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Research article

The relationship between isometric and dynamic strength in college football players

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Abstract
Previous research has demonstrated the importance of both dynamic and isometric maximal strength and rate of force development (RFD) in athletic populations. The purpose of this study was to examine the relationships between measures of isometric force (PF), RFD, jump performance and strength in collegiate football athletes. The subjects in this study were twenty-two men [(mean ± SD):age 18.4 ± 0.7 years; height 1.88 ± 0.07 m; mass 107.6 ± 22.9 kg] who were Division I college football players. They were tested for PF using the isometric mid thigh pull exercise. Explosive strength was measured as RFD from the isometric force-time curve. The one repetition maximum (1RM) for the squat, bench press and power clean exercises were determined as measures of dynamic strength. The two repetition maximum (2RM) for the split jerk was also determined. Vertical jump height and broad jump was measured to provide an indication of explosive muscular power. There were strong to very strong correlations between measures of PF and 1RM ($r = 0.61 - 0.72$, $p < 0.05$). The correlations were very strong between the power clean 1RM and squat 1RM ($r = 0.90$, $p < 0.05$). There were very strong correlations between 2RM split jerk and clean 1RM ($r = 0.71$, $p < 0.05$), squat 1RM ($r = 0.71$, $p < 0.05$), bench 1RM ($r = 0.70$, $p < 0.05$) and PF ($r = 0.72$, $p < 0.05$). There were no significant correlations with RFD. The isometric mid thigh pull test does correlate well with 1RM testing in college football players. RFD does not appear to correlate as well with other measures. The isometric mid thigh pull provides an efficient method for assessing isometric strength in athletes. This measure also provides a strong indication of dynamic performance in this population.

Key words: Isometric strength, American football, power.

Introduction

Previous research has demonstrated the importance of isometric maximal strength (PF) and rate of force development (RFD) in a variety of athletic populations including track cyclists (Stone et al., 2004), track and field athletes (Stone et al., 2003b) and weightlifters (Stone et al., 2005). We have previously shown the value of measuring PF in college wrestlers (McGuigan et al., 2006). Generally there is no consensus in strength and conditioning regarding how much strength is required for optimal performance in most sports (Stone et al., 2002). However research does suggest that the importance of maximum isometric strength is underestimated in a variety of athletic populations (Stone et al., 2003a; 2003b; 2004).

Previous research has investigated the strength and power characteristics of American football players (Black and Roundy, 1994; Fry and Kraemer, 1991). Maximum strength has been shown to discriminate between athletes of different performance levels within sports such as American football (Fry and Kraemer, 1991). The power clean, bench press and vertical jump were found to differentiate between various playing levels in college football (Fry and Kraemer 1991), although other researchers have found this is dependent on position and the type of test used (Black and Roundy, 1994). Although not applicable to some sports, having significant isometric strength may be advantageous for sports such as football and wrestling. However there is a lack of research examining the relationship between dynamic and isometric strength in football.

The isometric mid thigh pull test has been shown to correlate well with one- repetition maximum (1RM) testing in college wrestlers (McGuigan et al., 2006). This test was first described by Haff et al. (1997) and has shown to be highly reliable and reflect dynamic characteristics determined on jumping and 1RM tests. Similar relationships have been observed in a number of other sports including weightlifting (Haff et al., 2005; Stone et al., 2005), track cyclists (Stone et al., 2004) and track and field athletes (Stone et al., 2003b). As there is a high force and power component associated with American football, it would seem likely that similar relationships between static and dynamic performance may exist. Therefore the purpose of this investigation was to examine the relationships between measures of PF, RFD, jump performance and strength in collegiate football players.

Methods

Subjects

Twenty-two men were recruited from a NCAA Division I Football program and were subjects in this investigation. Subject characteristics were as follows (mean ± SD): age 18.4 ± 0.7 years; height 1.88 ± 0.07 m; mass 107.6 ± 22.9 kg. Subjects were informed of the potential risks and gave their written informed consent to participate prior to beginning the study. This was approved by the University's Institutional Review Board for use of human subjects.

Experimental procedures

The following testing battery was administered to the subjects over a three day period. All athletes were familiarized with the tests prior to completing the testing sessions. Testing was conducted at the same time of day for each subject and the subjects were given instructions to

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maintain their standard diet over the course of the testing period.

Isometric strength assessment

Isometric strength assessment involved testing PF using the isometric mid-thigh pull exercise (Haff et al., 1997; Stone et al., 2003b). Vertical ground reaction force data were collected at 960 Hz using an oversized (400X800 mm) OR6 force platform (Advanced Mechanical Technologies, Inc, Newton, MA, USA). The time series of force data were then analysed via Eva 6.0 software (MotionAnalysis, Corp, Santa Barbara, CA, USA).

Subjects were instructed to pull on the immovable bar (performed in a power rack with pins) as quickly as possible and were required to maintain effort for 5 seconds. It has been suggested that instructions stated as "hard and fast" produce optimal results for recording maximal force and RFD (Bemben et al., 1990; Haff et al., 1997; Sahaly et al., 2001). Subjects performed 3 x 5 sec trials and were allowed 3 min of rest between sets. The highest value of the three trials was used for later analysis. The bar height was adjusted at 2 cm increments so that the knee angle was 130 degrees (extended leg = 180 degrees). The subjects were required to maintain this knee angle throughout the duration of the trial. Force-time curves were analysed during the mid thigh pull. The variables that were analysed included isometric RFD and isometric PF. The test-retest reliabilities (intraclass correlation, ICC) of these tests were $R \geq 0.96$.

Dynamic strength assessment

The 1RM for the back squat, bench press, and power clean exercises were determined as a measure of dynamic strength. A 2RM was also determined for the split jerk exercise. In the case of the back squat, bench press, and power clean, multiple warm-up trials were given prior to actual 1RM testing as modified from Wilson et al. (1993). These consisted of 5 repetitions at 30% followed by 2 min rest, 4 repetitions at 50% followed by 2 min rest, 3 repetitions at 70% followed by 3 min rest, 1 repetition at 90% followed by 3 min rest (% are given of subject estimated 1RM obtained through use of an Epley chart (Epley, 1985) and previous data from the subjects training logs). From the last warm-up set, loading was increased through subject feedback on level of repetition intensity so that 1RM was achieved within 3 trials. Four minutes of rest was given between each 1RM effort. The squat exercise required the subjects to rest the bar on their trapezius and the squat was performed to the parallel position, which was defined as when the greater trochanter of the femur was lowered to the same level as the knee. Adequate depth of the squat trials was ensured by the investigator and verbal feedback provided to the subject that they had reached the required depth. The subject then lifted the weight until their knees were fully extended.

Bench press testing was performed in the standard supine position. The bench press was included as an assessment of upper body strength. The subject lowered the bar to mid-chest, and then pressed the weight until the elbows were fully extended. No bouncing of the weight was permitted. An acceptable lift for the power clean was determined by the athlete being able to catch and hold the bar in a steady position for 3 seconds. The power clean was performed from the floor. The reliability of this method of 1RM testing in our laboratory is high (ICC = 0.98).

The testing method for the split jerk exercise was slightly different due to the nature of the activity as compared to the other lifts. In addition, the subjects in this study, while they perform this lift on a regular basis, had not previously performed the split jerk maximally. There was some concern as to both the safety and efficacy so it was determined that a 2RM would be performed as the subjects regularly train with two repetitions during normal conditioning. As in the case of the other exercises, subjects were given multiple warm-up trials prior to 1RM testing (% are given of subject estimated 1RM), 1 sets of 5 repetitions at 30% followed by a 2 min rest, 3 repetitions at 50% followed by a 3 min rest, 2 repetition at 70% followed by a 3 minute rest, and 2 repetitions at 90% followed by a four minute rest. From the last warm-up set, loading was increased through subject feedback on level of repetition intensity so that 2RM was achieved within 3 trials. Four minutes of rest was given between each 2RM effort. A successful lift for the split jerk was determined by the subject completing two repetitions without any pressing of the bar following the jerk an ability to maintain position for 3 sections once a standing position had been re-established. Subjects were familiar with the testing procedure because of its similarity to the testing they are exposed to as part of their sport.

Vertical jump

Vertical jump height was measured via a Vertec vertical jump tester (Sports Imports, Hilliard, OH, USA) to give an indication of explosive muscular power (Canavan and Vescovi, 2004). Each subject performed three trials with one minute of rest in between each jump and the highest jump height was used in the data analysis. The following procedure was used for each subject during data collection. The Vertec was adjusted to match the height of the individual subject by having them stand with their dominant side to the base of the testing device. Their dominant hand was raised and the Vertec was adjusted so that their hand was the appropriate distance away from the marker based on markings on the device itself. At that point, subjects performed a countermovement jump. Arm swings were allowed but no preparatory step was performed.

Broad jump

Standing broad jump was measured via a tape measure. Subjects were required to stand with their toes behind the zero point of the tape measure prior to jumping. Subjects were not allowed a preparatory step of any kind but arm swings were allowed at the discretion of the subject. Distance was determined measuring the point at which the heel of the trail leg touched the ground. Each subject performed three trials with 1 minute of rest in between each trial. The best jump of the three was used for analysis.

Statistical analyses

Correlations between the variables were calculated using the Pearson product moment correlation coefficient. Hopkins (2007) and Cohen (1988) have ranked the meaningfulness of correlations as r = trivial (0.0), small (0.1), moderate (0.3), strong (0.5), very strong (0.7), nearly perfect (0.9), and perfect (1.0). The criterion for statistical significance of the correlations was set at $p \leq 0.05$.

Results

The results of the tests were given in Table 1. There were strong to very strong correlations between measures of PF and 1RM (r = 0.61 – 0.72). The correlations were nearly perfect between the power clean 1RM and squat 1RM (r = 0.90). There was a strong correlation between 1RM squat and vertical jump (r = 0.54). There were very strong correlations between 2RM split jerk and clean 1RM (r = 0.71), squat 1RM (r = 0.71), bench 1RM (r = 0.70) and PF (r = 0.72). There were strong to very strong correlations between body mass and clean 1RM (r = 0.45), bench 1RM (r = 0.78), broad jump (r = -0.60), 2RM split jerk (r = 0.57) and PF (r = 0.53). There were no other significant correlations with other variables and no significant correlations with RFD.

Table 1. Results for the various tests. Values are means (± SD.).

	Team averages
Power Clean (kg)	119 (14)
Squat (kg)	188 (38)
Bench Press (kg)	145 (33)
Split Jerk (kg)	103 (19)
PF (N)	2159 (218)
RFD ($N \cdot s^{-1}$)	13489 (4041)
Vertical Jump cm)	76 (9)
Broad Jump (cm)	249 (24)

RFD = rate of force development
PF = isometric force

Discussion

Previous research has demonstrated the important role of isometric strength to performance across a range of different sports (Stone et al., 2003b; 2004; 2005, McGuigan et al., 2006). The results of this study indicate that in collegiate football athletes the isometric mid thigh pull test does correlate well with 1RM testing. However, RFD was shown to be not as critical in relation to maximal strength in these athletes. These results suggest that isometric testing provides a good indication of an athlete's dynamic performance during 1RM testing, including the back squat, power clean, bench press and split jerk exercises.

As with our previous study with college wrestlers (McGuigan et al., 2006), we did not find a strong relationship between RFD and measures of strength and power in this study. The realization that strength and power are different qualities is very important in the correct design and assessment of resistance training for athletes and this has often been misunderstood by coaches. Interestingly, the RFD results were considerably less in the present study compared to our previous study using college wrestlers using a similar testing protocol. However, RFD may be an important performance variable to study within football players because explosive exercises tend to enhance the ability to generate high RFD (Aagaard et al., 2002; McBride et al., 2002). It appears that RFD is an independent strength quality and further research is required to determine its importance in high force sports such as football.

The vertical jump test is a simple and reliable test that can provide useful information about power and performance characteristics of athletes (Canavan and Vescovi, 2004). We also used the standing broad jump test to provide information about the player's horizontal jump performance. There were no significant relationships between jump performance other than 1RM squat and vertical jump (r = 0.54). There was also no relationship with RFD or PF. This would suggest that these jump tests are providing information about specific power and performance qualities. However it should be noted that these tests were only used to measure performance in terms of jump height. Previous research has shown nearly perfect relationships between peak power during vertical jumping and PF (>0.88) during the isometric mid thigh pull (Haff et al., 2005).

There is little research on the jerk exercise in high performance sport, both from training and testing perspectives. The split jerk exercise is used in many strength and conditioning programs to improve explosive power. Interestingly, this test provided the greatest number of significant relationships with the other tests conducted. Hakkinen et al. (1986) showed a significant correlation between PF and clean and jerk (r = 0.66) in elite weightlifters. Haff and colleagues (2005) found similar results (r = 0.66) with female weightlifters. The PF during the isometric mid thigh pull was significantly related to 2RM split jerk (r = 0.72). This further highlights the utility of specific isometric testing and that PF is strongly related to dynamic strength.

A limitation of the present investigation is the relatively small number of subjects who were tested. With sufficient numbers of athletes it would be interesting to compare different playing positions. Previous research has shown that strength and power characteristics vary depending on the position being played (Fry and Kraemer, 1991; Secora et al., 2004). There is also evidence that certain tests can differentiate starters from nonstarters but it is dependent on the position (Black and Roundy, 1994). The athletes used in the present study were freshmen who had recently entered the program. It would also be interesting to see if the results would be similar in athletes who had been in the program for a longer period of time.

Maximum strength appears to be a major factor influencing performance in a variety of different sports (Stone et al., 2004). It has been previously been shown that absolute strength and power are an important component of American football (Fry and Kraemer, 1991; Secora et al. 2004). While traditional weight training results in large changes in strength among untrained subjects, and strength appears to be an important physical capacity in most sports, whether standard strength training methods can enhance sporting performance appears to depend upon the particular sport. Strength-dominated sports that involve the production of large forces over relatively long time periods (such as American football) would appear to be readily improved by strength training. Not surprisingly, body mass was significantly correlated with several of the 1RM tests and inversely related to broad jump distance.

Certain strength measures represent specific or independent qualities of neuromuscular performance that can be assessed and trained independently. Many prefer isometric testing because it is not confounded by issues of movement velocity and changing joint angle. It has been suggested that isometric movement position can strongly influence the relationships that are observed with dynamic tasks (Haff et al., 1997). The PF determined using the isometric mid thigh pull seems to be strongly related to performance on other dynamic tests such as 1RM testing.

A potential practical application of these findings is that the isometric mid thigh pull can be used by Strength and Conditioning coaches to provide important information about maximal strength in American football players. In situations where coaches are required to test large squads of athletes, they can confidently use this test to provide strength data and perform the testing sessions quickly and efficiently. Given that the test seems to indicate to a large extent the dynamic performance characteristics of athletes, it may not be necessary to perform 1RM testing on a large number of exercises. There may also be some potential benefits of including this type of isometric exercise in training programs but this area requires more research.

Conclusion

American football is a sport that requires high levels of both strength and power. The isometric mid thigh pull test does correlate well with 1RM testing for the power clean, squat and bench press and the 2RM for the split jerk. RFD does not appear to be as important in college football. The isometric mid thigh pull provides an efficient method for assessing isometric strength in athletes. Given that isometric strength may potentially differentiate between successful and less successful athletes (Stone et al., 2002), this test can provide important information in the strength diagnosis of football players. This measure also provides a strong indication of dynamic performance in this population. The lack of strong correlations with other variables such as RFD may be a result unique strength and power capacities represented by those specific tests. This highlights the importance of assessing and training these unique capacities and not relying on one single test such as a 1RM test to provide a strength profile of an athlete.

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Key points

- In Division I college football players the isometric mid thigh pull test correlates well with 1RM testing.
- Rate of Force Development does not appear to be as closely related to dynamic and isometric strength in college football players.
- The isometric mid thigh pull provides a quick and efficient method for assessing isometric strength in athletes.

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