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Validity of an isometric mid-thigh pull dynamometer in male youth athletes

ABSTRACT

The purpose of the present study was to investigate the validity of an isometric mid-thigh pull dynamometer against a criterion measure (i.e., 1,000 Hz force platform) for assessing muscle strength in male youth athletes. Twenty-two male adolescent (age 15.3 ± 0.5 years) rugby league players performed four isometric mid-thigh pull efforts (i.e., two on the dynamometer and two on the force platform) separated by 5 minutes rest in a randomised and counterbalanced order. Mean bias, typical error of estimate (TEE) and Pearson correlation coefficient for peak force (PF) and peak force minus body weight (PF_{BW}) from the force platform were validated against peak force from the dynamometer (DynoPF). When compared to PF and PF_{BW}, mean bias (with 90% Confidence limits) for DynoPF was *very large* (-32.4 [-34.2 to -30.6] %) and *moderate* (-10.0 [-12.8 to -7.2] %), respectively. The TEE was *moderate* for both PF (8.1 [6.3 to 11.2] %) and PF_{BW} (8.9 [7.0 to 12.4]). Correlations between DynoPF and PF (r 0.90 [0.79 to 0.95]) and PF_{BW} (r 0.90 [0.80 to 0.95] were *nearly perfect*. The isometric mid-thigh pull assessed using a dynamometer underestimated PF and PF_{BW} obtained using a criterion force platform. However, strong correlations between the dynamometer and force platform suggest that a dynamometer provides an appropriate alternative to assess isometric mid-thigh pull strength when a force platform is not available. Therefore, practitioners can use an isometric mid-thigh pull dynamometer to assess strength in the field with youth athletes but should be aware that it underestimates peak force.

Keywords: Strength, peak force, adolescent, force platform

INTRODUCTION

Muscle strength is an important physical quality for most sports (18) and has recently been advocated as a key training focus for young athletes (16). To compliment strength programming, the accurate assessment of muscle strength should be an important consideration for the practitioner working with young athletes. Maximal strength assessment methods typically include dynamic isoinertial measures using free-weight apparatus (e.g., one repetition maximum squat; 21) or resistance training machines (e.g., leg press; 19). However, free weight exercises require close supervision and should only be used when correct technical competency is demonstrated, limiting its use within younger and inexperienced groups, whilst resistance training machines lack applicability to sporting movements. To address these limitations, research has promoted the use of the isometric mid-thigh pull (IMTP) as an assessment of full body maximal strength in adults (6; 17; 20) and youths (3; 8).

Isometric strength tests such as the IMTP involve an athlete applying maximal force to an immovable object. Strength qualities are quantified through the ground reaction forces using a force platform to attain measures such as peak force and rate of force development (18). Although numerous techniques have been utilised (e.g., knee angle, hip angle, 2; 20) studies have shown the IMTP to be a reliable strength assessment method (4; 6; 13). Relationships between IMTP strength and dynamic actions such as sprinting, 18), jumping (14) and weightlifting performance (1; 9) have been shown but are not consistent for all studies (15). Therefore, research to date recommends the IMTP as a useful method for assessing maximum strength. However, the utility of the method is likely to be limited by the availability of a force platform (18), which is often of high cost potentially limiting its use within youth athletes.

Recently, James and colleagues (13) compared the IMTP using a more cost-effective single axial loading cell against a force platform in recreationally active male adults. Results showed that the peak force obtained via the two devices was highly related, however acceptable validity showed the single axial loading cell underreported peak force compared to the force platform. Therefore, the single axial loading cell offers an alternative IMTP assessment but the validity and reliability within other populations (e.g., youth athletes) is unknown. Furthermore, although the single axial loading cell offers a force-time examination at a reduced cost, this still may not be accessible for all practitioners working with youth athletes. Instead, the development of a custom built IMTP dynamometer offers a more cost effective method for the measurement of full body maximal strength (5). However, for practitioners it is important to understand the validity of any new device against the criterion method (10). Therefore, the purpose of this study was to compare the peak force obtained during the IMTP performed on a custom-built dynamometer (i.e., practical measure) and force platform (i.e., criterion measure) within male youth athletes.

METHODS

Experimental Approach to the Problem

The study was designed to assess the validity of an IMTP exercise performed on a dynamometer against a force platform. All subjects underwent a familiarisation session performing two IMTP attempts on the dynamometer and force platform, respectively. One week later, all subjects completed two IMTP assessments on the dynamometer and force platform in a randomised and cross-over design with five minutes rest between efforts. The peak force obtained from the dynamometer was compared with that of the force platform.

Subjects

Twenty-two male adolescent rugby league players (age 15.3±0.5 years, stature 177.9±5.0 cm, body mass 77.0±13.3 kg) participated in this study. Ethics approval was granted by the university ethics board and written informed assent and parental consent was acquired from all subjects.

Procedures

The study was conducted during the pre-season training phase with the testing session preceded by a standardised warm up (light jogging, dynamic stretches and submaximal isometric mid-thigh pull efforts). For the IMTP, subjects were positioned on each repetition to represent the 2nd pull of the power clean with shoulders placed over the bar and feet hip width apart (See Figure 1) consistent with previous studies (7; 13). Subjects were instructed to pull as hard and fast as possible after a 3 second countdown as this is known to elicit the greatest peak force (1).

INSERT FIGURE 1 HERE

Dynamometer: A custom built IMTP dynamometer was designed and built to include a T.K.K.5402 dynamometer (Takei Scientific Instruments Co. Ltd, Niigata, Japan), wooden platform (80x50 cm) with rubber foot grips (31x20 cm), chain (51cm) and latissimus pulldown bar (120cm; Decathlon, United Kingdom). The T.K.K.5402 dynamometer was removed from its original base (31.5x31.5 cm) and attached to the wooden platform to allow subjects to adopt a wider foot position, with a wider bar allowing subjects to grip the bar representative of that during the second pull of the power clean. Subjects were positioned by standing on the foot grips and adjusting the chain length so they were positioned in the above position. Subjects gripped the bar without the use of straps and prior to pulling maintained tension on the chain so a jerk action was not performed. The dynamometer score was recorded in kilograms and then multiplied by 9.81 to represent a peak force (DynoPF) value in Newtons.

Force Platform: A commercially available portable force platform (AMTI, ACP, Watertown, MA) with a sampling rate of 1,000 Hz was used as the criterion measure. The force plate base was 101x80 cm with bar dimensions of 140x3.3 cm. Subjects were positioned as above by standing on the force platform and adjusting the bar height on a customized fixed rack, which enabled adjustments in bar height by 3 cm increments, whilst further smaller adjustments were made by placing 1 cm wooden boards on the force platform. The highest peak force (PF) in Newtons was used for analysis. In addition, peak force minus the subject's body weight (PF_{BW}) was also used for analysis as the dynamometer did not measure the subject's body mass.

Statistical Analyses

All analysis was undertaken using an Excel spreadsheet (12). Within session reliability was assessed using intraclass correlation coefficients (ICCs) and coefficient of variation (CV). To analyse the validity between the dynamometer and force platform was assessed mean bias, typical error of the estimate (TEE) and Pearson correlation coefficient, all with 90% confidence limits. Mean bias was rated as *trivial* (<0.19), *small* (0.2-0.59), *medium* (0.6-1.19) or *large* (1.2-1.99). The TEE was rated as *trivial* (<0.1), *small* (0.1-0.29), *moderate* (0.3-0.59) or *large* (>0.59). Correlations were rated as *trivial* (<0.1), *small* (0.1-0.29), *moderate* (0.3-0.49), *large* (0.5-0.69), *very large* (0.7-0.89) or *nearly perfect* (0.9-0.99) (12). Linear regression analysis was used to determine a prediction equation to estimate the criterion measure from the practical measure along with regression statistics (R^2). Using a 50/50 split of the sample, a cross-validation of the prediction equations sought to establish whether there was minimal shrinkage in the R^2 value relative to the model.

RESULTS

The intra-session reliability for the dynamometer was ICC = 0.91 and CV = 6.0%. The intra-session reliability for the force platform was ICC = 0.94 and CV = 4.3%. The agreement between the IMTP PF and PF_{BW} (criterion measures) with the DynoPF (practical measure) are shown in Table 1.

INSERT TABLE 1 HERE

The regression analysis based upon the cross-validation sample revealed that DynoPF explained 76.3% (adjusted R^2 = 0.76) of the variance in PF, yielding the equation: PF = (0.7288*DynoPF) + 306.82. Cross-validation analysis revealed a non-significant bias between the predicted and observed PF, with an adjusted R^2 (78.2%). The overall regression model revealed that DynoPF explained 81.1% of the variance in PF. The equation was PF = (0.5716*DynoPF) + 88.96.

The regression analysis based upon the cross-validation sample revealed that DynoPF explained 77.5% (adjusted R^2 = 0.78) of the variance in PF_{BW}, yielding the equation: PF_{BW} = (0.783*DynoPF) + 124.61. Cross-validation analysis revealed a non-significant bias between the predicted and observed PF_{BW} with an adjusted R^2 (79.4%). The overall regression model revealed that

DynoPF explained 77.5% of the variance in PF. The equation was: PF_{BW} = (0.7496*DynoPF) + 230.34.

DISCUSSION

This study compared the peak force obtained during the IMTP performed on a dynamometer (i.e., practical measure) with a force platform (i.e., criterion measure) in male youth athletes. Findings demonstrated that the dynamometer IMTP underestimated peak force on a force platform, when body weight was and was not included identifying the dynamometer was not valid for assessing peak force. However, the good relative agreement between the dynamometer and force platform, as indicated by the near perfect correlations, suggests that the dynamometer may be used as an alternative to a force platform for assessing IMTP with the regression equations applied to estimate PF.

Large differences between DynoPF and PF were apparent as a force platform measures the weight of an individual compared to the dynamometer measuring the 'pull' force, as opposed to the ground reaction forces (18). Although this seems obvious it is an important consideration as most studies (e.g., 3) report absolute peak force from a force platform without considering body weight. However, when body weight was removed (PF_{BW}), the dynamometer still underestimated peak force, which may have occurred due to the open chain design of the dynamometer, which could increase the likelihood of force being applied outside of the vertical axis (13) alongside increased proprioception requirements within the open chained dynamometer compared to the closed chain force platform (13). Furthermore, the grip on the dynamometer could have resulted in reduced peak force as the bar could more easily spin when gripped by the subjects compared to the fixed bar of the force platform. A further limitation is that body positions (e.g., joint angles) were not measured in each assessment and is therefore a limitation of the study

Although peak force was underestimated, nearly perfect correlations were observed suggesting that the dynamometer is able to measure IMTP strength and can discriminate between stronger and weaker individuals. Therefore, the dynamometer can be used to measure IMTP strength in youth athletes with the regression equations applied to calculate peak force. If the purpose is to assess muscle strength of large groups of athletes, especially within large field-based testing studies (e.g., 11), the dynamometer seems a useful assessment method, especially considering the appropriate reliability.

Although this study suggests that a dynamometer can measure IMTP strength, the advantages of using a force platform should still be acknowledged. Force platform analysis allows force-time characteristics (e.g., impulse, rate of force development) to be assessed across varying time points (6), compared to the dynamometer providing a single maximum peak force. Therefore, when working with small athlete groups and a force platform is available this would allow a more detailed profile of athletic performance.

In conclusion, IMTP strength assessed using a dynamometer underestimated peak force obtained using a force platform, even when body weight was removed. The dynamometer is therefore not a valid measure of IMTP strength. However, nearly perfect correlations between the devices suggest that the dynamometer can discriminate between stronger and weaker individuals and can be used to assess IMTP strength in male youth athletes with regression equations applied to estimate peak force.

PRACTICAL APPLICATIONS

An IMTP performed on a dynamometer is not a valid measure of peak force obtained from a force platform. However, the near perfect correlations between the methods suggest an IMTP dynamometer could be considered as part of a testing protocol. Practitioners should understand that peak force obtained using a dynamometer underestimate scores compared to a force platform, though regression equations can be used to estimate peak force. The IMTP is a safe, accessible and efficient method for assessing strength when working with a large number of youth athletes where expensive laboratory-based equipment is not available.

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FIGURE CAPTIONS

Figure 1. Isometric mid-thigh pull position performed on a (A) dynamometer and (B) force platform

Table 1: Comparison of DynoPF, PF and PF_{BW}. Data are mean (± standard deviation (SD)) and mean bias, typical error of the estimate and Pearson correlation coefficient, all with 90% confidence limits.

Criterion Measure Peak Force (N)	**Practical Measure Peak Force (N)**	**Mean bias %**	**TEE %**	***r***
PF = 2374.9 ± 418.6	DynoPF = 1446.5 ± 265.7	-32.4 [-34.2 to -30.6] (*very large)*	8.1 [6.3 to 11.2] (*moderate)*	0.90 [0.79 to 0.95] (*nearly perfect*)
PF_{BW} = 1619.2 ± 314.2	DynoPF = 1446.5 ± 265.7	-10.0 [-12.8 to -7.2] (*moderate*)	8.9 [7.0 to 12.4] (*moderate*)	0.90 [0.80 to 0.95] (*nearly perfect*)

1