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Reliability, Variability and Minimal Detectable Change of the Isometric Mid-Thigh Pull in Adolescent Dancers

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Abstract:	Introduction: The importance and potential benefits of muscular strength in the adolescent's development for health and fitness but also injury prevention has been demonstrated in the literature. Muscular strength and its assessment, however, is not part of the assessment criteria in the selection of young talented dancers. Methods: The present study evaluated the within- and between session reliability, variability, and minimal detectable change (MDC) of the isometric mid-thigh pull (IMTP). Thirty-five participants (female n=17) participated in two identical assessments on the same day with 4-hour break in between. Results: Within-session the ICC indicated excellent reliability (ICC= 0.99, 95% CI: 0.98-0.99). Between-session reliability was excellent (ICC= 0.98, 95% CI: 0.95 to 0.99). The standard error of measurement was 4% (48N), the minimum detectable change was 12% (134N) and the CV was 3%. There were no within-session statistically significant differences, but statistically significant differences between-session were observed (p< .001). Limits of agreement ranged from -121N (95% CI -186 to -56N) to 307N (95% CI 243 to 372N). Conclusion: The observed results demonstrated excellent within- and between-session reliability, low variability, and an MDC of 12%. The consistency of the within-session scores suggest that peak force data may be obtained with single try efforts. The statistically significant difference in the means of the retest session, however, suggests that the time of the day and/or the time since entrained awakening may be affecting performance in adolescent dancers. The results of the current study indicate that the IMTP is a reliable assessment tool for maximal muscular strength in adolescent dancers.

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Key Words: muscular; strength; maximal; testing

Key Points

- The isometric mid-thigh pull is a reliable assessment tool for maximal muscular strength in adolescent dancers.
- Providing that young dancers have enough time to familiarize themselves with the isometric mid-thigh pull protocol, single try efforts may suffice for peak force assessment.
- Practitioners are advised to consider the time of the day as a confounder when they conduct the isometric mid-thigh pull test.

Introduction

Over the last decade experts in youth development have published an international consensus on the importance of muscular strength in children and adolescents.[1] Empirical evidence further supports this, indicating that muscular strength enhancement in young athletes can improve physiological performance,[2] reduce associated injury risk factors,[3] and have a positive effect on health and well-being.[1]

Numerous studies have demonstrated that increased maximal strength relative to body mass can improve performance in explosive lower body movements, such as sprinting, agility[4] and vertical jumping.[5,6] Jumping is an integral part in the training of an adolescent dancer, with jumping rates similar to those that are observed in volleyball.[7] Jumping and landing have been identified as a common mechanism of injury in professional ballet dancers.[8,9] Jumping is also regarded as a fundamental motor skill in youth development.[10] Higher levels of fundamental motor skills demonstrate higher level of sport specific skill.[11,12]

Research on the relationship of muscular strength and aesthetic performance in aesthetic sports and dance is limited but there is some evidence indicating that higher level gymnasts produce greater rate of force development.[13] In dance, Bianco and colleagues suggest that higher countermovement jump is associated with higher quality in the grand jeté, a ballet specific jump.[14] Nevertheless, muscular strength and power assessment is not included in talent identification of youth dance. Potentially, the appropriate assessment of these parameters in adolescent dancers can assist practitioners to monitor physiological development and performance.

There are several established methods of maximal muscular strength assessment; repetition maximum tests, predictive protocols, isometric assessments and eccentric protocols.[15] It has been demonstrated that repetition maximum tests are safe and appropriate for adolescents, as long as they show technical competency and are supervised by qualified professionals.[16] When competency or training age is low, however, the use of multi-repetition maximum protocols seems a more plausible method of assessment.[1] The practitioners or researchers can then predict the one repetition maximum in youth. These tests are not as accurate for maximal strength evaluation and can increase the risk of fatigue accumulation.[17]

The isometric mid-thigh pull (IMTP) is an assessment tool for maximal isometric strength frequently used in the adult based literature,[18] in a variety of sports. [4,19,20] Even though the test is isometric, it statistically correlates to dynamic athletic tasks such as vertical jump performance,[18] and sprinting.[21] The assessment has two primary applications, (1) the quantification of maximal force-generating capacity, known as peak force, and (2) to assess the rate at which force can be generated, known as rate of force development (RFD).[4] The IMTP has been established as highly reliable in trained adults,[22-24] and professional athletes.[25] Recent studies have utilised the IMTP to assess maximal isometric strength in young male soccer players,[19] young female athletes,[26] and young female gymnasts.[13]

For an assessment tool to be deemed suitable for use, it needs to display the necessary level of reliability.[24] The aim of the study, therefore, was to investigate the within- and between-session reliability, variability and MDC of the peak force during the IMTP in adolescent students of dance.

Methods

Experimental Approach to the Problem

The participants were required to attend two identical data collection sessions separated by four hours. Both sessions took place on a Sunday as this was the only day the participants would have had 24 hours rest from their last dance class, and they would not participate in any other form of training on the day.

Participants

An open invitation was verbally given to seven year groups (n= 160 participants) at a vocational dance school for participation. The youngest year group was excluded as the students were not familiar enough with the testing protocol. Based on Morrow and Jackson (1993) recommendations on establishing the reliability of a test or a measurement, the sample size target was >30 participants.[28] Thirty-five adolescent dancers (male: n= 18, age: 14 ± 2.17 years, height: 160.0 ± 9.7cm, mass: 46 ± 11.1 kg; female: n= 17, age: 14 ± 1.05 years, height: 156.0

± 6.67 cm, mass: 40 ± 5.75 kg) volunteered for this study. Participants needed to be injury free prior to data collection, and they needed to have had experience in the IMTP test protocol, minimum four times within one academic year. Four testing sessions in an academic year would equate to minimum 24 isometric pulls (3 warm-up pulls plus 3 assessment pulls multiplied by 4 sessions). The participants were exposed to varied amount of dance hours per week (range: 17 to 27 hours per week). Parental informed consent was obtained for all the participants and ethical approval was attained from the [BLINDED] ethics committee.

Procedure

The sessions began with a warm-up that consisted of a 2-minutes light cardiovascular exercise and dynamic stretches targeting the large muscles of the lower body, the back, and shoulders. All participants were familiar with the IMTP test protocol as it was routinely used to monitor their fitness, typically four time in a year. A three second IMTP was used as the measure of lower body strength. Participants stood on a custom-made platform where a load cell (LCM Systems Ltd, Newport, UK) was anchored, and the signal was processed by Powerlab (AD Instruments, Dunedin, New Zealand). On the other end of the load cell there was a chain and at the end of the chain a small bar that was placed at mid-thigh. They were asked to assume the position by self-selecting their hip and knee angles[4] whilst following the instructions, to place the chain between your feet, and their feet underneath their hips, to keep their knees soft, their back flat (neutral) and upright, and their chest out. The height of the bar was recorded for the re-test assessment (Figure 1).

---------------------------- Figure 1 approximately here-------------------------------

Each participant was provided two warm-up pulls, one at 50% and one at 75% of the participant's perceived maximum effort, with 1 minute rest in between.[19] Once the warm-up pulls were completed the participants were given a countdown of "3, 2, 1, Pull". The participants were instructed to relax before the command "Pull!" to avoid the precontraction.[4] They were then asked to pull the bar with their hands and push the platform away with your legs whilst maintaining their posture, with no backward leaning. The participants were instructed refrain from a final moment jerk in their pull just before the completed one try. The pull lasted for three seconds, for three consecutive times with 60 seconds rest between the pulls. Strong verbal encouragement was given for each trial. The peak force (N) was then recorded and was used for the analysis.

Statistical Analyses

To evaluate the reliability the within- and between-sessions intraclass correlation coefficient (ICC) needs to be calculated.[24] Minimal detectable change (MDC) can then be calculated to assist practitioners understand the difference between noise and meaningful change in the data.[27] The mean and standard deviation (SD) of the peak force was calculated from the three trials from the two sessions. The assumption of normality was assessed with the Shapiro-Wilk test. Within-sessions reliability was assessed by the intraclass correlation coefficient (ICC), and the 95% confidence intervals (CIs). The between-session reliability was established by the calculation of the $ICC_{(2,1)}$ and the 95% CIs with a 2-way mixed-effects model for absolute agreement.[29] ICC values less than 0.50 are indicative of poor reliability, values between 0.50 and 0.75 suggest moderate reliability, values between 0.75 and 0.90 indicate good reliability, and values greater than 0.90 suggest excellent reliability.[29]

Standard error of the measurement (SEM) and minimum detectable change (MDC) were also calculated to establish the between-sessions random-error scores.[30] SEM was calculated with the following equation $SEM = SD\sqrt{1-ICC}$ where SD was the between-subject standard deviation at the first session. The MDC was calculated with the following equation $MDC = 1.96\, x \sqrt{2}\, x\, SEM$. The mean value from the three attempts of each participant was used to calculate the between-sessions reliability in order to reduce the noise in the data.[31]

Analysis of variance (ANOVA) was conducted to assess the change of the within-session means. Paired-sample t-test was conducted to assess the difference of the between-sessions means. The relationship between the difference and the magnitude of the between-session measurements together with the potential systematic bias were assessed by the Bland-Altman plot and the 95% Limits of Agreement (LOA). LOA was set as the mean difference between test and retest scores ±2 SD from the mean.[32]

Data are presented as mean ± *SD*, whereas alpha level was set at $p \leq 0.05$. The descriptive statistics, ICC, and SEM together with their 95% CIs were calculated with SPSS v28 statistical software (SPSS Inc., Chicago, IL, USA). The between-session intra-subject variability was established through the coefficient of variation (CV) which was calculated using the EnvStats R package. All remaining analysis was conducted using the statistical software Jamovi version 1.6 (www.jamovi.org).

Results

Descriptive statistics for all the tries in the two sessions are presented in Table 1. Within-session the ICC indicated excellent reliability (ICC= 0.99, 95% CI: 0.98-0.99).

---------------------------- Table 1 approximately here-------------------------------

Between-session reliability was excellent (ICC= 0.98, 95% CI: 0.95 to 0.99). The standard error of measurement was 4% (48N), the minimum detectable change was 12% (134N) and the CV was 3%. There no within-session statistically significant difference, but statistically significant difference between-session was observed ($p < .001$).

Limits of agreement ranged from -121N (95% CI -186 to -56N) to 307N (95% CI 243 to 372N). The Bland-Altman distribution plot demonstrated that, if a new individual from the studied population was assessed, the differences between any two tests would be expected to lie within the limits of agreement with an approximate 95% probability.[33] The estimated mean of the differences (bias) was 93N (95% CI: 55 to 131N) (Figure 2).

---------------------------- Figure 2 approximately here-------------------------------

Discussion

This is first study to assess the reliability of the IMTP in adolescent dancers. The aim of this study was to assess the within- and between-session test-retest reliability, variability and MDC of this assessment tool. The findings indicate excellent levels of reliability as described by within-session ICC of 0.99 and between-session ICC of 0.98, with low variability (CV= 3%). The associated confidence intervals can provide more insight about the consistency of the measurements as for both the within and between-session ICC, the lower bound remains >90. The SEM (4%) was lower than the MDC (12%). The relationship between the difference and the magnitude of the between-session measurements together with the potential systematic bias that were assessed by the Bland-Altman plot and the 95% Limits of Agreement (LOA) suggest that the IMTP is a reliable method for assessing peak force in adolescent dancers.

Our results indicate similar within- and between-session reliability scores to De Witt et al.[22] (ICC_{within}= 0.98, $ICC_{between}$= 0.89), Thomas et al.[34] ($ICC_{between}$= 0.95, MDC= 3.1%, CV= 3.8%) and Dos' Santos et al.[19] (ICC_{within}= 0.97-0.98, CV= 4%, $ICC_{between}$= 0.96, MDC= 8.5%, CV= 4.6%). Similarly to the Dos' Santos et al.[19] study, the current study did not inspect rate of force development from the IMTP. Our results report similar between-session reliability scores, standard error but higher MDC (14% vs 8.5%). The Dos' Santos et al.[19] study, however, was conducted with a small sample (n= 13). Even though the authors conducted a post-hoc power calculation, their results indicate lack of statistical power, and they need to be considered with caution. It has been demonstrated that post-hoc power calculation is not informative and can lead to misinterpretation of the results.[35,36]

Similar to James et al.[24] the findings of the current study further support the utilisation of a customised portable isometric mid-thigh pull rig. James and colleagues assessed the reliability and validity of their custom-made rig against a force plate, and they observed excellent ICC= 0.96 (90% CI: 0.90-0.98), CV= 3%, and acceptable validity ICC= 0.88 (90% CI: 0.71-0.95), CV= 9% (90% CI: 7-14%) for the assessment of peak force.[24] The small sample of convenience may have affected their results and therefore need to be considered with caution.

We observed no statistically significant difference between the tries in both sessions. This is further supports the findings of a study with adolescent gymnasts.[26] Moeskops et al. suggest that providing young athletes enough familiarisation time with the IMTP test, peak force measurement can be obtained from a single trial. This makes the IMPT easier to administer and more time efficient.

There was between-session statistically significant difference in the scores (p> .001). This may be associated with the time of the day that the pre (11am) and post (3pm) testing took place. It has been previously suggested that personal best performance of athletes is affected by the time of the day in swimmers,[37,38] judo athletes,[39] and young soccer players.[40] Facer-Childs and Braandstaetter however, suggest that time since entrained awakening is a strong predictor of peak performance,[41] and not just the time of the day. Although we did not check the time our participants had woken up, the first assessment was performed closer to their wake-up time, approximately 2-3 hours after breakfast. Whilst the IMTP indicates excellent reliability, practitioners should consider the time of the day when they conduct the assessment. More than three hours from the time the adolescents wake-up or simply conducting the assessment in the afternoon may be advisable if they want to obtain peak force scores closer to the individual's personal best.

Test-retest reliability sessions are customary conducted with minimum 24-hour rest in between.[19,22,26] The current study's test-retest assessments were conducted on the same day with four hours break between, with no signs of fatigue in the pre-post measurements. It has been previously suggested that the IMTP induces minimal fatigue and is time efficient.[25] For these reasons, practitioners in similar environment of high training load and lack of availability time for the participants may consider utilising the IMTP as an assessment tool for maximal muscular strength.

This study is characterised by several limitations. Maturation status was not taken into consideration. Moeskops and colleagues have indicated the pre-peak height velocity athletes showed greater variability in absolute and relative peak force than post-peak height velocity athletes.[26] The authors further suggest that there is systematic bias within the less mature group, therefore, further familiarisation may be necessary.[26] Due to the age range of our cohort, there may have been individuals at a different maturation status. All our participants, however, had a minimum of one year experience with the test (minimum 24 isometric pulls) and therefore any potential learning effect bias may have been eliminated. We did not investigate the rate of force development, therefore, further research is needed for more detailed force-time curve variables in adolescent dancers with biological maturation taken into consideration.

Practical Applications

There are many different test protocols to assess muscular strength capacity in adolescent dancers, however, these protocols require some level of technical competency for adolescents to safely perform them. The IMTP is validated against 1RM squat performance,[18] therefore it is a reliable alternative for maximal strength capacity assessment in young individuals with low training age or experience. Providing that the participants are given enough time to familiarise with the protocol, the IMTP is a safe assessment for adolescent dancers, as there is no vertical load on the immature body and is self-regulated. Health practitioner and strength and conditioning coaches can use the current findings to monitor and establish real changes in IMTP performance and should look for changes in peak force greater than 12% to identify meaningful changes in response to training in adolescent dancers. The time of the day of the assessment together with the time since entrained awakening should be taken into consideration for practitioners to obtain closer to personal best peak force performance in adolescent dancers. Lastly, it may not be feasible for non-boarding schools to have a 24-hour break between the assessment day and the last training day. Further research should focus on testing peak force on a dance day to assess the magnitude of the dance schedule on the scores.

Conclusion

This is the first study to investigate the within- and between-session reliability, variability, and MDC of peak force in the IMTP. The results demonstrated excellent within- and between-session reliability, low variability, and an MDC of 12%. The consistency observed in the scores for all the tries suggest that peak force data may be obtained with single try efforts, once the participants are familiar with the testing protocol. Higher scores were observed in the retest session; therefore, practitioners are advised to conduct the IMTP test in the afternoon instead of the morning. The findings of this study make the isometric mid-thing pull a reliable assessment tool for maximal muscular strength in adolescent dancers.

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Table 1. Descriptive statistics for IMTP, standard deviation, standard error, and minimum detectable change

	Mean (95% CI)	SD	SE (%)	MDC (%)
Test – Try 1	1105 (996 to 1214)	329	56 (5)	154 (14)
Test – Try 2	1122 (1011 to 1233)	336	57 (5)	157 (14)
Test – Try 3	1121 (998 to 1244)	372	63 (6)	174 (15)
Retest – Try 1	1206 (1082 to 1330)	376	64 (5)	176 (15)
Retest – Try 2	1218 (1090 to 1346)	386	65 (5)	181 (15)
Retest – Try 3	1205 (1078 to 1332)	385	65 (5)	180 (15)

CI: Confidence intervals, SD: Standard deviation, SE: Standard error, MDC: Minimum detectable change

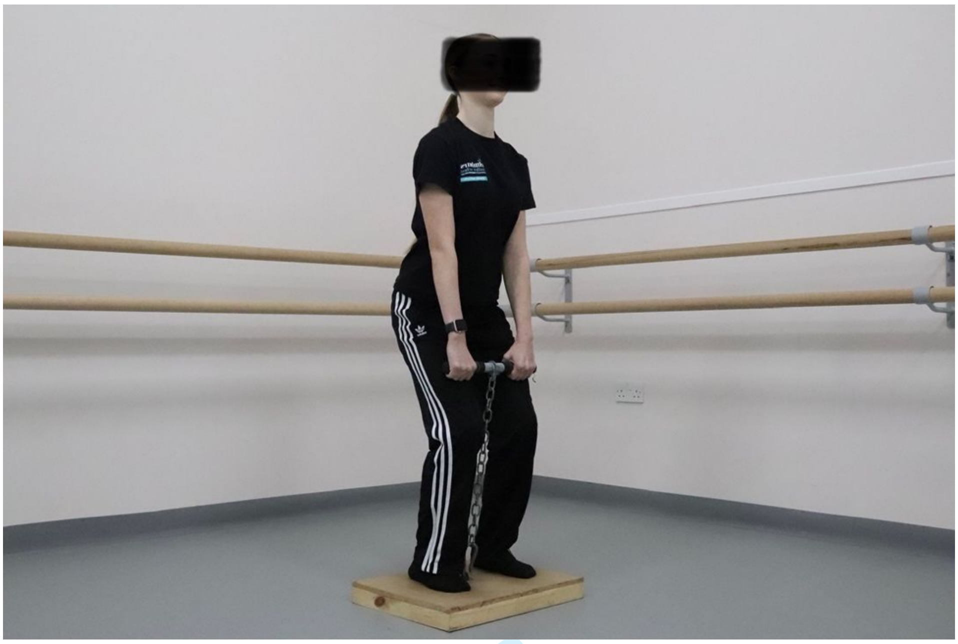

Figure 1 Isometric mid-thigh pull setup.

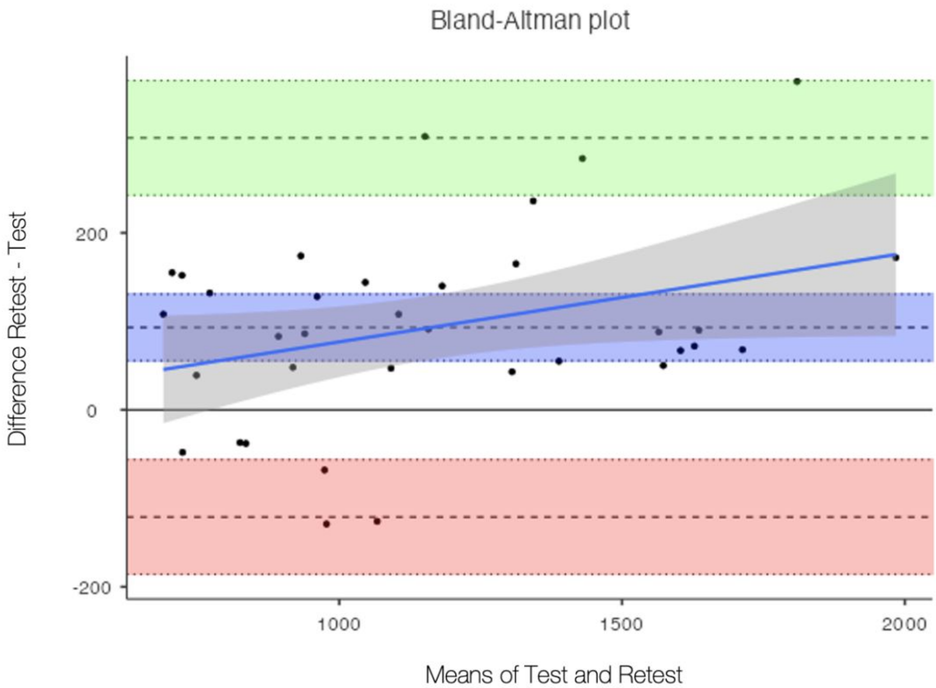

Figure 2 Bland-Atlman distribution of the between-sessions IMTP agreement analysis (n=35). Limits of Agreement are shown in dotted black lines with 95% confidence intervals in light green for upper limit and light red for lower limit. Bias (as dotted line) with 95% confidence interval (purple area), and regression fit of the differences on the means (as solid blue line) and 95% confidence interval (grey area).