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Force-Time Characteristics in Collegiate Weightlifters Using Two Isometric Pull Protocols

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ABSTRACT

The isometric mid-thigh pull (IMTP) is commonly used to measure isometric strength of characteristics of weightlifters. The isometric pull from the start position (IPSP) has not been studied as much as the IMTP but may potentially be a viable option for a weightlifting monitoring program. This study aims to compare isometric force-time characteristics from both the IMTP and IPSP to weightlifting competition performance. Collegiate weightlifters' performances were compared to isometric peak force (IPF), rate of force development (RFD), and allometrically scaled peak force (IPFa) of both isometric testing protocols by a Pearson's Correlation Coefficient. Strong correlations between weightlifting performance and force-time characteristics for both protocols were found with IPSP having slightly higher correlations. This suggests that both isometric testing protocols are viable tools for predicting weightlifting performance. It may be useful to include both protocols in a weightlifting monitoring program.

Keywords: Strength Relationship; Snatch; Clean & Jerk; Force; Weightlifting

INTRODUCTION

Periodically monitoring strength characteristics and performance in weightlifters is an important part of the training as this type of feedback allows the coach to "gauge" the athletes' progress (or lack of it) and reduces the potential for non-functional overreaching. The isometric mid-thigh pull (IMTP) is a monitoring tool that is used to measure force-time characteristics of weightlifters such as isometric peak force (IPF), and rate of force production (RFD). Strong correlations have been found between these variables and weightlifting performance [1].

For many years, the IMTP protocol has been a primary test used to monitor weightlifters' force-time characteristics [2]. From a coaching standpoint this is both in an effort to obtain a neuromuscular profile of the athlete as well as to monitor the athlete's preparedness [2]. Generally, the body position utilized for IMTP mimics the "power position," the position in which 2nd pull is initiated from when performing a clean [3].

Recently there has been an increased interest in the literature with having weightlifters perform isometric pulls at other key positions that occur during the double knee bend technique, specifically the positions that occur prior to the "power position" [4,5]. These positions include, 1) from the floor (isometric pull start position = IPSP) [4,5] (representative of 1st pull) and 2) in front of the knee (representative of the start of the transition phase) [5].

Recent studies by Joffe et al. [4] and Ben-Zeev et al. [5] demonstrated very strong correlations between IPSP isometric peak force (IPF) and weightlifting total. In both cases, IPSP IPF correlated to weightlifting performance to a greater extent than IPF from IMTP, however IPF from IMTP still produced strong correlations. Based on these results [4,5] and the discussions provided by the authors in both studies, IPSP appears to a very promising assessment to both go along with and compare to IMTP.

MATERIALS AND METHODS

This study was an examination of the relationship between the IMTP and IPFF with weightlifting competition performance in the Snatch (SN), Clean & Jerk (CJ), and Total (TOT). Participants: In this study, fourteen collegiate male and female weightlifters (7 males; body mass:89.0 ± 10.8, body height 177.4 ± 7.3, 7 females; body mass:74.0 ± 8.1, body height 163.7 ± 4.9) ranging in age from 19 to 26 years volunteered to participate in this study. The participants were recruited through convenience sampling as three of the authors of this study were weightlifting coaches for this group of weightlifters. The mean weightlifting experience of each participant based off when their first competition occurred to the day of testing was 2.9 years ± 1.9. To qualify as a weightlifter for this study, each participant must have competed in a USAW sanctioned weightlifting meet. Within the subject group, 3 participants were qualified for the USAW National Championships or American Open Finals. The remaining participants competed at a qualified standard (e.g., University Championships, USAW American Open Series, etc.). Prior to testing, written consent was obtained from the participants. Procedures: Force-plate technology (Hawkins Dynamics, Westbrook, ME) was used to measure isometric force-time characteristics of weightlifters at one testing session within one month of competition. The warm-up and testing procedures were overseen by the investigators who consisted of graduate students, faculty, and coaches, who were all NSCS-CSCS certified. The warm-up consisted of 1 set of 25 jumping jacks, followed by 1 set of barbell mid-thigh pulls at 20kg, then 3x5 mid-thigh pulls at 60kg for men and 40kg for women. This is a warm-up previously validated in iso-pull literature [6-8]. Maximum effort unweighted static and countermovement jumps were performed next as this was a normal process in the athletes' monitoring program. Each type of jump was performed 4 times with two jumps holding a dowel rod and 2 jumps with a 20kg barbell. For the IMTP test, the participants were instructed to stand on force plates and orient their body in the same position of the second pull in the clean. Knee angles (125-135°) were then measured with a hand-held goniometer [9]. The participants maintained an upright torso with a hip angle of 1450 through the trial as described in previous literature [10]. Each participant performed the IMTP test followed by the IPSP test. The order of testing was selected because it was believed that the IPSP was the most discomforting test for the athlete's back [11]. Thus, the IPSP was tested last to reduce the amount of back stress the participants had going into the following test. The barbell was placed at a measured height of 22.5 cm at the center of the bar to the floor to replicate the height of the bar at the start of the clean. The participants were given two warm-up pulls at 50% and 75% of maximum effort for both isometric tests. The participants were instructed to pull as hard and fast as possible until instructed to stop. Two max effort trials were taken for both isometric tests. The participants rested approximately 1 minute between trials. Statistical analysis: All statistical analyses were per-formed through SPSS (Version 29.0). Test-retest reliability between trials was assessed through Intra-class Correlation Coefficient (ICC). A Pearson's Correlation Coefficient was conducted to assess the relationship between force-time variables of interest and weightlifting performance variables in the SN, CJ, and TOT. Variables of interest included IPF, IPFa, and peak RFD measured at 250ms.

RESULTS

The mean ± SD for all variables is shown in Table 1. The ICC showed a high degree of reliability between trials for Peak Force (IPF) and RFD 0-250ms (RFD) in both protocols. For IPSP, the average measure ICC was 0.989 (95% CI [0.966, 0.996], F(1,12)= 84.971 $p<.001$) and an average ICC of 0.919 (95% CI [0.745, 0.974], F(1,12)= 11.549 $p<.001$) respectively. For IMTP, the average measure ICC was 0.985 (95% CI [0.954, 0.995], F(1,12)=62.8 $p<.001$) and an average ICC of 0.936 (95% CI [0.798, 0.979], F(1,12)=14.508 $p<.001$) respectively. Results from the correlation analysis between IMTP IPF and weightlifting performance indicate that there may be a relationship between them (Table 2). The analysis between IPSP IPF and weightlifting performance showed that there may be a slightly stronger relationship between them compared to IMTP (Table 2). These results suggest that the IPF from both protocols are related to weightlifting competition performance and may be predictors of weightlifting performance (Table 2). The analysis between IMTP RFD and weightlifting performance and the analysis between IPSP RFD and weightlifting performance showed similar results with IPSP having slightly larger correlations to performance (Table 3). This would suggest that RFD measurements from both protocols may predict weightlifting performance. Furthermore, the analysis between IPFaMTP and weightlifting performance showed that there may be a relationship between them (Table 2). Similarly, the results indicate that there may be a relationship between IPFaPSP and weightlifting performance (Table 2). The difference between IMTP and IPSP is more pronounced when allometrically scaling with IMTP having *large* correlations and IPSP having *very large* correlations (Table 2). This suggests that allometrically scaled IPFa in the IPSP protocol may be the better predictor of weightlifting performance.

DISCUSSION

The purpose of this study was to compare the performances of collegiate weightlifters to force-time characteristics of the IMTP and IPSP. Both protocols appear to be predictors of weightlifting performance, although the IPSP appears to be the stronger predictor with *very large* IPF correlations to SN, CJ, and TOT (r = 0.81, r = 0.85, r = 0.84, respectively). This may possibly be explained by weightlifters performing weight-lifting movements typically starting with the bar in the start position but may not get the bar to the proper power position with efficient technique. Also, the weightlifter may have a weak position off the floor which may preclude them from obtaining a proper 2nd pull. An additional explanation might be what they perform (as planned) in training - if training emphasizes pulling from the floor - this also could explain the relationships found here. This would then cause them to train this position less frequently or incorrectly and cause them to have weaker power positions and thus resulting in the smaller correlation. Furthermore, in a study measuring barbell acceleration during the snatch [12] shows that a high peak barbell acceleration that occurs during the 2nd pull may be due to errors occurring earlier in the lift. It may be that during the lift the weightlifter has to re-accelerate the bar following the transition. This may result in "over-developing" the 2nd pull, which may be a reason the IMTP IPF and RFD are not as strongly correlated with performance when compared to IPSP.

The IMTP produced greater IPF and RFD than produced by IPSP. This is likely due to the IMTP having greater mechanical advantage than the IPSP. This agrees with the findings of Joffe et al. [4] where the two protocols were compared in elite weightlifters. When allometrically scaled, the IPSP shows a larger correlation than normal IPF. Contrarily, when allometrically scaling the IMTP IPF the correlation is smaller. It is important to

Table 1. Mean ± SD of absolute and allometrically scaled isometric testing measurements.

Snatch (kg)	CJ (kg)	Total (kg)	IMTP IPF (N)	IPSP IPF (N)	IMTP RFD (N·s-1)	IPSP RFD ($N \cdot s^{-1}$)	IMTP IPFa ($N \cdot kg^{0.67}$)	IPSP IPFa ($N \cdot kg^{0.67}$)
80.38 ± 22.62	103.36 ± 25.47	182.85 ± 48.75	4242.51 ± 981.17	2204.82 ± 468.62	7207.48 ± 2693.13	2904.57 ± 959.67	222.79 ± 36.41	115.75 ± 15.65

Table 2. Correlations with 95% CI's between weightlifting performances and IPF/IPFa of IMTP and IPSP

	IMTP IPF			IPSP IPF			IMTP IPFa			IPSP IPFa		
Variable	r value	95% CI	Descriptor	r value	95% CI	Descriptor	r value	95% CI	Descriptor	r value	95% CI	Descriptor
Snatch	0.67*	[0.19, 0.89]	Large	0.81**	[0.46, 0.94]	Very Large	0.65*	[0.15, 0.88]	Large	0.87**	[0.61, 0.96]	Very Large
Clean & Jerk	0.71**	[0.29, 0.90]	Very Large	0.85**	[0.59, 0.59]	Very Large	0.62*	[0.14, 0.87]	Large	0.89**	[0.67, 0.96]	Very Large
Total	0.69**	[0.23, 0.90]	Large	0.84**	[0.53, 0.59]	Very Large	0.65*	[0.15, 0.88]	Large	0.88**	[0.64, 0.96]	Very Large

Table 3. Correlations with 95% CI's between weightlifting performances and RFD of IMTP and IPSP

	IMTP RFD			IPSP RFD		
Variable	r value	95% CI	Descriptor	r value	95% CI	Descriptor
Snatch	0.66*	[0.17, 0.89]	Large	0.76**	[0.36, 0.92]	Very Large
Clean & Jerk	0.70**	[0.27, 0.90]	Very Large	0.79**	[0.44, 0.93]	Very Large
Total	0.68*	[0.21, 0.90]	Large	0.78**	[0.40, 0.93]	Very Large

*Note. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (6). * Indicates p < .05. ** indicates p < .01.*

note that RFD was not reported by Joffe et al. [4]. Regardless, IPFa of both testing protocols have strong correlations to weightlifting performance. Similarly, findings were reported in a study by Ben-Zeev et al. [5] in which the authors studied correlations between three different positions in the clean including the IMTP and IPSP positions in Israeli national weightlifters. The results of that study showed that there were slightly greater correlations in the IPF IPSP position than the IMTP among the male and combined groups. The authors also reported large significant correlations between IPSP RFD at 250ms and weightlifting performance in the combined group. Albeit the correlations were not as large as found in the current study. In contrast, the current study found large correlations between weightlifting performance and IMTP RFD whereas, Ben-Zeev et al. [5] did not find large correlation in IMTP RFD. It is unclear why these differences have occurred. The findings of this study suggest that the IPSP may be a monitoring tool to use in conjunction with the IMTP.

It is expected that the average IPF of the IMTP would be larger than IPSP because of the mechanical difference between positions. When comparing isometric tests to dynamic activities, the joint angles should be that which allow the muscle to produce the most force during the dynamic activity [13]. Thus, the strongest position is at the start of the 2nd pull. This is commonly termed as the "power position" [14]. With that considered, for tests of maximal isometric strength and RFD, the IMTP is the better monitoring tool [2, 10].

The IPSP protocol is potentially the easier test to conduct. Contrary to the IMTP, the IPSP does not re-quire measuring and adjusting the bar height for each participant. This is because the bar height remains constant when pulling a barbell from the floor because of the standard barbell plate diameter. However, the use of both tests should be considered beyond "what correlates best". For example, maximal strength development and expression is undoubtedly important for weightlifting performance. When comparing peak forces between IPSP and IMTP, the peak force was 2204.82 ± 468.62 and 4242.51 ± 981.17 newtons of force respectively, the IMTP clearly results in greater peak forces. This is consistent with Joffe et al. [4] where IPSP and IMTP IPF were 1443 ± 425 and 2640 ± 767 respectively. Thus, perhaps IPF from IMTP is a better surrogate measure for maximal strength. During both protocols, the weightlifter needs to, as best possible, maintain their position. This appears to be more challenging for the IPSP protocol. Strength off the floor is certainly important and IPSP appears to be a very good assessment for this. The stronger the athlete is off the floor, theoretically the easier it is for them to possess a technically sound 1st pull and transition which leads to a sound power position.

If the practitioner has the time and resources, both IMTP and IPSP should be used rather than choosing one protocol over the other. Conversations such as "this test or that test" would better be framed as how might various questions be answered by various tests that all fit into a larger athlete monitoring framework. The IMTP should be used more consistently through the monitoring program such as once every block of training because of the changes in RFD from block to block [15]. The IPSP protocol can be used less often, such as after every macrocycle. This allows the practitioner to monitor the efficacy of the training program by comparing force-time characteristics with previous individual IPFF results. Future investigations may choose to examine the coaching style of lifters compared to their performances in both protocols. Different coaches may teach the power position differently as some coaches may isolate the position as a training tool and others may use a more dynamic movement such as a clean pull or hang clean. Future research is needed to address other positions that occur during the double knee bend (e.g., isometric pull from the knee). Theoretically, different isometric pull positions may provide information that could be useful in addressing issues in a weightlifters pull.

CONCLUSIONS

Both the IMTP and IPFF multi-joint isometric protocols are reliable and valid methods to monitor weightlifting performance. In the current study, the IPSP protocol had somewhat stronger correlations to weightlifting performance in collegiate level athletes than the IMTP protocol. IMTP and IPFF protocols can be used by the coach to monitor collegiate weightlifters for program efficacy and adaptations to training. The IPFF protocol may be more time efficient to use for some professionals because the bar height would not need adjusting between athletes. However, for maximal strength assessment it is notable that IMTP had much great-er IPF. Furthermore, the IPSP position would likely raise injury potential as the back is in a weak position. This is likely true – however, the position does not allow as much force production and therefore it can be argued that the tissues are under less strain [4].

AUTHOR CONTRIBUTIONS

For research articles with several authors, a short paragraph specifying their in-dividual contributions must be provided. The following statements should be used "Conceptualization, Kyle Rochau. and Guy Hornsby; methodology, Guy Hornsby.; software, Kyle Rochau.; validation, Andrew Layne., Michael H. Stone and Wesley Gawel.; formal analysis, Kyle Rochau.; investigation, Wesley Gawel.; re-sources, Jarrod Burton.; data curation, Jarrod Burton.; writing—original draft preparation, Kyle Rochau.; writing—review and editing, Michael H. Stone.; visualization, Kyle Rochau; supervision, Kyle Rochau.; project administration, Guy Hornsby; funding acquisition, Guy Hornsby. All authors have read and agreed to the pub-lished version of the manuscript.

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The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of WEST VIRGINIA UNIVERSITY protocol code 2111463309 approved 05/17/2022.
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