Effect of Lifting Straps on Peak Force During an Isometric Mid-thigh Pull

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EFFECT OF LIFTING STRAPS ON PEAK FORCE DURING AN ISOMETRIC MID-THIGH PULL

by

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ABSTRACT

Objectives: The primary purpose of this study was to examine the difference in peak force (PF) production with and without the inclusion of lifting straps (LS) during an isometric mid-thigh pull (IMTP). An additional goal of this study was to identify potential asymmetry during the two protocols while evaluating the potential use of a dual force plate IMTP as a tool for player monitoring programs. **Methods**: Twenty-one NCAA division I men (n=10) and women (n=11) soccer players performed a maximal IMTP over dual force plates with and without the assistance of LS. The PF total between the two plates for both conditions was used to examine the effect of LS. Asymmetry was assessed by the PF of the separate force plates by calculation of a symmetry index (SI). **Results**: The PF achieved with the assistance of LS was significantly greater for males (strapped: 2102.3±506.2N, unstrapped: 1468.6±286.0N; $p<0.001$) and females (strapped: 1105.0±294.7N, unstrapped: 940.6±155.7N; $p<0.05$). Both males (strapped: 9.2±4.9%, unstrapped: 6.5±5.2%) and females (strapped: 9.0±7.1%, unstrapped: 4.2±4.9%) demonstrated asymmetry, however there was no significant difference in SI between conditions for either sex. **Conclusion**: The inclusion of LS on the IMTP allowed for a significantly greater PF production for male and female soccer athletes. However, the increase in PF with the inclusion of LS was greater in the males who saw a large effect size (d=1.959, $p<0.001$) whereas the effect size seen in the females was moderate (d=0.802, $p=0.024$). Both male and female soccer players possessed some level of asymmetry that did increase with the inclusion of LS, but no significant difference was found between conditions.

DEDICATION

To my Dad, the kindest man I have ever met, for providing unwavering support and answering any late-night calls with words of wisdom.

To my Mom, the hardest worker I know, who has taught me strength and perseverance.

To Tonna, thank you for the mothering I never asked for, but could not live without.

To my Aunt Pammy, thank you for teaching me the hardest, but the most valuable, lesson that I have learned.

To Cynthia, for giving me this chance to succeed. Any success that I may have is a result of the opportunity that you have provided.

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CHAPTER ONE: INTRODUCTION

Background

The isometric mid-thigh pull (IMTP) is a common evaluation used in scientific literature, mostly in the context of assessment of athletic performance and associated variables. The IMTP is performed with the subject exerting a maximal force against an immovable bar placed in a position correlating to the “second pull” of a power clean at the mid-thigh. This position has been shown to produce the greatest ground force making it the ideal position to measure variables associated with force (Comfort et al. 2011). Due to the involvement of a large amount of the body’s musculature recruited during a maximal IMTP, similar to that required during sport, it has become a popular method to assess force production in athletes. The muscles that are recruited during an IMTP require a synchronous full body contraction between muscles of the upper extremities, trunk and muscles of the lower extremities, (DeWeese et al. 2013).

The advantage of assessing force during an isometric contraction compared to an alternative measurement of strength such as a 1 rep max is the increased repeatability and reduced skill involved. An isometric contraction avoids the eccentric portion of a lift which produces a greater amount of muscular damage (Jones et al. 1989, Proske and Morgan 2001). This reduction in muscular damage offers benefits, such as reduced load on athletes pre- or mid-season. In addition, due to the lack of movement during the contraction less coordination is required. It is possible that this may be a safer option to novice athletes compared to the dynamic counterpart, the second pull of a power clean, which requires more technical ability.

Purpose

Currently the protocols used in the methods of studies involving the IMTP are mixed with some including the ergogenic aid of lifting straps (LS) and others excluding them. The purpose of lifting straps is to reduce the involvement of grip strength during weightlifting movements, such as the deadlift or power clean. Due to the dependency on hand grip during a maximal IMTP there is a potential that the exclusion of LS would result in a decreased ability to achieve a peak force (PF). Depending on the goal of the study measuring IMTP without the assistance of LS and thus the limiting factor of hand grip could be a detriment to data collection. Without the inclusion of LS, the data may more closely represent the subject's grip strength rather than their full body strength. Thus, the primary goal of this study is to look at differences in PF of athletes performing an IMTP with lifting straps (LS) (IMTP-S) and with no LS (IMTP-NS).

Additionally, the IMTP device used in this study offers a novel testing parameter by using separate force plates to measure the force produced by the individual legs as well as having increased portability. By analyzing the difference in PF acting upon the separate force plates it becomes possible to identification potential unilateral asymmetries in strength. These asymmetries may be present in athletes that repeatedly experience unilateral forces associated with sports, such as soccer. At present there are mixed findings on the level of asymmetry present in soccer athletes suggesting a further need for exploration. Previous studies have successfully used a similar dual force plate IMTP to assess asymmetry amongst athletes. Therefore, the secondary goal of this study is to examine potential asymmetry in participating NCAA Division-I soccer athletes.

CHAPTER TWO: REVIEW OF THE LITERATURE

Needs Analysis of Soccer Athletes

Success in soccer is largely dependent on the athlete's aerobic and anaerobic ability. Aerobic capacity is demonstrated by the distance covered by soccer players during a match is typically around 10km, depending on the position of the player (Bangsbo et al. 2006). Anaerobic performance is demonstrated by the more explosive movements during play, such as accelerating, sprinting, kicking, and jumping. For example, soccer players perform short sprints every 90s during a match which typically last 2-4s and covers an average of 10-15m (Bangsbo et al. 1991, Mohr et al. 2005). When comparing high level soccer athletes with lower level athletes a contrast in anaerobic activities during match play can be seen. Mohr et al. (2003) reported that international players perform 28% more high intensity running and58% more sprinting than professional players of a lower standard. The performance during these sprints can be attributed by the athlete's ability to produce a force. Due to the short time and distances covered by these sprints, most anaerobic actions are spent in the acceleration phase rather than at maximal velocity. In fact, soccer players perform eight times more maximal accelerations than sprints per game (65±21 vs. 8±5 respectively) (Varley and Aughey, 2013). This acceleration both the player and ball during game play is determined by the ability to impart a force on an object (a=F/m).

Isometric Mid-Thigh Pull Peak Force and Correlation with Measures of Athletic Performance

Thus, peak force (PF) is an important variable in understanding success in sports, such as soccer. Evidence for this has been shown by previous studies showing that the PF achieved during a IMTP are significantly related with sprint time, change of direction, agility, reactive strength, and vertical jump, (Beckham et al. 2014, Thomas et al. (2015, 2017), Townsend et al. 2019, Wang et al. 2016). Further correlations with IMTP PF, have been found in measures of dynamic strength such as 1 rep max back squat, front squat, bench press, hang clean, power clean, and 2RM split jerk. (McGuigan et al.2008, Wang et al. 2016). Additionally, IMTP PF has even been shown to correlate with sport-specific measures of performance such as club head velocity and sprint cycling time (Wells et al. 2018, Stone et al. 2004).

Isometric Mid-Thigh Pull Reliability and Validity

The IMTP has been shown to not only have a significant correlation with measures of dynamic performance, but it has also been proven to have a high degree of validity and reliability. Previous studies have determined that the IMTP possesses a significant reliability and acceptable validity for IMTP PF both within and between sessions (James et al. 2017, De Witt et al. 2018, Dos' Santos et al. 2017, Guppy et al. 2018). The high degree of correlation with measures of athletic ability and the high degree of validity and makes the IMTP an excellent tool in scientific literature and potential for player monitoring.

Lifting Straps

Although there is a large amount of literature involving the IMTP the methodology between studies is inconsistent. Between studies there is a varied measure of knee and trunk angle used as well as a mixed inclusion of lifting straps (LS). This inconsistency between procedures has been partially explore by Comfort et al. (2019). In this study the effect of different knee and trunk angles during an IMTP was measured and no significant differences in among kinetic variables was found. However, there is currently no literature assessing potential differences during an IMTP with LS (IMTP-S) and without LS (IMTP-NS). A LS is an ergogenic aide used during resistance training that uses a strap attached to the wrists of an athlete and then wrapped around a barbell. The inclusion of a LS allows the "force to be transferred to the wrist of the user with the result that no gripping of the equipment by the hand of the user is necessary (U.S. Patent No. 6,168,556, 2001)." This assures that the limiting factor in the lift is not due to grip strength. Protocols in previous studies have been varied with the use of IMTP-S or IMTP-NS. Although there are no studies directly measuring LS effects during an IMTP, there has been research on the differences seen during resistance training. In a study by Coswig et al. (2015) the use of LS during a deadlift allowed for an increase of 20-28% in force favoring LS. Cowan and DeBeliso (2017) had similar findings investigating the power clean showing the 1RM power clean with the use of LS was 79.0±18.4 kg while the 1RM without LS was 72.7±15.9. However, the peak vertical ground reaction force during the submaximal testing slightly favored the lift without LS (without LS: 2004.0±443.7 N, with LS:1953.3±450.7 N). In addition, Jukic et al. (2020) showed no significant differences between a submaximal deadlift with and without the use of LS for mean velocity, peak velocity, mean power, and peak power. Due to the lack of knowledge on the effect of LS on IMTP it would be beneficial to explore the potential differences between IMTP-S and IMTP-NS.

Prevalence of Asymmetry in Soccer Athletes and Potential Effects on Performance

It has been hypothesized that the repeated exposures to asymmetrical forces experienced during unilateral based sports, such as soccer, can lead to the development of potential asymmetry. Thus, the identification of asymmetry may be of particular use to soccer athletes. However, the presence of asymmetry amongst soccer athletes in previous research has been inconsistent. The findings of Chin et al. (1994), Erun et al. (2004), Masuda et al. (2005), and McLean and Tumility,

(1993) revealed some level of asymmetry while Capranica et al. (1992), Rochongar et al. (1988), and Zakas, (2006) discovered no significant asymmetry. This suggests that the presence of asymmetry amongst soccer athletes needs to be examined further.

The effects of asymmetry on athletic performance has also been conflicting. Studies by Sannicandro et al. (2011), Bailey et al. (2015), and Bell et al. (2014) have found a relationship between asymmetry and reduced ability in athletic performance. However, many studies have found no correlation with athletic performance (Chiang, Lockie et al 2014, Exxel et al. 2017, Meyers et al. 2017, Haugen et al. 2018, Lockie et al. 2017). In fact, Lockie et al. (2012) found that faster athletes demonstrated a greater asymmetry in concentric knee extension at 180°/s and 240°/s but had less asymmetry in eccentric strength in knee flexion. It is possible that moderate asymmetries may develop as an adaption to the unilateral demands of various sports with no resulting detriment to performance.

Asymmetry as a Potential Indicator of Increased Injury Risk

Previous research has revealed correlations with strength asymmetry and potential risk of injury. Dauty et al. (2016) found that an indicator of hamstring injury was concentric hamstring-hamstring ratio at 60° which showed a prediction probability of 34% when athletes had a strength ratio lower than 0.85. Knapik et al. (1991) found that the athletes with knee flexion that was ≥15% stronger in the right leg were 2.6 times as likely to sustain injury. Fousekis et al. (2010) found that professional soccer players with eccentric hamstring strength asymmetries (odds ratio [OR]=3.88; 95% CI 1.13 to 13.23), functional leg length asymmetries (OR=3.80; 95% CI 1.08 to 13.33) and no previous hamstrings injuries (OR=0.15; 95% CI 0.029 to 0.79) were at greater risk of sustaining a hamstring muscle strain. Additionally, Fousekis et al. (2011) found that players with eccentric hamstring strength asymmetries (OR=3.88; 95% CI 1.13 to 13.23), functional leg length asymmetries (OR=3.80; 95% CI 1.08 to 13.33) and no previous hamstrings injuries (OR=0.15; 95% CI 0.029 to 0.79) were at greater risk of sustaining a hamstring muscle strain and that players with eccentric strength (OR=5.01; 95% CI 0.92 to 27.14) and flexibility asymmetries (OR=4.98; 95% CI 0.78 to 31.80) in their quadriceps were more likely to sustain a strain in this muscle group. Furthermore, Fousekis et al. (2012) found that professional soccer players with eccentric isokinetic ankle flexion strength asymmetries (OR = 8.88; 95% confidence interval [CI], 1.95-40.36, P =.005) were more at risk of sustaining noncontact ankle sprains during season. These findings provide support for asymmetry as a predictor of injury. This relationship suggests that monitoring asymmetry in athletes could provide useful insight in the prevention of injuries.

Isometric Asymmetry as a Player Monitoring Tool

A relative finding for the case for isometric strength asymmetry as an in-season player monitoring tool was made by Schache et al. (2010). In this case study an Australian rules football player with a history of right hamstring strains was followed through a season. Weekly assessment of isometric hamstring asymmetry was measured. In the 5th week a 10.9% asymmetry was found which was followed by a hamstring injury 5 days after. Minimal asymmetry was found in the 4 weeks prior (no greater than ±1.2%). The authors of this study speculate that the change in asymmetry leading to the injury was the result of subtle damage or inhibition within the hamstring muscle. This may reveal that a potential cause of acute asymmetry is due to muscular damage or inhibition in addition to the separate unilateral adaptation that may develop in athletes. In addition, Wollin et al. (2018) was able to successfully measure maximal isometric contractions during a hamstring dynamometer in response to a period of congested match play (two matches within three days). The findings revealed a significant decrease in hamstring strength amongst some of the individual youth Australian football athletes suggesting incomplete recovery. The possibility to safely collect individual data pertaining to recovery and injury risk during a season could be a valuable tool for athletics and requires more study.

Potential of the Dual Force Plate Isometric Mid-Thigh Pull as a Player Monitoring Tool

Previous studies have proved the efficacy of using a dual force plate IMTP device to assess asymmetry (Owens 2011, Bailey et al. 2013, Gleason 2015). A varying degree of asymmetry was found amongst the athletes measured in all three studies. Owens (2011) was able to identify that subjects (40 males and 26 females) possessed a mean percent difference of 7.2 ± 5.9. Additionally, the asymmetry evaluation was able to reveal 6 subjects (5 men and 1 woman) who exhibited a ≥15% asymmetry, a value previously associated with increased risk of injury (Knapik et al. 1991). Bailey et al. (2013) reported that the PF-SI was 6.6 % ±5.1 amongst their subjects (n=36 males). In contrast to other findings, it was found that force production asymmetry had a significant, but moderate negative association with jump variables in a squat jump (r=-0.34 to -0.52) and a countermovement jump (r=-0.28 to -0.49). Gleason (2015) found that in their study on there was no significant relationship found between symmetry and 505 agility test times with right and left foot plants and little correlation with left or right-foot forward 10m sprint starts, but did find a large correlation ($r=0.55$, $p < 0.021$) the symmetry index(SI) at 150ms and 10m sprint time asymmetry.

An additional feature of the study by Gleason (2015) was the use of the dual force plate IMTP in a player monitoring program over the course of a year. Subjects were twenty-five male and twenty-eight female Division- I NCAA athletes who completed at least three testing sessions over a year. The results of these sessions revealed that intra-session PF values (4.12±1.57%) as well as the interclass correlation coefficients of PF for left (0.84) and right (0.89) legs showing that the PF data collected had a good reliability. The interclass correlation coefficient for SI was 0.52 denoting a moderate level of reliability. The mean SI range between the three sessions was 16.04±10.72 showing a considerable degree of variability (with respect to the previously proposed ≥15% threshold). These results suggest that presence of asymmetry among athletes over a year in training is varied. However, the author speculated that the variability could be the result of acute fluctuations due to muscular damage, cumulative fatigue, etc. While the use of the dual force plate IMTP for assessing asymmetry during a maximal effort trial seems promising the moderate reliability and considerable degree of variability between sessions suggests that more study is needed to explore the potential of a dual force plate IMTP.

Previous research has shown the potential correlation between asymmetry and injury risk, the safety of maximal isometric testing for in season athletes, and the possibility for acute asymmetries to predict injury. The benefit of using the dual force plate IMTP to assess asymmetry is the time efficient assessment of full body muscular strength as well as the portability of the design allowing for testing to be performed in the weight room, athletics training room, or on the field. Due to the potential of the dual force plate IMTP discussed previously as well as the conflicting findings regarding asymmetry in soccer athletes, an additional goal of this study is to assess the potential presence of asymmetry in NCAA Division-I soccer athletes as well as explore the ability of the dual force plate IMTP as a player monitoring tool by evaluating the use of the particular IMTP device in a collegiate weight room setting.

CHAPTER THREE: METHODS

Evaluation consisted of three sessions including two testing sessions. On the initial day, prior to the testing sessions, subjects signed an informed consent, completed a Physical Activity Readiness Questionnaire (PAR-Q), performed body composition and anthropometrics assessments and completed a familiarization session with the IMTP protocol and exercise technique to be used during testing. The study was approved by the University's Institutional Review Board.

Subjects

Twenty-one NCAA division I men (n=10, 20.54 ± 1.72 years, 171.57 ± 5.77 cm, and 72.94 ± 9.62 kg) and women (n= 11, 19.5± 1.43 years, 164.34 ± 6.63 cm, and 62.87 ± 7.24 kg), college soccer players, (See Table 1.) volunteered to participate in this investigation. All components of the testing procedures were explained to each participant, and informed consent was received before the initial testing session. To eliminate the potential of fatigue-related performance decrements, participants were asked to refrain from any strenuous physical activity for the previous 48 hours.

Body Composition

Height and body mass (BM) were measured with a calibrated standard medical scale (439 Physician Scale; Detecto, Webb City, MO, USA). Body composition was measured using a multi-frequency bioelectrical impedance analysis (BIA) device (InBody 770, Cerritos, CA, USA) that transmits a minute electrical current to be conducted through the body to determine body composition variables, including body fat percentage. Before the testing sessions, participants were asked to be sufficiently hydrated and to have abstained from food consumption or exercise for a minimum of two hours. Participants removed their footwear, including socks, and stood on the BIA scale while holding two handles out to the side, for approximately 45 seconds. All BIA and anthropometric measurements were recorded for each subject on the initial day of testing.

Isometric Mid-Thigh Pull Testing

Before the initial day of testing a series of three familiarization trials under both conditions were performed to ensure proper technique for the exercise for the remainder of the study. The testing sessions were conducted on two different days separated by a minimum of 48 hours. The IMTP protocol to be used on the first testing day was determined at random using a coin toss, "heads" would be IMTP-S on day 1 and "tails" IMTP-NS on day 1. The athlete would then use the remaining protocol on the second day of testing. During the testing sessions, subjects performed three maximal IMTP attempts with the determined protocol, each attempt was followed by three minutes of rest before the next attempt was completed.

The mid-thigh pull position was determined for each participant before his or her first attempt. Participants were instructed to position themselves on the portable IMTP rack and force plate system in their preferred deadlift stance. Bar placement height was selected by placing the bar at the midpoint distance between the knee and hip joint resulting in hip and knee angles of $127.6 \pm 8.8°$ and $132.5 \pm 13.4°$ respectively. Participants were instructed to use a pronated grip, regardless of condition (with or without LS), for all the attempts. Bar height from the force plates, for each participant was recorded to ensure consistency between testing sessions. All testing sessions were conducted by the same investigator, providing the same instructions, under similar conditions for all participants.

For each IMTP attempt, all participants were instructed to stand on the force plates, address the bar with proper grip and stance (maintaining a neutral spine throughout), place slight upward tension on the bar and prepare to lift on the command of “pull.” Participants were instructed to pull vertically on the bar and reach their maximal effort within the first two seconds and to maintain that effort until given the command “done” (pull effort lasted approximately 6 seconds). These commands were consistent for all participants throughout all testing sessions and were given to avoid any jerking or pre-contraction that may occur. For each session, three maximal attempts were performed by each subject, separated by 3 minutes of passive rest between attempts.

The IMTP rack and force plate system were a custom designed frame made of square tubular steel (7.5x5cm). The design consisted of two vertical bars attached to a rectangular base (50x100cm) of the same steel framing and utilized a standard diameter Olympic bar with the collar and sleeves cut off. The vertical bars had holes (3.5cm diameter) spaced 6.5cm apart to allow for multiple bar height adjustments. The base of the device had a steel plate on one face that could be used as a platform to adjust the height of the bar, if necessary while accommodating two portable force plates (37 cm × 37 cm; PASCO, Pasport PS-2142, Roseville, USA) regardless of the side used.

The force plates were used to record the PF for each trial during all testing sessions. Each two-axis portable force platform collected data at a sample rate of 1,000 Hz using five force beams: four corner beams to measure the normal force (ranging from −1,100 N to +4,400 N) and a fifth beam to measure the parallel force (ranging from −1,100 N to +1,100 N).

Statistical Analysis

The PF with LS (PF-S) and without LS (PF-NS) was defined as the highest force achieved during the 6 seconds isometric test without the participant's body weight in Newtons. Body weight was calculated as the average force exerted by the subject's body mass while standing on the platform without their hands off of the bar. Additionally, the forces acting upon the separate force plates at the time the subject achieved a total PF was recorded as PF 1 and PF 2. The level of asymmetry was determined by calculating the symmetry index (SI).

$$SI= [PF\ 1-PF\ 2]/total\ PF*100 \quad (1)$$

The equation 1 was used to calculate the SI for trials with LS (SI-S) and without LS (SI-NS). The descriptive data is presented as mean and standard deviation. A paired t-test was used to determine statistical difference between PF-S and PF-NS as well as SI-S and SI-NS. Cohen's d value effect size was calculated to show practical significance, and was interpreted as follows: trivial (< 0.19), small (0.20 - 0.59), moderate (0.60 – 1.19), large (1.20 – 1.99), and very large (2.0 – 4.0) (Hopkins 2000). Additionally, Pearson correlation coefficients were determined to assess the level of relationship between variables. The interpretation of relationships was as follows: greater than 0.5 is considered large, 0.3-0.5 is moderate, 0.1-0.3 is small, and less than 0.1 is trivial (Hopkins 2000). Statistical analysis was performed using Microsoft Excel and JASP (Version 0.13.1)[Computer software].

CHAPTER FOUR: RESULTS

The anthropometrics of the subjects is displayed in Table 1. The mean PF-S and PF-NS can be observed in Table 2. Both males and females were able to achieve a significantly greater PF-S. However, the relative increase between PF-S and PF-NS was greater in the males. The inclusion of LS had a large effect size (d=1.959, $p<0.001$) whereas the effect size seen in the females was moderate (d=0.802, $p=0.024$).

Table 1. Subject anthropometrics.

	Age (years)	Body Fat (%)	Body Mass (kg)	Height (cm)
Male (n=10)	20.54 ± 1.7	12.57 ± 2.58	72.94 ± 9.62	171.57 ± 5.77
Female (n=11)	19.5 ± 1.43	19.57 ± 4.9	62.87 ± 7.2	164.34 ± 6.63

Table 2. Peak force with and without the inclusion of lifting straps for males and females

	PF-S (N)	PF-NS (N)	Cohen's d
Male	2102.3±506.2	1468.6±286.0***	1.959
Female	1105.0±294.7	940.6±155.7*	0.802

* p<0.05, **p<0.005, ***p<0.001

Table 3. Symmetry index with and without the inclusion of lifting straps for males and females.

	SI-S	SI-NS
Male	9.2±4.9%	6.5±5.2%
Female	9.0±7.1%	4.2±4.9%

* p<0.05, **p<0.005, ***p<0.001

As seen in Table 3. both males and females possessed some level of asymmetry among both conditions. However, the difference between SI-S and SI-NS was not proven to be significant for males or females. The SI-NS showed one male athlete with an asymmetry greater than 15% while the SI-NS revealed an additional male and female possessing a ≥15% asymmetry. Table 4. shows the correlations between the PF, SI, and weight. The males showed a significant relationships in the large range between PF-S and PF-NS (r=0.806, p=0.005), PF-NS and SI-S (r=0.678, p=0.031), and PF-NS and weight (r=0.782, p=0.008) and the females showed a large significant correlation between PF-S and PF-NS (r=0.752, p=0.008). No other relationships were deemed significant.

Table 4. Correlations between peak force, symmetry index, and weight.

	PF-S	PF-NS	SI-S	SI-NS	Weight
Male					
PF-S	-				
PF-NS	0.806*	-			
SI-S	0.239	0.678*	-		
SI-NS	0.092	0.134	0.460	-	
Weight	0.609	0.782**	0.561	-0.266	-
Female					
PF-S	-				
PF-NS	0.752*	-			
SI-S	-0.080	-0.211	-		
SI-NS	0.193	-0.173	-0.072	-	
Weight	0.016	0.125	-0.413	-0.130	-

* $p<0.05$, ** $p<0.005$, *** $p<0.001$

CHAPTER FIVE: DISCUSSION

Lifting Straps Effect on Isometric Mid-Thigh Pull Peak Force

The primary goal of this study was to determine the difference in PF with and without the use of LS. It was hypothesized that the use of LS would increase the PF that the athletes were able to achieve during the IMTP. The difference in PF between the LS and non-LS groups may suggest that the limiting factor in force production may have been due to a relative deficit in grip strength. These results were similar to the findings of Coswig et al. (2015) who showed a 20-28% increase in force during a submaximal deadlift using LS, and Cowan and DeBeliso (2017) who found that subjects were able to achieve a greater power clean 1RM with the inclusion of LS (79.0±18.4kg vs. 72.7±15.9kg).

The findings of this study show that grip strength is likely a limiting factor during maximal effort testing such as the IMTP-NS. This could potentially explain the difference in findings during submaximal testing like that performed by Jukic et al. (2020), who found no difference in PF during a submaximal deadlift, and Cowan and DeBeliso (2017), who found that the PF achieved during a submaximal power clean without LS (2004.0±443.7 N) was greater than with LS (1953.3±450.7 N). Although grip strength can be an excellent predictor of old age disability and nutritional status, there are already reliable testing methods to assess hand strength such as the Dexter and Jamar evaluations (Norman et al. 2011, Rantanen et al. 1999, Bellace et al. 2000). The findings of this study suggest that due to the limiting factor an IMTP-NS may more closely represent the subject's grip strength rather than the full body strength expressed during an IMTP-S.

Considerations for Isometric Mid-Thigh Pull Methodology Involving Lifting Straps

In the future, researchers and practitioners may consider which protocol will allow for a more specific measurement of force production in context to the demands of the athlete's sport. Relevant to the population used in this study, during an analysis of the biomechanics and demands during a soccer match by Lees and Nolan (1998) there is no mention of the need for grip strength. Conversely, as previously discussed, PF has been shown to correlate with many factors that are involved with athletic performance. Thus, when testing soccer athletes, it may be flawed to impose a limitation on their ability to produce a PF that they will not be exposed to during their sport. This would suggest that IMTP-S may offer a more valuable evaluation for these athletes. For future use of an IMTP as a performance measure or assessment, it may be more relevant to have athletes who are not dependent on grip strength to perform the test with the use of LS. However, future study may be needed to quantify the difference of IMTP-S and IMTP-NS in reference to tests of athletic performance (jump performance, sprint time, etc.) to determine which protocol allows for the most accurate data collection in athletes. In reference to previous research, it is possible that correlations established with PF-S and PF-NS may be extrapolated to the counterpart due to the large relationship found between PF-S and PF-NS in this study (males: $r=0.806$, $p=0.005$; females: $r=0.752$, $p=0.008$). However, the relationship between PF-S and PF-NS was not perfect meaning the same level of confidence cannot be used.

Evaluation of Asymmetry

The additional feature of the dual force plates in the IMTP device allowed for the observation of asymmetry in the population tested. The symmetry index of both strapped (Male: 9.2±4.9%; Female: 9.0±7.1%) and unstrapped (Male: 6.5±5.2%; Female: 4.2±4.5%) trials showed some level of asymmetry. These results agree with the finding of Chin et al. (1994), Erun et al. (2004), Masuda et al. (2005), and McLean and Tumility, (1993) who observed the presence of asymmetry in soccer athletes. During the IMTP-NS one male athlete was observed that demonstrated a SI of ≥15% (this athlete also scored over ≥15% during the IMTP-S). However, the IMTP-S resulted in two additional athletes (one male and one female) with a ≥15% asymmetry that were not seen with during the IMTP-NS. This value of asymmetry has previously been found to be an indicator of increased risk of injury (Knapik et al. 1991). Although, the sample size was small the IMTP-S may allow for greater identification of athletes that possess the level of asymmetry associated with increased injury.

Inclusion in a Player Monitoring Program and Future Research

The efficacy of the portable dual force plate IMTP as a means for player monitoring appears to be promising. The testing was able to be performed in the weight room in a time effective manner without the occurrence of any complications. Incorporating the dual force plate IMTP into a player monitoring program would allow for the coaching and athletic training staff to compile data over the course of a season to aid in practice and game decisions as well as provide insight for personalized resistance training programs. The previous literature has indicated that chronic and acute asymmetry may predict injury suggesting that it would be advantageous to include regularly scheduled data collection to ensure that factors associated with an increased risk of injury are detected (Dauty et al. 2016, Knapik et al. 1991, Fousekis et al. 2010, Fousekis et al. 2011, Fousekis et al. 2012, Schache et al. 2010). It may be advantageous for future studies to develop a method to distinguish between functional asymmetry, such as that shown in some studies on unilateral athletes, and asymmetry that develops as a result of subtle damage or inhibition within the muscle, like that discussed by Schache et al. (2010). Additionally, the results presented by Gleason (2015) suggest that further research involving in-season monitoring of an athletic population is necessary to determine a normal threshold for asymmetry variability and a threshold that may be indicative of overtraining, injury, etc. Gleason (2015) suggested that a potential explanation of their findings was due to acute fluctuations in asymmetry due to factors related to sport and training. Therefore, it would be advantageous of such a study to include reference to influencing factors such as training load, game play, practice, etc.

CHAPTER SIX: CONCLUSIONS

The use of LS during an IMTP allowed the athletes to produce a significantly greater force than without LS suggesting grip strength as a potential limiting factor. Given the advantages of the IMTP to assess force production through a full body multi-joint contraction and the nature of studies using IMTP it may be advantageous to future researchers to consider the sport specific needs of the population being studied when deciding the IMTP protocol. The results of the SI-S and SI-U both show that it is likely that some level of asymmetry is present in the soccer athletes who participated in this study. Additionally, the ability to perform the data collection in the weight room of a collegiate weight room provides support for potential use in future player monitoring programs.

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