of a test, the ICC, CV and 90% CIs should be calculated (Hopkins, 2000). Very few studies have reported all three together and this leaves the level of reliability questionable across studies. With the inclusion of the CI, a more informative depiction of the reliability measure can be made. All measures of PF for both male and female participants met the minimum threshold for reliability set in this study (ICC > 0.8, CV <10%). In addition, the lower limit of the CI for an ICC was ≥ 0.92 and the upper limit of the CI for a CV was ≤ 9.9% (Table 2).

Participants produced significantly (p = 0.01) greater PF (additional 11%) during an IsoSquat compared with an IMTP, which is similar to the findings of Nuzzo et al. (2008). Therefore, the IsoSquat may be more reflective of an athlete's lower extremity strength compared to the IMTP. These tests were performed at the same knee and hip angles (135 - 140°) and therefore the only difference between the two tests is the inclusion of the upper extremity during the IMTP. The difference between females IsoSquat PF and IMTP PF was > 20%, this was not significantly different but this may be due to the limited number of female participants in this study. Females have shown to be weaker in the upper extremity compared to their male counterparts (Yanovich et al., 2008), which may be a possible reason for the difference in sexes when comparing PF generated between the two tests. Future research should determine the reliability of other biomechanical characteristics for both the IMTP and IsoSquat and compare the results of both tests using a larger sample size.

CONCLUSION: Isometric strength testing is widely used by coaches to determine an athlete's maximum strength capabilities. PF produced during an IsoSquat is significantly greater ($p = 0.01$) than the PF produced during the IMTP. The IsoSquat may be the more accurate test to use when examining an athlete's maximum strength. Strength and conditioning coaches should consider the reliability of the biomechanical characteristics of the test. When examining the literature of the IMTP and IsoSquat, the ICC is the most commonly reported when determining the reliability of a measurement. However, it is important that the CV and 90% CIs are reported in conjunction with the ICC so a more informative depiction of the reliability of a measure can be made. Ideally a reliable measure should have an ICC > 0.8 and a CV < 10% with 90% CI reported. Both the IMTP and IsoSquat showed high levels of reliability in this study. Further research should compare further variables such as rate of force development (RFD) and impulse, determining the reliability and values produced. This will help determine what test is most suited to testing and describing an athlete's maximum strength and explosive strength capabilities.

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