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# The Reliability and Validity of Isometric Midthigh Pull Measures Obtained from a Portable Isometric Dynamometer

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## ABSTRACT

The purpose of this investigation was to establish the reliability and concurrent validity of measures of peak and early force production obtained from a portable isometric dynamometer (PID). Twenty resistance trained males completed one familiarization and two isometric mid-thigh pull testing sessions separated by 48-72 hrs. During testing sessions data was simultaneously collected from the PID and force plates (FP) both sampling at a frequency of 1000 Hz. Measurements of peak force (PF) and force at 100 ms (Force100) and 200 ms (Force200) obtained from both the PID and the FP demonstrated acceptable reliability (ICC's = 0.793-0.966; CV% = 2.7-9.2%). However, PF was significantly and meaningfully greater ($P < 0.001$; $d = 1.00$) 1.27% greater when obtained from the FP compared to the PID. In contrast, $Force_{100}$ obtained from FP was significantly lower to that obtained from PID by 229% ($P < 0.001$; $d = 3.96$). Similarly, $Force_{200}$ obtained from FP was significantly lower to that obtained from PID by 38.87% ($P < 0.001$; $d = 1.43$). Whilst the measures of force production obtained from the PID was shown to have acceptable reliability they displayed questionable validity, particularly with respect to measures of early force production.

**Keywords:** Peak force, rate of force development, early force development, strength.

## INTRODUCTION

The use of isometric strength tests to assess an athlete's force generating capability has been gaining popularity in recent years (Comfort et al., 2019; Lum et al., 2020). Possible reasons for this increase in popularity are because they are relatively simple to administer, pose minimal injury risk and have high test-retest reliability (Brady et al., 2018; Lum et al., 2020). In addition, isometric strength test is considered less fatiguing than 1 repetition maximum (1RM) testing (Lum et al., 2020), and measuring isometric peak force is not confounded by movement velocity or inter-muscular coordination (James et al., 2023). Moreover, apart from measuring peak force (PF), isometric strength tests also allow for the measuring of rate of force development and early force development (force produced in <100ms), which may be of greater importance than PF in the context of sports performance.

Force plates are the most common equipment used for measuring the force generated during multi-joint isometric tests such as isometric mid-thigh pull (IMTP), isometric squat, isometric bench press and isometric prone bench pull (Comfort et al., 2019; Drake et al., 2018; Lum & Aziz, 2020; Lum & Aziz, 2021). However, this equipment may be considered costly. While several researchers have investigated the validity of different portable dynamometer and strain gauges, they have reported differences in isometric peak force and measures on force-time curve (i.e. rate of force development and early force development) between the portable devices and force plates (Dobbin et al., 2018; James et al., 2023). Other limitation of investigated device included low sampling rate (100-125 Hz) (James et al., 2023; Montoro-Bombú et al., 2023). These limitations may lead to the avoidance of performing isometric strength tests by practitioners. Hence, the availability of a lower-cost portable isometric dynamometer with high validity and reliability may help further promote the use of isometric strength tests.

In view of the above reasons, the purpose of the current study was to explore the concurrent validity and reliability of a portable isometric dynamometer (PID) in comparison to the gold standard force plate (FP) version of the IMTP test. It is hypothesized that the measures obtained from the PID would reach acceptable levels of validity and reliability. The IMTP test was selected as it is one of the most commonly used isometric tests that can be used to measure different strength qualities, and measures obtained from IMTP are significantly correlated to various athletic performance (Grover et al., 2024; Lum et al., 2020).

## METHODS

### *Experimental Approach to the Problem*

This investigation employed a within subjects repeated measures design. Participants attended one familiarization session and two testing sessions separated by 48-72hrs. During the familiarization session, participants were briefed on the testing procedure, familiarized with the IMTP test, and measured for the optimal bar position for the IMTP test. The IMTP measures of PF, force at 100ms ($Force_{100)}$ and force at 200ms ($Force_{200}$) were obtained during the two testing sessions.

### *Participants*

A power analysis conducted using G power (G power, Dusseldorf, Germany) indicated that a sample size of at least 18 participants was required to obtain a statistical power of 0.80, based on a moderate effect size and a minimum acceptable intra-correlation coefficient of 0.60 (moderate) (Borg et al., 2022). Therefore, to account for potential dropout, twenty resistance trained males were recruited. Inclusion criteria were: i) 18-45 years old; ii) at least 1 year of resistance training experience; iii) had experience in performing maximal strength test of any mode; and iv) had not sustain any injury and chronic illness (e.g. cardiovascular diseases, cancer, diabetes and chronic respiratory diseases) in the 6 months prior to participation. All participants were briefed on the procedure of the experiment and signed an informed consent form. Ethical approval for this investigation was obtained by the Singapore Sport Institute Institutional Review Board application number SC-EXP-041.

### *Procedure*

Participants were asked to avoid consuming heavy meals for two hours prior to each testing session. All testing sessions were conducted at a similar time of day (within 1 hour) to avoid diurnal effects on muscular force production. Upon arrival at the testing venue for each session, participants were required to perform a standard warm up protocol which included five minutes of self-paced cycling on a cycling ergometer followed by 10 repetitions of body weight squat, hip hinges, forward lunges, submaximal CMJ and ankle hops. Following the warm-up, participants rested for 1 min prior to performing the IMTP.

#### *Isometric mid-thigh pull*

The IMTP was performed on portable dual force plates (FP) (Force Decks, VALD Performance, FD4000, Queensland, Australia) sampling at 1000 Hz. The commercially available ForceDecks software (VALD Performance, ForceDecks, Queensland, Australia) was used to analyze all force-time data obtained during the tests. A stiff steel powerlifting bar (Eleiko, Halmstad, Sweden) was used for the IMTP and attached to the PID (Force Hooks, Ascend Laboratories, Western Australia) sampling at 1000 Hz which were securely mounted on a squat rack (Figure 1). Participants adopted a posture that reflects the start of the second pull of the clean with a knee flexion angle of 125-145o measured using a handheld goniometer (Medpro, Netherlands), an upright torso and slight dorsi flexion of the ankle (Comfort et al., 2019). During the performance of the IMTP, participants were required to hold the bar with elbows fully extended, using lifting straps to ensure that grip strength was not a limiting factor (Torun et al., 2024). Prior to each test, participants performed a 3 second IMTP at 50%, 70% and 90% perceived maximal effort. Each repetition was separated by 60 s (Comfort et al., 2019). During the test, upon the tester's command, "3, 2, 1 push", participants

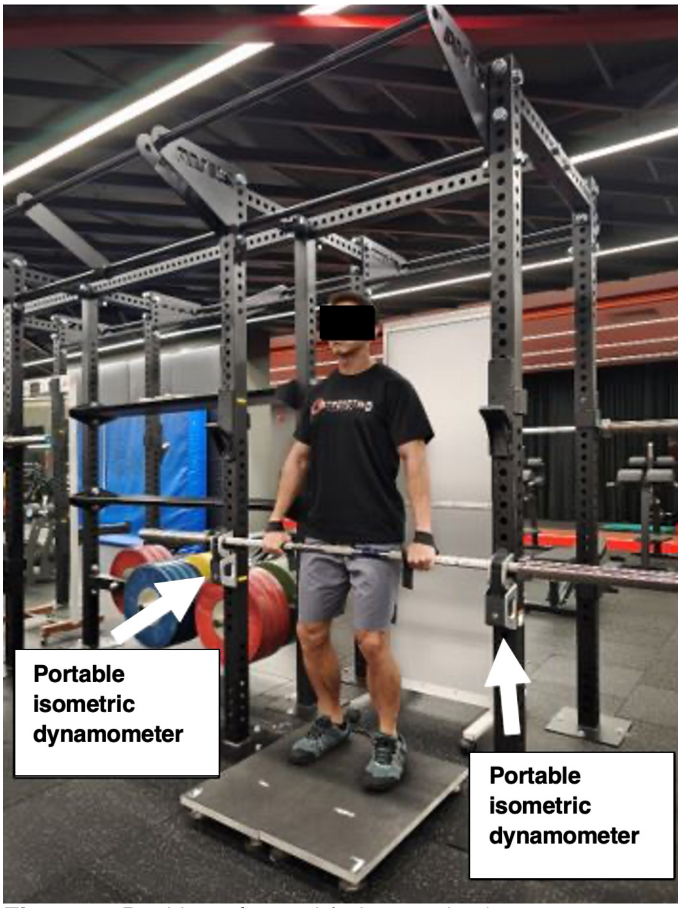


**Figure 1.** Position of portable isometric dynamometer.

drove their feet into the floor, "as fast and as hard as possible" and maintained the tension for a period of 5 seconds, with acceptable trials demonstrating no countermovement and peak force between trials demonstrating a difference <250 N. Each repetition was separated by 2 minutes (Comfort et al., 2019). The net peak force, Force100 and Force200 from the onset of pull was determined for each trial. All trials were recorded and used for further analysis. For the FP, the onset of pull was determined based on an increase of >5 standard deviation (SD) of participants body mass during the phase of quiet standing prior to the pull (Dos' Santos et al., 2017). For the PID, the onset of pull was manually identified (Guppy et al., 2024) as recommended by the manufacturer. The manual identification of force-onset was performed in Force Hooks online software. The analysis commenced through the investigator approximating the initiation and end of the trial using movable sliders in the online software.

*Statistical Analysis*

All tested variables were expressed by Mean (±1 SD). Within session test-retest reliability was assessed using two-way, mixed intraclass correlation coefficients (ICC) and coefficient of variation (%CV) for all measured variables. ICC values were deemed as poor, moderate, good, or excellent if lower bound 95% confidence interval (CI) of ICC values were <0.50, 0.50-0.74, 0.75-0.90, or >0.90, respectively (10). Acceptable within-session variability was classified as <10% (2). A total of 40 data sets (2 trials per participant) for each variable was used to compare the difference in measures obtained from FP and PID. Paired t-tests, Bland-Altman plot and Cohen's d effect size were used to compare the difference between force variables obtained between testing devices. Cohen's $d$ was computed: (i) trivial effect size if $d$ <0.25; (ii) small effect size $d$ = 0.25-0.50 and; (iii) moderate effect size if $d$ = 0.51-1.0; (iv) large effect size if $d$ >1.0 (Flanagan, 2013).

## RESULTS

The reliability analysis of all measured variables is displayed in Table 1. Excellent reliability was observed for peak force obtained from PID. Good and moderate reliability was observed for Force200 and Force100 for both devices, respectively. Bland-Altman analysis showed a mean bias of 29.8 N, 95%CI = 20.3 to 39.2 N for peak force, -1210.0 N, 95%CI = -1307.6 to -1112.4 N for Force100, and -471.4 N, 95%CI = -576.9 to -365.9 N for Force200 (Table 2 and Figure 2). Significant difference between peak force (1.27 ± 1.24%, $P$ < 0.001, $d$ = 1.00), Force100 (-229.5 ± 145.50%, $P$ < 0.001, $d$ = 3.96) and Force200 (-38.87 ± 33.39%, $P$ < 0.001, $d$ = 1.43) obtained from both devices were observed.

**Table 1.** Reliability of force measures using force plate and portable isometric dynamometer.

| Variables | ICC | 95%CI | %CV | 95%CI |
|---|---|---|---|---|
| FP_Peak Force | 0.966 | 0.939 – 0.981 | 2.7 | 2.0 – 4.5 |
| FP_Force100 | 0.793 | 0.655 – 0.881 | 9.2 | 6.6 – 15.6 |
| FP_Force200 | 0.915 | 0.852 – 0.953 | 3.6 | 2.6 – 6.0 |
| PID_Peak Force | 0.964 | 0.936 – 0.980 | 3.1 | 2.2 – 5.1 |
| PID_Force100 | 0.846 | 0.737 – 0.912 | 4.8 | 3.5 – 8.0 |
| PID_Force200 | 0.858 | 0.757 – 0.919 | 4.0 | 2.9 – 6.7 |

*FP = force plate, PID = portable isometric dynamometer.*

**Table 2.** Results of paired T-test and Bland-Altman analysis on force measures obtained from force plate and dynamometer. PID = Portable Isometric Dynamometer

| Variables | Force Plate | Portable Isometric Dynamometer | Mean Difference (95% CI) | Percentage Difference from Force Plate (%) | *P* | *d* |
|---|---|---|---|---|---|---|
| Peak Force (N) | 2302.8 (432.0) | 2273.0 (423.7) | 29.8 (20.3 to 39.2) | 1.27 (1.24) | < 0.001 | 1.00 |
| $Force_{100}$ (N) | 639.3 (228.0) | 1849.3 (273.5) | -1210.0 (-1307.6 to -1112.4) | 229.5 (145.50) | < 0.001 | 3.96 |
| $Force_{200}$ (N) | 1437.8 (341.6) | 1909.2 (288.8) | -471.4 (-576.9 to -365.9) | 38.87 (33.39) | < 0.001 | 1.43 |

## DISCUSSION AND IMPLICATIONS

The purpose of the current study was to explore the concurrent validity and reliability of a portable isometric dynamometer to the gold standard force platform version of the IMTP test. Although results showed a significant and moderate difference between peak force obtained from FP and PID, mean bias was only 29.8 N Hence, peak force obtained from PID was considered valid and reliable. However, the results suggested that PID may not be a valid tool for measuring IMTP Force100 and Force200 as both values showed significantly large difference from that obtained from FP with a mean bias of -1210.0 N and -471.4 N, respectively.

The PID resulted in the same reliability ratings for all measures as the FP. An excellent reliability was attained for peak force. However, a good and moderate reliability was observed for Force200 and Force100, respectively. While the reliability value for peak force from both devices corresponded to that observed in previous studies, the reliability values for the early force development were lower (Dos' Santos et al., 2017; Montoro-Bombú et al., 2023). One possibility was that previous studies recruited participants with greater experience in performing IMTP, while a majority of the participants in the current study had limited experience performing the IMTP. Therefore, two sessions of IMTP familiarization may not be sufficient for the participants to attain stable early force values (Drake et al., 2018). In addition, it has been reported that a protocol with shorter sustained contraction duration (1 s vs 5 s) may result in higher reliability when measuring early force and rate of force development (Guppy et al., 2022). Hence, future study may adopt the shorter contraction protocol to improve on the reliability of time dependent isometric strength measures.

Despite a statistically moderate and significant difference in peak force obtained from FP and PID, the absolute percentage difference was 1.27%. This was less than the reported %CV obtained from both devices. This level of difference was lower to that observed in previous studies that investigated other portable dynamometers (Dobbin et al., 2018; James et al., 2023). However, it should be noted that individual variability existed as shown in the Bland-Alman plot. A possible reason for the could be due to the difference in location where force was applied on the two devices. With the FP, force was applied with the feet while with the PID, force was applied with the bar. In this case, the action of the upper limb would have greater influence on the force measured by PID as compared to FP. For example, participants may have pulled the bar in a different direction as with their upper limb as opposed to directly vertical, which resulted in altered force measurement by the PID. Future investigations may include more familiarization sessions to overcome this limitation. Nevertheless, it can be stated that the current PID is a valid tool to assess the IMTP peak force due to the low magnitude of bias. Practitioners can be confident in using the PID for measuring peak force while performing IMTP.

The results also indicated that the measures of $Force_{100}$ and $Force_{200}$ derived from the PID were not valid for the IMTP, despite the acceptable reliability for both variables. Force100 obtained from PID showed no correlation to and was ~229% higher than that obtained from FP. Similarly, Force200 obtained from PID was ~39% higher than that obtained from FP, despite a significant moderate correlation. These findings correspond to the results of a similar study which showed that the force-time measure obtained from an attached S-type load cell did not reach acceptable levels of validity (James et al., 2023). James et al. (2023) attributed their findings to the low sampling rate of the load cell (100 Hz), which was much lower than that of the force plate (1000 Hz). However, in the current study, both devices had the same sampling rate of 1000 Hz.

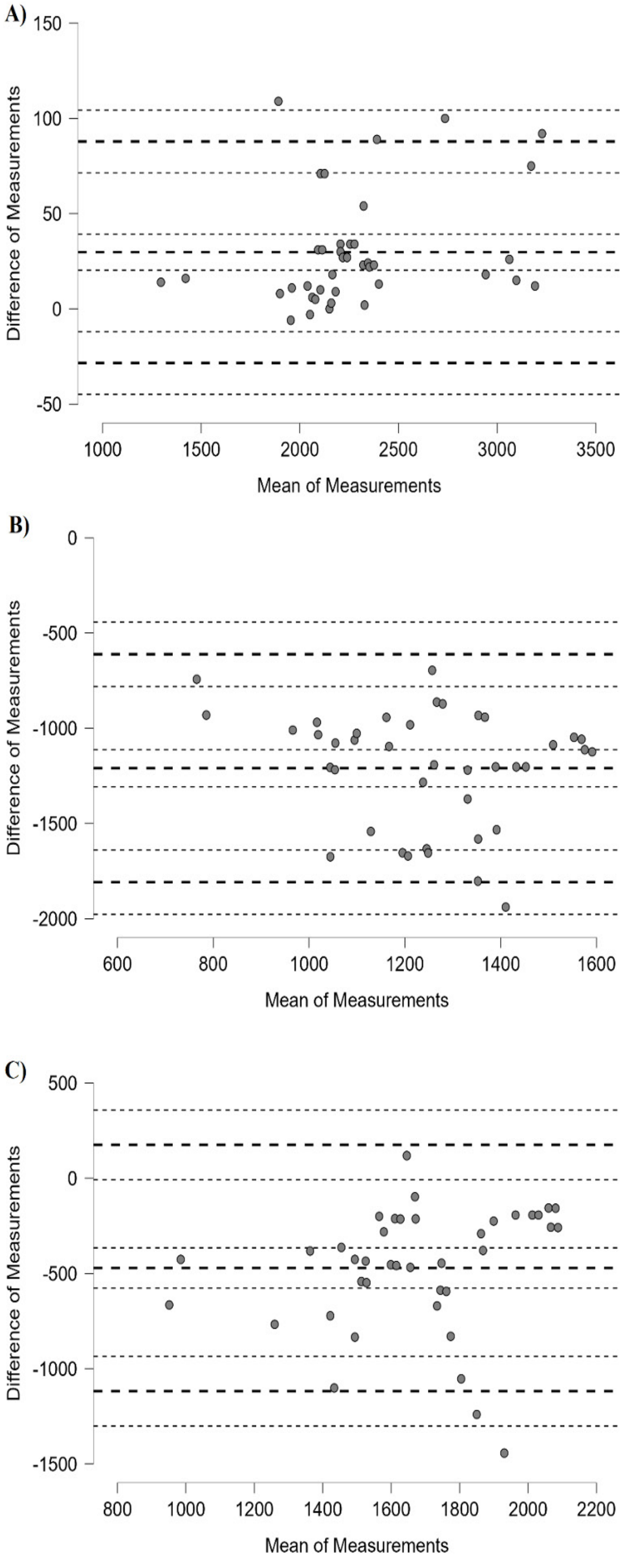


**Figure 2.** Bland-Altman plot for A) peak force, B) Force at 100 ms and C) Force at 200 ms.

Hence, the difference in early force measures would have been due to reasons other than sampling rate. One possible reason for the difference in early force measures could be linked to the difference in how the onset of pull was determined. Although previous researchers have reported that methods used to determine the onset of the pull are not interchangeable (Dos' Santos et al., 2017; Guppy et al., 2024), the mean bias observed between $Force_{100}$ (-1210 N) and $Force_{200}$ (-471.4 N) obtained from FP and PID in this study was a lot higher than that observed in previous study (Guppy et al., 2024). Guppy et al. (2024) reported a mean bias of only -289.4 N and -147.5 N for IMTP force at 90 and 200 ms, respectively, when comparing early force development based on a manual determination of onset of pull and onset of pull determined by force increment of >5 SD methods. Hence, the large difference in early force data obtained from the two devices was likely not simply because of the difference in how the onset of pull was determined. Another possible reason could be the accuracy of early force measures, regardless of the onset of pull. As displayed in Table 2, the difference between Force100 and Force200 obtained from PID was minimal (3.2%). This level of difference was much lower than those observed in previous studies that used both force plate and portable dynamometer (39.5 – 71%) (5,11,16). Therefore, the current results do not support the use of the PID for measuring early force measures during IMTP.

A limitation of the study was that a majority of the participants were inexperienced in performing the IMTP, which may have affected the technical execution and the results. However, despite this limitation, all data obtained were considered reliable and acceptable. Future research may want to investigate the impact of extended familiarization on the validity of early force measures using the PID. Additionally, future research investigating the reliability and validity of the PID to assess force generating capacity in other positions such an isometric squat or bench pull, and the sensitivity to the effects of training is warranted.

In summary, the findings of the current study support the use of the PID for measuring peak force. Based upon the results of this investigation strength and conditioning coaches and sport scientists using the PID should be aware that although measures of early force were reliable, they did not demonstrate acceptable validity when compared to the use of force plates. Practitioners using the PID should exercise caution when interpreting measures of early force production.

## CONFLICTS OF INTEREST

The authors report no conflicts of interest.

## FUNDING

No funding was received for this study to be carried out.

## ETHICAL APPROVAL

Ethical approval for this investigation was obtained by the Singapore Sport Institute Institutional Review Board application number SC-EXP-041.

## DATES OF REFERENCE

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