DIFFERENCES IN MAXIMAL STRENGTH CAPACITY BETWEEN ISOMETRIC SQUAT AND MID-THIGH PULL TESTS IN ELITE TRACK AND FIELD ATHLETES.

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The aim of this study was to compare the vertical peak force (PF) generated during the isometric mid-thigh pull (IMTP) and isometric squat (ISqT) performed at the same knee and hip angles. Fourteen elite track and field athletes performed 3 maximal efforts of isometric IMTP and ISqT tests. The vertical PF was measured by a force platform (Kistler 9290CD, AG Winterthur, Switzerland). Our findings revealed significant higher PF and relative PF during ISqT than IMTP (Mean difference: 953 ± 224 N, $p < 0.001$, $d = 1.62$ and 14.6 ± 2.4 $N \cdot kg^{-1}$, $p < 0.001$, $d = 3.8$, respectively). The results of this study suggest that ISqT may be more appropriate testing procedure for identifying athletes' maximum isometric strength capacities in elite track and field athletes.

KEYWORDS: mid-thigh pull, isometric squat, peak force

INTRODUCTION: The ability of neuromuscular system to produce maximum level of force is essential parameter on athletic performance (Kawamori et al., 2006). Isometric assessments are typically performed to determine the force-time characteristics and the overall force production capacity of athletes. Multi-joint isometric tests such as mid-thigh pull (IMTP) and isometric squat (ISqT) are able to provide valid and reliable information for the peak force (PF) generation capability of athletes. The PF provides a measure of maximal strength during an isometric voluntary contraction (Maffiuletti et al., 2016). Previous studies reported that athletes, especially the females, during ISqT procedures generated higher amounts of PF, compared to IMTP performed at the same knee and hip angles (140º) (Nuzzo et al., 2008; Brady et al., 2018; Silva et al., 2020). This difference may be exhibited due to the position of the bar height that allows athletes producing maximal force. During the IMTP, participants pull the bar from the second-pull weightlifting position, whereas during the ISqT, participants push the bar, which is positioned on the upper extremity, to transmit forces from the ground. However, limited research has been conducted to examine which isometric assessment is more appropriate to identify the maximum strength in elite athletes. Therefore, the aim of this study was to compare vertical PF as well as the relative vertical PF achieved during the IMTP and ISqT tests performed at the same knee and hip angles in elite level track and field athletes.

METHODS: Fourteen elite track and field athletes, 8 females (Mean ± standard deviation (SD): age 23 ± 3.2 years; body mass 63.9 ± 6.5 kg; height 1.71 ± 0.09 m) and 6 males (age 25 ± 2.2 years; body mass 75.4 ± 5.2 kg; height 1.81 ± 0.05 m), gave their written informed consent to participate in this study, which was approved by the local ethical committee, in agreement with the Declaration of Helsinki. Among the females there were four 100 m sprinters (personal best (pb) = 11.7 ± 0.3 s), one 200 m sprinter (pb = 23.91 s), one 400 m hurdler (58.88 s), one high jumper (pb = 1.94 m) and one pole vaulter (pb = 4.70 m). Among the males were two 100 m

sprinters (pb = 10.4 ± 0.2 s), three 200 m sprinters (pb = 21.28 ± 0.7 s) and one 400 m hurdler (pb = 50.67 s). No participants reported physical limitations, health problems or musculoskeletal injuries that could compromise testing.

Participants visited the lab three times during the competitive period of the season. In the first session participants were familiarized with both ISqT and IMTP testing procedures. During the next two sessions participants were tested randomly in the ISqT and IMTP. Prior to testing, participants performed a general warm-up, which included 3 min of cycling and 10 repetitions of bodyweight squat, forward lunge and glute-bridge. Following that, participants performed an isometric specific warm-up, which consisted of either ISqT or IMTP (depending on which test was performed) for 5 s at self-directed 50%, 3 s at 70% - 80% and 3 s at 90% of maximal effort with 1 min recovery between trials (Brady et al., 2019). After warm-up, participants rested for 2 min before the isometric tests. For the IMTP, participants were set in position at the beginning of the second-pull weightlifting position (knee and hip angles were set at 141° ± 4° and 138° ± 2° respectively). Grip width and foot position were standardized within participants. In order to ensure that the correct body position was maintained throughout the tests, the angles were measured using a hand-held goniometer prior to each trial. To standardize grip strength, participants used lifting straps. Participants were required to maintain the position throughout the tests. Participants were instructed to apply their maximum force as fast as possible for 4 s. Three maximum trials were performed with 2 min interval. For the IMTP trial, participants were instructed to “Pull as hard and fast as possible, while driving feet into the ground” to ensure maximal force was achieved (McGuigan, 2019). Additionally, verbal instruction was given in order to get into position and apply a steady amount of pre-tension to the bar, to reduce slack in the body, and to help minimize a countermovement (Brady et al., 2019). Participants were instructed to get ready, and then were given a countdown of “3, 2, 1, Go!”. Verbal encouragement was provided during each trial. For the ISqT test, participants were set in position, which adopted the same knee and hip angles attained during the IMTP, with the bar positioned across the shoulders (Brady et al., 2019). The procedure used for the ISqT was the same as that for the IMTP, with the exception that subjects were instructed to “Push as hard and fast as possible, while driving feet into the ground” (McGuigan, 2019) and lifting straps were not required. The best of the three trials according to the maximal force production of each test was used for further analysis.

All isometric tests were conducted on the 1080 Quantum Syncro (1080 Motion AB, Stockholm, Sweden) smith rack. The vertical force was measured by a force platform (Type 9290CD; Kistler Instrument AG Winterthur, Switzerland), sampling at 500 Hz and data analysis performed with MARS v.4.0.0.87 software (S2P Ltd, Ljubljana, Slovenia). The collection period for each trial was set at 12 s, and a baseline was measured during the 3-sec countdown prior to the initiation of the pull/push. Contraction onset threshold was defined using 5 SD of body weight (Dos’Santos et al., 2017). The maximum force which was generated during the 4 s IMTP and ISqT procedures was reported as the PF. Relative PF was calculated to take into account the athletes body weight (PF / body weight in $N \cdot kg^{-1}$). Data are presented as mean ± SD. Data were analyzed with statistical software (IBM SPSS version 25.0, Chicago, IL, USA). Before analyses, all variables were checked for normality and homogeneity of variance, using the Shapiro-Wilks and Levene tests, respectively. Independent samples *t*-tests were used to compare the PF and the relative PF from both isometric procedures. The criteria to interpret the magnitude of the ES (Cohen’s d effect size [ES]) was as follows: small ($d \geq 0.2$), medium ($d \geq 0.5$), and large ($d \geq 0.8$) (Cohen, 2013).

RESULTS: The descriptive data of the vertical PF and the relative vertical PF for IMTP and ISqT tests are shown in table 1. Our main findings revealed significant higher PF and relative PF during ISqT than IMTP (Mean difference: 953 ± 224 N, $p < 0.001$, $d = 1.62$ and 14.6 ± 2.4 $N \cdot kg^{-1}$, $p < 0.001$, $d = 3.8$, respectively).

Table.1. Descriptive data presented as mean ± SD, 95% confidence intervals of PF and relative PF for the IMTP and ISqT.

Variables	Mean ± SD	95% CI
Peak Force *(N)*		
IMTP	2515 ± 587	2170 – 2859
ISqT	3467 ± 590	3127 – 3808
Relative Peak Force *($N \cdot kg^{-1}$)*		
IMTP	36.9 ± 5.4	33.8 – 40
ISqT	51.5 ± 7	47.4 – 55.6

PF: Peak Force; IMTP: Isometric Mid-thigh pull; ISqT: Isometric Squat.

DISCUSION: The aim of this study was to compare the vertical PF and the relative vertical PF achieved during the IMTP and ISqT tests when they are performed at the same knee and hip angles, in elite level track and field athletes. Our main finding confirms recent observations of higher PF and relative PF expressions during the ISqT test compared to IMTP (Brady et al., 2018; Silva et al., 2020) with the magnitude of these differences being large. Therefore, the ISqT may be more appropriate testing procedure for identifying an athlete's maximum strength capacity compared to the IMTP. Both tests were performed at the same knee and hip angles (140°) and therefore the only difference between the two isometric tests was the position of the bar height that allowed athletes producing maximal force. The higher PF is probably associated with the elimination of the use of upper extremity force during the ISqT, providing a potential advantage to athletes with weakness in their upper extremity (Brady et al., 2018). Furthermore, higher PF during ISqT procedure may be attributed to bar position as this is likely a determinant moderator of the loading requirements in each individual exercise, influencing the kinetic, kinematic and muscle activation patterns (Ebben et al., 2009). Previous researches have indicated higher electromyography activity (EMG) in anterior muscles (quadriceps) during ISqT test (McBride et al., 2006; Silva et al., 2020). On the contrary, EMG activity was higher in posterior muscles (hamstrings) during IMTP test compared to ISqT (Silva et al., 2020). Additionally, quadriceps provides higher force production capacity compared to hamstrings (Silva et al., 2013) and this may explain the differences in maximum force production capacity between isometric tests. The results of this study emphasize that ISqT may be more appropriate to identify the athletes' maximum force production. However, the different mode of muscle activation between the two tests, highlights the need of applying both isometric procedures to gain a deeper insight into the maximal force generation capacities of elite athletes. This approach may contribute to design more appropriate training programs for elite track and field athletes.

CONCLUSION: Overall, this study demonstrates that vertical PF and relative vertical PF production during ISqT is significantly higher than IMTP in elite track and field athletes. Additionally, the magnitude of these differences is large. The results of this study support that ISqT may be more appropriate testing procedure for identifying an athlete's maximum strength capacity compared to the IMTP. Both tests are useful to be performed in order to gain a deeper insight into the maximal force generation capacities in elite track and field athletes.

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