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Original Article

Influence of grip type on peak force during isometric mid-thigh pull and its relationship with hand grip strength in elite badminton players

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Abstract:
Approach: An isometric mid-thigh pull (IMTP) test is highly reliable for monitoring neuromuscular performance but the influence of grip type on the ability to exert force during IMTP remains unclear. **Purpose:** The purpose of this study was to compare the effects of different grip types on peak force (PF) during the IMTP, and investigate the relationship between hand grip strength and IMTP PF in elite badminton players. **Methods:** Thirty-five elite Thai badminton players participated in a randomized counterbalanced research design, performing experimental sessions over five weeks and rotating through the five conditions: 1) IMTP with a hook grip (IHG), 2) IMTP with a pronated grip (IPG), 3) IMTP with a supinated grip (ISG), 4) IMTP with a mixed grip (IMG), and 5) a hand grip strength test (HGS). A repeated measures analysis of variance was used to determine differences in PF. Within-session reliability for PF was calculated from intraclass correlation coefficients (ICC) with 95% confidence intervals (95% CI) and coefficients of variation (CV). Correlations between hand grip strength and IMTP PF were calculated using Pearson's product-moment. **Results:** Results revealed significant differences in PF among the grip types ($p < 0.01$), with the IPG producing the highest PF and the IHG producing the lowest PF. Reliability within sessions was excellent for PF in all grip types ($r \geq 0.99$ [95% CI: 0.99-1.00], CV= 2.03-6.49%). A large and positive correlation was found between hand grip strength and IMTP PF across all grip types ($p < 0.01$, $r = 0.86$-0.89). **Conclusion:** These findings highlight the influence of grip type and hand grip strength on force production during the IMTP in badminton players. We suggest that coaches and practitioners should select the pronated grip and assess hand grip strength to optimize IMTP assessment for badminton players and other athletes.
Keywords: **athletic training, racket sport, physical fitness assessment, sports performance monitoring**

Introduction

Badminton is the fastest racket sport with shuttle speeds of up to 300 mph (Hussain et al., 2011; Singh & Yogesh, 2010), and this highly demanding game is characterized by intermittent actions with quick changes in specific movements such as lunging, jumping, and powerful strokes (Phomsoupha & Laffaye, 2015). During a match, elite players perform to their maximum limits of speed, agility, flexibility, endurance, strength, and explosive power to compete and maintain effective performance (Raman & Nageswaran, 2013). Previous studies reported that badminton was the most grueling racket sport in the world (Liddle et al., 1996) and that players require outstanding physical ability, especially agility, strength, and explosive power to succeed at the highest level (Jeyaraman et al., 2012).

Nowadays, at least 27 badminton tournaments are held annually around the world, with 2 or 3 tournaments in some months. Fatigue from travel, exercise, and competition can affect muscular strength and training programs of elite badminton players (Prajongjai & Songsupap, 2019)., Tiwari et al. (2011) reported that the ability of players was related to speed, agility, and explosive strength; therefore, the physical condition of badminton players should be regularly tested or monitored, with suitable training programs designed to reduce the risk of injuries through overtraining (Abdullah et al., 2023; Sands et al., 2017).

An isometric mid-thigh pull (IMTP) is a common testing method that quantifies maximal strength as a peak force (PF) while holding a barbell set in the mid-thigh position, with data collected using one or two force plates (Comfort et al., 2019). This test is often used because it is safer and less fatiguing than maximal dynamic strength tests such as the 1 repetition maximum (1RM) squat or deadlift (De Witt et al., 2018). Several studies reported a correlation between the absolute PF recorded in IMTP and 1RM in the squat, power clean, and deadlift (De Witt et al., 2018; Haff et al., 2005; McGuigan & Winchester, 2008), sprint, change of direction and agility (Spiteri et al., 2014; Thomas, Comfort, et al., 2015) and vertical jump performance (Kraska et al., 2009; Secomb et al., 2015). Consequently, the IMTP is usually utilized to evaluate and track changes in muscular

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strength and athletic performance (Darrall-Jones et al., 2015; Hornsby et al., 2021; Mason et al., 2021), as well as to develop training programs and assess recovery responses from exercise and competition (Bartolomei et al., 2017; Thomas, Jones, et al., 2015).

Previous studies have also shown that the IMTP is a reliable test that can be used in sports practice and for research purposes (De Witt et al., 2018; Grgic et al., 2022) but several factors affecting its consistency should be considered including body position, sampling frequency, grip width, and lifting straps (Comfort et al., 2019). Research studies demonstrated that sampling frequencies above 500 Hz and differences in joint angles during IMTP did not influence PF output (Comfort et al., 2015; Dos'Santos et al., 2019). The use of lifting straps and grip width may affect the ability to exert force while pulling, thereby reducing limiting factors such as grip strength (Haff et al., 2005). However, limited studies have examined these factors, especially among athletes who mainly use their arms to perform their skills. Rhodes et al. (2022) found that grip strength influenced PF output during IMTP in elite footballers and recommended that practitioners should consider the effect of grip strength on IMTP performance, while DeWeese et al. (2013) recommended that the IMTP grip should be similar to the clean pull exercise but athletes were evaluated using a mixed grip (Malyszek et al., 2017). No research has investigated the effects of different grip types on PF during IMTP but Oranchuk et al. (2019) reported that a hook grip produced higher PF than a pronated grip during power clean exercise.

Therefore, the purposes of this study were to (a) compare the effects of the IMTP using different grip types: hook, pronated, supinated, and mixed grip on PF, and (b) determine the relationship between hand grip strength and IMTP PF in elite badminton players using different grip types. We hypothesized that IMTP using different grip types would result in statistically significant differences in PF. Furthermore, we expected to find a positive relationship between hand grip strength and PF during the IMTP using different grip types. The findings of this study will improve the understanding of standards and methods for the IMTP assessment.

Materials & methods

A randomized and counterbalanced research design was employed to compare PF during the IMTP using four different grip conditions and investigate the relationship between hand grip strength and PF. Elite Thai badminton players were recruited as study participants and randomly assigned into five groups that completed five different experimental sessions across five weeks rotating through the five conditions: 1) IMTP with a hook grip (IHG), 2) IMTP with a pronated grip (IPG), 3) IMTP with a supinated grip (ISG), 4) IMTP with a mixed grip (IMG), and 5) a hand grip strength (HGS) test.

Participants

Thirty-five (twenty-one males and fourteen females) elite Thai badminton players volunteered for this study. The descriptive characteristics of the participants are presented in Table 1. All participants were right-hand dominant and members of the Badminton Association of Thailand, competing at the national level and attending 300-1000 Badminton World Federation (BWF) world tour tournaments. All the participants were healthy, with no history of serious injuries for at least 3 months before data collection. Ethics approval was granted by the Human Research Ethics Review Committee of Chandrakasem Rajabhat University and complied with the principles of the Declaration of Helsinki. All participants were informed of the risks and benefits of the study and supplied written informed consent.

Table 1: Descriptive characteristics of the participants

Variable	Mean ± SD (n=35)
Age (y)	21.97 ± 4.15
Height (m)	1.71 ± 0.07
Body mass (kg)	64.90 ± 8.29
Body fat (%)	20.19 ± 4.65
Hand grip strength (kg)	36.29 ± 6.21

Procedure

The participants were asked to visit the laboratory six times. The first visit was used to familiarize themselves with the five different conditions and collect biometric data. Body weight, height, and percentage of body fat were measured by a body composition analyzer with ultrasonic height measurement (ioi 353, Jawon Medical, Kyungsan City, Korea). Hand grip strength was assessed using a digital handgrip dynamometer (TKK Model 5401; Takei, Tokyo, Japan). All IMTPs were performed on a 400-series force plate with a portable mid-thigh pull rig (Fitness Technology, Adelaide, Australia). The force plate was set to sample at 600 Hz using a computer and software program (Ballistic Measurement System; BMS, Innervations, Perth, Australia). This sampling frequency was established as more than sufficient to measure PF by Hori et al. (2009). PF during the IMTP was determined using the protocol established by Comfort et al. (2015), which reported an intraclass correlation coefficient (ICC) of 0.99. The familiarization session was completed one week before the first experimental session to avoid any residual fatigue.

The participants were randomly assigned to one of five groups, with each group starting with a different condition in the first week. For each experimental session, the participants were instructed not to refrain from any intense training for at least 1 day before the testing session, as this might affect their performance. Before testing, all participants performed the standardized dynamic warm-up protocol proposed by Comfort et al. (2019) that consisted of 3-second repetitions of IMTP performance at 50%, 75%, and 90% of maximal effort, each completed 60 seconds apart. The participants then performed each testing session with their maximal performance. To eliminate confounding effects, the participants were tested at the same time for each session, with a one-week separation between sessions. The order of testing for each group rotated as presented in Table 2.

Table 2: Counterbalancing of the five evaluated conditions.*

	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
Group 1	Familiarization	IHG	IPG	ISG	IMG	HGS
Group 2	Familiarization	IPG	ISG	IMG	HGS	IHG
Group 3	Familiarization	ISG	IMG	HGS	IHG	IPG
Group 4	Familiarization	IMG	HGS	IHG	IPG	ISG
Group 5	Familiarization	HGS	IHG	IPG	ISG	IMG

*IHG = IMTP with a hook grip; IPG = IMTP with a pronated grip; ISG = IMTP with a supinated grip; IMG = IMTP with a mixed grip; HGS = hand grip strength test

During all the IMTP testing sessions, the participants performed two trials of each grip to determine whether there was any systematic bias within the session (trials 1 and 2) at a knee angle of 130 degrees and a hip angle of 145 degrees. Knee and hip angles were measured with goniometry to ensure accurate replication of the position during each trial, with the bar resting midway up the thigh (between the iliac crest and the midpoint of the patella). Afterward, the participants were instructed to pull as fast and as hard as possible for 5 seconds, with a 3-minute rest period allowed between trials to ensure complete recovery (Comfort et al., 2015). The PF was the maximum force generated during the 5-second protocol. Each grip was performed as follows: in the IHG the thumbs were wrapped underneath the rest of the fingers (Fig. 1A); in the IPG the thumbs were positioned laterally to the rest of the fingers with arm pronated (Fig. 1B); in the ISG the arms were supinated (Fig. 1C); whereas in the IMG the right arm was supinated and the left arm was pronated (Fig. 1D). The PF used in a repeated-measures analysis of variance was the highest value obtained among two trials of each grip.

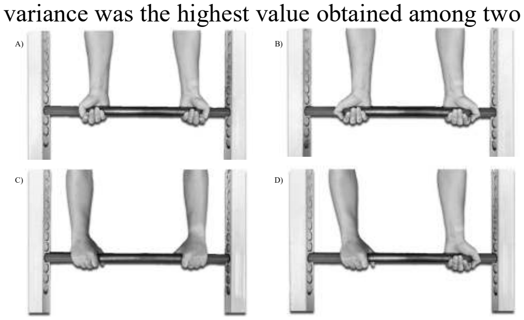

Fig. 1: Types of grip used in this study. (A) IMTP with a hook grip; (B) IMTP with a pronated grip; (C) IMTP with a supinated grip; (D) IMTP with a mixed grip. (All images were taken from the rear of the athlete and used for illustrative purposes only).

The HGS test followed the clinical assessment guidelines of the American Society of Hand Therapists (Fess & Moran, 1981). The dynamometer was set at the second handle position for each participant. During the test, the participants sat in a straight-backed chair with their backs supported and feet flat on the floor. The shoulder was adducted and neutrally rotated, while the forearm and wrist were kept in a neutral position. To ensure consistency, the elbow was extended to replicate a position that had previously demonstrated excellent reliability (Savva et al., 2013). Both the dominant and non-dominant sides of each participant were evaluated with two measurements of maximal grip strength using the dynamometer. The average of the four combined scores was used for analysis.

Statistical analysis

Data were reported as mean ± SD and analyzed using SPSS statistical software for Windows (Version 27.0, SPSS Inc., Chicago, IL, USA). The Shapiro–Wilk test of normality revealed that all data were normally distributed. Within-session reliability was computed for PF using the intraclass correlation coefficient (ICC) and coefficient of variation (CV) with 95% confidence intervals (95% CI). Coefficient of variation (CV) values less than 10% were deemed acceptable (Turner et al., 2015). Magnitudes of ICC were classified according to the following thresholds: >0.90 excellent, 0.75-0.90 good, 0.50-0.74 moderate, and <0.50 poor (Koo & Li, 2016). One-way repeated measures ANOVA with Bonferroni post hoc comparisons were conducted to determine significant differences between grip conditions. Effect sizes (ES) of a pairwise comparison for PF were calculated following Cohen's d statistic. The criteria for interpreting the magnitude of Cohen's d effect size were as follows: <0.2 trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2.0 large, and >2.0 very large (Hopkins et al., 2009). Correlations between hand grip strength and PF in the IMTP across four different grip conditions were calculated using Pearson's product-moment (r) with 95% CI. The strength of the relationship was classified as 0.10-0.29 small, 0.30-0.49 moderate, 0.50-0.69 large, 0.70-0.89 very large, and 0.90-1.00 nearly perfect (Hopkins et al., 2009). The level of statistical significance was set at $p < 0.05$ for all analyses.

Results

Descriptive statistics, as well as results of the one-way ANOVA with repeated measures and within-session reliability for PF in the IMTP across four grip conditions are presented in Table 3 Average PF values of all four grip conditions were significantly different ($p < 0.01$) but the ICC demonstrated excellent within-session reliability ($r \geq 0.99$ [95% CI: 0.99-1.00]) and showed acceptable CV values (2.03-6.49%) for PF determined in all four grip conditions. The post hoc and effect sizes of pairwise comparisons are reported in Table 4 The average PF of IHG was statistically lower than IPG ($p < 0.001$, ES = -0.68 [moderate]), ISG ($p < 0.001$, ES = -0.13 [trivial), and IMG ($p < 0.001$, ES = -0.53 [small]), while the average PF of ISG was statistically lower than IMG ($p < 0.001$, ES = -0.50 [small]). However, the average PF of IPG was statistically greater than ISG ($p < 0.001$, ES = 0.61 [moderate]) and IMG ($p < 0.001$, ES = 0.15 [trivial]). Significant correlations between average hand grip strength and average PF for IHG, IPG, ISG, and IMG ($p < 0.001$, r = 0.89 [95% CI: 0.80-0.94]; $p < 0.001$, r = 0.86 [95% CI: 0.74-0.93]; $p < 0.001$, r = 0.89 [95% CI: 0.79-0.94]; $p < 0.001$, r = 0.88 [95% CI: 0.77-0.94]) are shown in Fig. 2.

Table 3: Descriptive statistics and within-session reliability for PF in the IMTP across four grip conditions

	Peak force (N)				p
	IHG	IPG	ISG	IMG	
Mean ± SD	1857.59 ± 307.22$^{\#\dagger\ddagger}$	2312.48 ± 487.76*†‡	1906.96 ± 330.35$^{*\#\ddagger}$	2239.67 ± 461.95$^{*\#\dagger}$	<0.01
ICC	0.99	0.99	0.99	0.99	
(95% CI)	(0.99 - 1.00)	(0.99 – 1.00)	(0.99 – 1.00)	(0.99 – 1.00)	
CV	2.54%	6.49%	2.03%	3.06%	
(95% CI)	(1.46 - 3.62)	(5.42 - 7.57)	(0.91 - 3.16)	(2.02 - 4.11)	

*Significantly different compared to IHG conditions at $p < 0.05$.
$^{\#}$Significantly different compared to IPG conditions at $p < 0.05$.
†Significantly different compared to ISG conditions at $p < 0.05$.
‡Significantly different compared to IMG conditions at $p < 0.05$.

Table 4 Post hoc comparisons and effect sizes among the four grip conditions for PF

	Peak force (N)		
	p_{Holm}	Effect sizes	Interpretation
IHG vs. IPG	<0.001	-0.68	moderate
IHG vs. ISG	<0.001	-0.13	trivial
IHG vs. IMG	<0.001	-0.53	small
IPG vs. ISG	<0.001	0.61	moderate
IPG vs. IMG	<0.001	0.15	trivial
ISG vs. IMG	<0.001	-0.50	small

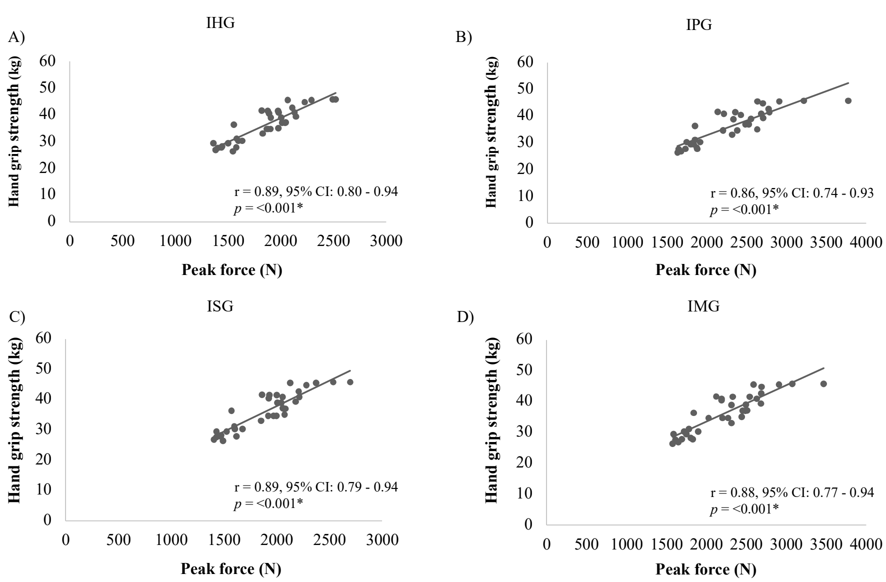

Fig. 2: Correlations between hand grip strength and peak force in the IMTP among the four different grip conditions: IHG (A), IPG (B), ISG (C), and IMG (D). *Indicates significant correlation ($p < 0.01$).

Discussion

This study compared the effects of different grip types on PF during IMTP and investigated the relationship between hand grip strength and IMTP PF using different grip types in elite badminton players. Results indicated significant differences in PF among IMTPs performed with different grip types but excellent within-session reliability of IMTP PF for all grip types, with a high correlation between hand grip strength and IMTP PF across all grip types.

The results supported our hypothesis that different grip types during the IMTP have a significant effect on PF in elite badminton players. The IPG provided statistically higher PF than the IMG, the ISG, and the IHG. These differences in PF among grip types may be attributed to variations in muscle recruitment and activation patterns. Our findings showed that the IPG may involve a larger amount of activated muscle fibers during the IMTP, allowing for maximal efforts to be exerted. These findings concurred with Pratt et al. (2020) who demonstrated that utilizing a pronated or hook grip maximized the degree of muscle activation in the forearm musculature during the deadlift exercise. Our results suggested that when maximum force is required, the IPG is more suitable.

Interestingly, in our study, the IHG provided the lowest PF compared to the other grip types. The IHG involves wrapping the thumbs underneath the fingers, and participants may be unable to tolerate the stress at the grip area, resulting in decreased force production. This finding aligned with Oranchuk et al. (2019) who stated that although the hook grip may have the potential to improve maximal force in the power clean, using this grip during maximal efforts in the exercise may cause discomfort and acutely decrease performance. The IMG also provided statistically higher PF than the ISG and IHG, possibly attributed to the pattern of the IMG, which combines supination and pronation of the arms, introduces symmetry in force distribution, and potentially reduces the overall perceived technical difficulty (Pratt et al., 2020). Our study results also aligned with Pratt et al. (2020) who suggested that lifters should utilize a grip that feels most comfortable when aiming to lift maximal loads.

These results indicated that the choice of grip type influenced the force production capabilities of badminton athletes during the IMTP; however, the within-session reliability of PF in the IMTP was excellent for all grip types. The resulting ICC exceeded 0.99, and the narrow confidence intervals (95% CI: 0.99-1.00) further supported the high reliability of the IMTP as a test for assessing PF in elite badminton players. The CV values were also within an acceptable range (2.03-6.49%), indicating minimal variability in PF measurements within the same session for all grip types. These findings concurred with previous studies that reported high reliability of the IMTP as a measure of maximal strength and athletic performance among athletes of various sports (Dos'Santos et al., 2018; Grgic et al., 2022; Mason et al., 2021; Rhodes et al., 2022). Thus, coaches and practitioners should carefully select and report the type of grip used during the IMTP assessment.

Furthermore, our results also demonstrated a significant and large to nearly perfect correlation between players' grip strength and PF during the IMTP across all grip types ($p < 0.01$, $r = 0.74$-0.94). Participants with greater hand grip strength tended to exhibit higher PF values during the IMTP. This outcome corresponded with Rhodes et al. (2022) who reported significant correlations between grip strength and PF during the IMTP in elite footballers. Our findings highlight the importance of hand grip strength as a contributing factor to force production in badminton as a racket sport that relies heavily on arm strength. Hence, our results suggest that the HGS should be tested to ensure optimal performance when conducting the IMTP, thereby providing valuable information for monitoring and designing training programs for athletic populations.

This study had some limitations and focused only on PF as the primary outcome measure. Future research should explore other relevant variables such as force-time characteristics, rate of force development, and impulse to provide a more comprehensive understanding of the effects of grip type on IMTP performance.

Conclusions

Findings revealed that grip types had a significant effect on PF during the IMTP in elite badminton players. The IPG resulted in significantly higher PF compared to other grip types, potentially due to variations in muscle recruitment and activation patterns. Interestingly, the IHG provided the lowest PF, possibly attributed to discomfort leading to decreased force production. The IMG produced higher PF than the ISG and the IHG, possibly due to balanced force distribution and reduced technical difficulty. However, the within-session reliability of PF was excellent for all grip types, indicating that the IMTP is a highly reliable test for assessing PF. A significant and large correlation was found between HGS and IMTP PF across all grip types. This finding emphasizes the importance of hand grip strength in force production during the IMTP. To ensure that maximal performance can be achieved when conducting the IMTP, coaches and practitioners should select the pronated grip and assess hand grip strength to optimize IMTP assessment for badminton players and other athletic populations including racket, team, and tactical athletes.

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Conflicts of interest - The authors declare no conflicts of interest.

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