# The Isometric Horizontal Push Test: Test–Retest Reliability and Validation Study

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## Abstract

***Purpose:*** To investigate the test-retest reliability and criterion validity of the Isometric Horizontal Push Test (IHPT), a newly designed test that selectively measures the horizontal component of maximal isometric force. ***Methods:*** Twenty four active males with ≥ 3 years of resistance training experience performed two testing sessions of the IHPT, separated by 3–4 days of rest. In each session, subjects performed three maximal trials of the IHPT with 3-min of rest between them. The peak force outputs were collected simultaneously using a strain gauge, and the criterion equipment, consisting of a floor-embedded force plate. ***Results:*** The test-retest reliability of peak force values was nearly perfect (ICC ~0.99). Bland-Altman analysis showed excellent agreement between days with nearly no bias for strain gauge 1.2N (95% CI: -3, 6N) and force plate 0.8N (95% CI: -4, 6N). A nearly perfect correlation was observed between the strain gauge and force plate ($r = 0.98$, $p < 0.001$), with a small bias of 8N (95% CI: 1.2, 15N) in favor of the force plate. The sensitivity of the IHPT was also good, with SWC > SEM for both the strain gauge (SWC: 29N; SEM: 17N [95% CI: 14, 20N]) and the force plate (SWC: 29N; SEM: 18N [95% CI: 14, 19N]) devices. ***Conclusions:*** The high degree of validity, reliability and sensitivity of the IHPT, coupled with its affordability, portability, ease of use, and time efficacy, point to the potential of the test for assessment and monitoring purposes.

***Keywords:*** assessment, force, monitoring, sport science, strength and conditioning

## Introduction

Sport scientists and applied practitioners regularly monitor and prescribe training programs based on assessments of force production tests. Two examples of such tests are the **i**sometric mid-thigh pull (IMTP) and the isometric squat (IS) tests.[1,2] Both require subjects to stand on a force plate and either pull or push a locked in-place barbell as hard and as fast as they can. The IMTP requires participants to pull the barbell placed in the mid-thigh position. The IS requires participants to push the barbell placed on their shoulder while maintaining **a quarter- or half-squat position**. Both are valid and reliable,[2,3] correlated with performance indices,[4,5] can distinguish between level of athletes,[6,7] easy to administer and time efficient.[1] These isometric tests are extensively studied and implemented. However, both have two limitations. First, they require a force plate that many cannot afford, and a unique set up to be administered, including a robust weight lifting cage securing the barbell as immobile as possible during the tests. Second, they solely measure forces produced vertically, which may limit carryover and insight to forces applied in a horizontal vector, such as those produced during sprinting[8-10] and **r**ugby **s**crums.[11]



**Recently, researchers examined if a single axial strain gauge devices can serve as a valid and reliable alternative to a force plate when measuring force during the IMTP assessment.[12-14] Peak force outputs obtained via the strain gauges and force plates were highly correlated. In continuation with the research attempts that simplify muscular strength tests, and in view of the other mentioned above limitations**, we designed a new isometric test—the Isometric Horizontal Push Test (IHPT)—that quantifies peak force outputs using a strain gauge. This test does not depend on a force plate, can be easily administered without a complex set up, and assesses the horizontal forces component. Our aims were to examine the test-retest reliability of the IHPT peak force outputs across two days, and establish criterion validity by comparing the results derived from the strain gauge cell to those from a force plate.

## Methods

### *Subjects*

A power analysis using G-power indicated that a total sample of 24 subjects would be required to detect **a** large correlation (r=.6) with 80% power and an alpha of 5%. Twenty-four active males (22.2 ± 3.3 years; 84.2 ± 9.7 kg; 1.76 ± 0.05 m), with at least three years of resistance training experience **participated to this study.** This study was in accordance with the Helsinki Declaration and approved by the Ethics Committee of the University of the West of Scotland, UK (Submission reference number 6239-4602).

### *Design*

**This study was designed to assess the test-rest reliability and the criterion validity of the IHPT force outputs measured with a portable strain gauge cell against those from a force plate. All subjects performed the IHPT twice, separated by 3-4 days of rest.** All tests were performed in the same location, time of the day, and ambient conditions.

### *Procedures*

Following a 10-min standardized warm-up that included running drills and dynamic stretches, subjects also completed three submaximal IHPT trials equal to 60, 70 and 80% of perceived maximal effort. The IHPT position required subjects to have both feet on the ground, approximately hip width apart, with the body leaning forward, and only the fingertips in contact with the floor to **ensure minimal** upper body contribution (Figure 1). A weightlifting belt was strapped around the waist and secured to an unmovable pole with a metallic chain. The strain gauge was connected at one end to a chain, and at the other end to a pole with metallic carabines. The trunk segment and the holding chain were parallel to the ground, the upper limbs kept perpendicular, with the hip, knee and ankle angles of approximately 96 ± 2, 102 ± 1 and 81 ± 2 degrees measured with a handheld goniometer (Fabrication Enterprises Inc, Elmsford, USA). The chain height and the distance from the feet to the hands, **consequence of the standardized testing position and joint angles**, were measured **for each subject** and replicated between days. Subjects were instructed to keep the resting position for 3 seconds before starting to push the feet against the ground "as hard and as fast as possible" for 6 seconds while strong verbal encouragement was provided by the same assessor.[1]



Three maximal trials were performed with 3 **minutes** of passive recovery between them. The force outputs were collected simultaneously by the strain gauge (Chronojump, Barcelona, Spain) and a floor-embedded force plate (Kistler, Ostfildern, Germany) sampling at 80 Hz and 1920 Hz, respectively. Data collected from the force plate were down-sampled to 80 Hz through the commercial software provided by the manufacturer (Kistler Bioware 5.1.3, Ostfildern, Germany). Data from both instruments were subjected to filtering through a 10 Hz Butterworth fourth order digital low pass filter. Then, only the horizontal force components ($GRF_x$) collected with the force plate were extracted and used for comparisons with forces measured with the strain gauge (Figure 2). The initiation of the push was manually identified as the time point corresponding to a force value 5SD greater than the resting position mean value.[1] The greatest force value at any point during the trials duration was identified as peak force (PF) (Figure2).

**Statistical Analyses**

Normality of data was confirmed by examining skewness and kurtosis values and with Shapiro-Wilk test. Within **and between**-days reliability of PF outputs **were** recorded by strain gauge and force plate over both days was examined using coefficient of variation (CV%) and intraclass correlation coefficient (ICC, 3.1). The average score of the three trials per day per modality was used to calculate PF test-retest reliability between-days using ICC and levels of agreement and systematic bias using Bland-Altman bias estimates. Linear relationship between the strain gauge and force plate PF values were assessed using Pearson's correlation coefficients and Bland-Altman bias estimates. Finally, sensitivity of the PF outputs obtained from the strain gauge and force plate were assessed by comparing the smallest worthwhile change (SWC) and standard error of measurement (SEM), and interpreted by using the thresholds proposed by Liow and Hopkins.[15] Statistical significance was set at $p < 0.05$. Analysis was performed using Jamovi statistics software (Version 0.8) and Hopkins spreadsheets.[16]

**Results**

Twenty four subjects completed the study. Normality of data (skewness ≤ 1 and kurtosis ≤ 2; **Shapiro**-Wilk test ≥ 0.013) was confirmed for all trials, in both days, and both modalities. The within-day PF reliability was excellent for each modality in both days (ICC ≥ 0.97 and CV% < 2%). The test-retest reliability of PF values **was excellent** and nearly perfect (ICC ~0.99 **and CV% < 2.8%) (Figure 3)**. Bland-Altman **analysis** showed excellent agreement between days with nearly no bias for strain gauge 1.2N (95% CI: -3, 6N) and force plate 0.8N (95% CI: -4, 6**N**). A nearly perfect correlation was observed between the strain gauge and force plate (r= 0.98, p< 0.001), with a small bias of 8N (95% CI: 1.2, 15) in favor of the force plate. The sensitivity of the IHPT was good, with SWC > SEM for both the strain gauge (SWC: 29N; SEM: 17N [95% CI: 14, 20]) and the force plate (SWC: 29N; SEM: 18N [95% CI: 14, 19]) devices.

## Discussion

The newly designed IHPT conducted with a portable strain gauge is highly reliable and has high criterion validity, as measured against the force plate. These results are of both practical and scientific value. From an applied perspective, the IHPT quantifies horizontal forces, which are the crucial mechanical demands in common athletic tasks such as acceleration, sprinting, jumping for distance, and changes of direction.[8-10] In this regard, the IHPT is advantageous compared to other commonly used force production isometric tests, such as IMTP and IS, which can only assess vertical forces.[4,6] From a scientific perspective, the high reliability and validity together with the good sensitivity of the IHPT support its suitable application as a testing and monitoring tool, allowing for reliable assessment and precise comparison of changes in performance.[15] **Now that these**

**features are established, future studies are required to investigate if the IHPT performance and complementary time-domain measures (e.g. rates of force development) are correlated with other performance indices, such as sprinting start and speeds,[8,10] and distance covered in horizontal jumping which are characterized by explosive action horizontally oriented.** Studies are also required to examine if IHPT performance can distinguish between lower and higher level of athletes and to test other populations (e.g., elite level athletes, females). Given the benefits of the HIPT, this work seems like a worthwhile scientific endeavor.



**Practical application**

The IHPT has the potential to be used for several purposes by strength and conditioning, sports science, and rehabilitation professionals. The IHPT scores could be used to accurately and reliably monitor and adjust acute and chronic training interventions, the time-course effects of detraining, the residual effects of fatigue on force production capabilities, the preparedness before competition, and the recovery progression during rehabilitation programs. The affordability and portability of the testing instrumentation allow its implementation in a variety of athletic performance settings with large number of athletes to be assessed. For example, it can be used in track and field complexes, gyms, and studios by simply securing the strain gauge to an anchor point without the need for a complex set up.

**Conclusion**

The IHPT is a valid and reliable monitoring tool for practitioners who wish to measure and monitor isometric horizontal force production with a good degree of sensitivity. The IHPT can be easily administered with the use of relatively cheap equipment, including a strain gauge, weightlifting belt, chain and carabineer hook. In addition to these benefits, the IHPT is time efficient and requires only few trials to familiarize with.

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**Captions**

**Figure 1.** Isometric Horizontal Push Test setup

**Figure 2.** Force-time output plot example of the Isometric Horizontal Push Test

**Figure 3.** The individual absolute data points of the forces produced by all subjects, on both days, with the strain gauge and the force plate. The cross represents group mean and standard deviation

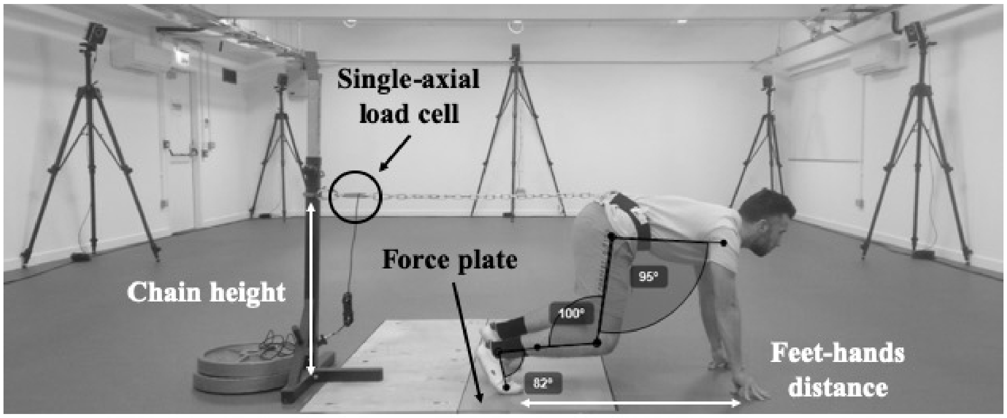


Figure 1. Isometric Horizontal Push Test setup

222x92mm (72 x 72 DPI)

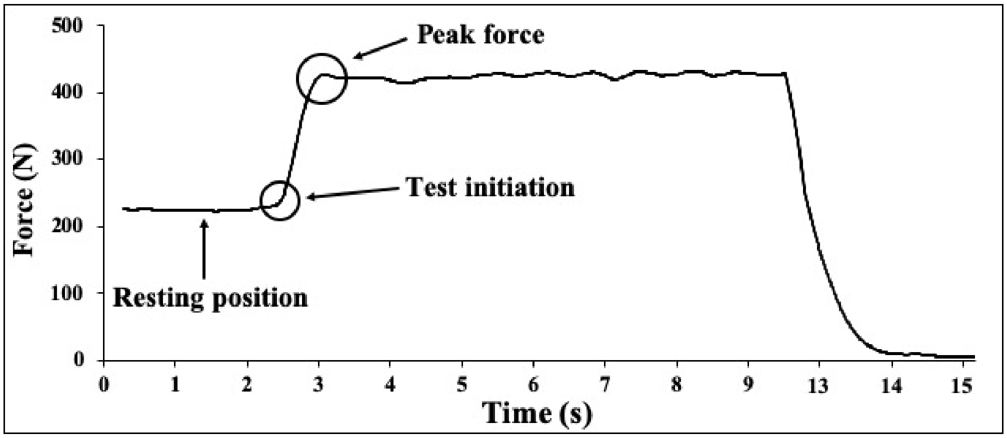


Figure 2. Force-time output plot example of the Isometric Horizontal Push Test

223x96mm (72 x 72 DPI)

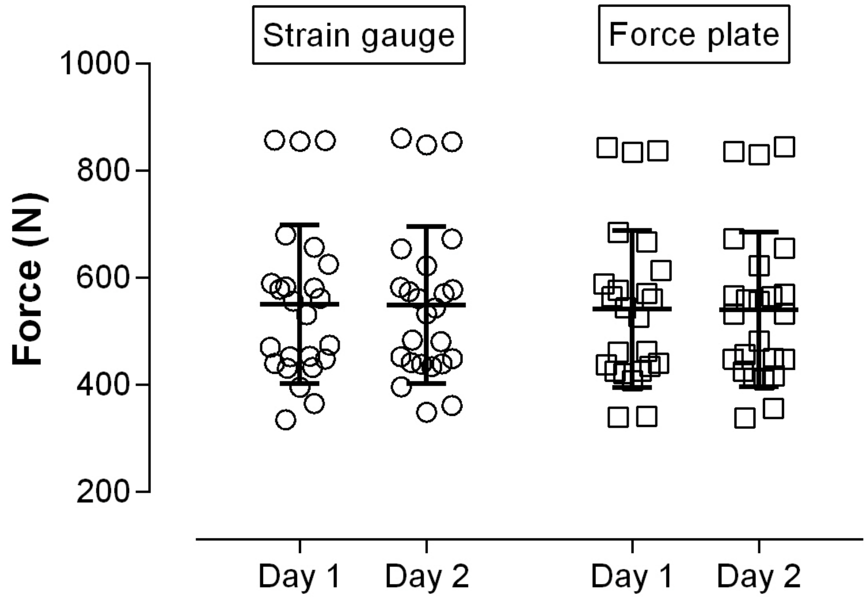


Figure 3. The individual absolute data points of the forces produced by all subjects, on both days, with the strain gauge and the force plate. The cross represents group mean and standard deviation

106x69mm (300 x 300 DPI)