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CORRELATION BETWEEN VARYING BACK SQUAT DEPTHS ON SPEED AND VERTICAL JUMP PERFORMANCE IN NORTH AMERICAN HIGH SCHOOL FOOTBALL PLAYERS

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ABSTRACT

The back squat exercise is perhaps the most popular and most effective exercise for developing lower body musculature. For athletes in particular, developing lower body strength can be of utmost importance. There is however dispute over which back squat depth is most optimal. This study attempted to determine which of two back squat depths (90 degree knee flexion and 45 degree knee flexion) would correlate with superior sprint times and VJ performance. Participants were high school aged (14-17 years) males on a North American football team. Twenty-three athletes performed the 36.6 meter (36.6M) sprint and VJ tests along with performing a 3RM back squat at 90 and 45 degrees of knee flexion on separate days. A Pearson Correlation Coefficient (r) test was used to compare the variables. Low correlations were found at both knee flexion angles: 90 degrees 3RM squat (36.6Mr=-0.32, VJr=0.33, p<0.01), and 45 degrees 3RM squat (36.6Mr=-0.31, VJr=0.33, p<0.01). However, moderate correlations were revealed when comparing the 3RM back squat/body mass with the participant's 36.6M sprint times (90r=-0.46, 45r=-0.46, p<0.01). Within the parameters of this study, low to moderate correlations were determined between back squat strength and sprint speed as well as VJ at both 90 and 45 degree knee flexion.
***Keywords:** Squat depth, sprint, vertical jump.*

1. INTRODUCTION

Without question the back squat is a staple strength exercise within football strength and conditioning programs across America. It is also perhaps the most

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important exercise for developing lower body strength (O'Shea, 2000) that is vital for creating football players that are strong and explosive at the point of attack. Developing high explosive- and speed-strength levels requires variation of different program parameters such as different exercises, intensities, and training methods during the preparation and competition period (Hartmann, Wirth, Klusemann, Dalic, Matuschek, & Schmidtbleicher, 2012). Football is a game of leverage and speed. "The low man always wins" and "speed kills" are common adages amongst football coaches and analysts alike. The back squat takes precedence as a core exercise in periodized programs because of its high translation to development of lower body strength and subsequently explosive movements (Comfort, Haigh, & Matthews, 2012).

Football players often times find themselves in situations throughout a game in which lower body strength and power is relied on in order to carry out their responsibilities. For example, linemen, either offensive or defensive, have the duty of trying to control the man across from them on every down. Offensive linemen must prevent the defensive linemen from penetrating into the backfield while also redirecting the path of that opponent to wherever the play design calls them to go. This requires that the offensive linemen have great lower body strength and also superior leverage in which to translate that lower body strength into the upper body to move the opponent out of their zone.

The back squat has a high applicability to football performance. Performing heavy back squats increases the available maximal force potentiation in the large muscles of the lower body and that can subsequently lead to increases in acceleration and speed skills (Wisloff, Castagna, Helgerud, Jones, & Hoff, 2003). There have been multiple studies done with regards to varying squat depths and which is deemed optimal for explosive movement. Strong correlations were found in a study performed by Sleivert and Taingahue (2004) when using a quarter squat depth (120 degree knee flexion) and sprint performance. Likewise, Wisloff *et al.* (2003) found a correlation between the back squat performed at half depth (90 degree knee flexion) and vertical jump performance. McBride, Blow, Kirby, Haines, Dayne and Triplett (2009) also found a correlation between parallel depth (~60-70 degree knee flexion) and sprint performance. Evidence in past studies has revealed varying results as to which depth is best for athletic performance. It is important to find an optimal depth so that athletes can train their lower body musculature to their highest potential for athletic performance.

Hence, the purpose of this study was to compare two back squat depths of varying degrees, 90 degree knee flexion and partial depth at 45 degree knee flexion to sprint and vertical jump performance in North American high school football players. The research hypothesis under consideration suggests that the 90 degree knee flexion squat depth will correlate with lower sprint times and higher VJ measurements than the 45 degree knee flexion back squat depth.

2. METHODS AND MATERIALS

2.1 Participants

The participants for this study were high school freshman, sophomores, and juniors aged 14-17 from a local southern California high school. The study was approved by the Southern Utah University Institutional Review Board before commencement. All participants and participants' legal guardians gave written consent to perform in the study. The study procedures were explained in full detail, along with the risks involved, before consent was given. Participants were reminded that their participation was completely voluntary and they could withdraw at any time if desired.

Participants were required to be current members of the high school football program with at least one year of playing experience. Participants were also required to have a minimum of six months experience training in a weight room to ensure familiarity with the back squat technique. The inclusion criteria for the study were that the participants were injury free and without a disability that would prevent them from participating in the testing protocols. The principal investigator was present at all at all testing sessions.

2.2 Instruments and Apparatus

The testing for the 36.6 meter (40 yard) sprint was held at the participant's game field on campus. The facility is a synthetic turf field. The actual times were recorded using a hand held stopwatch (Accusplit Pro Survivor A601x stopwatch) operated by the study administrator and a study assistant (football coach). A strong intraclass correlation value of approximately ICC=0.98 was found by Hetzler, Stickley, Lundquist, & Kimura, (2008) between using hand held timing systems and electronic timing systems. Hetzler *et al.* (2008) reported hand held timing systems producing roughly -.04 ± -.24 for a single tester and -.05 ± -.24 seconds faster with multiple testers than electronic timing. Hetzler *et al.* (2008) deemed the difference insignificant and the use of handheld timing systems a viable option for testing sprint performance testing. The vertical jump was recorded using the Vertec Vertical Jump Measuring Device. A goniometer (Baseline Plastic Goniometer 360 Degree Head 30.5 cm Arms) was used to establish the specific knee flexion angles required for the study, 90 degrees and 45 degrees (see Figure 1 a-c). The same weight room was used throughout the study.

Figure 1: Participant back squatting at air squat to assess knee angles (a), 45 and 90 degrees of knee flexion (b & c)

(a) **(b)** **(c)**

2.3 Procedures

The study took place during the late fall (post football season) in conjunction with the beginning of the off-season. The study consisted of testing on three separate days as described below (Figure 2). Warm-ups were administered prior to each testing session. All participants were assessed for 36.6M sprint speed times, VJ height, and 3RMs at both 45 and 90 degrees of knee flexion. Testing days lasted approximately 45-60 minutes in duration. Participants were given 48 hours between testing days to allow for adequate muscle recovery.

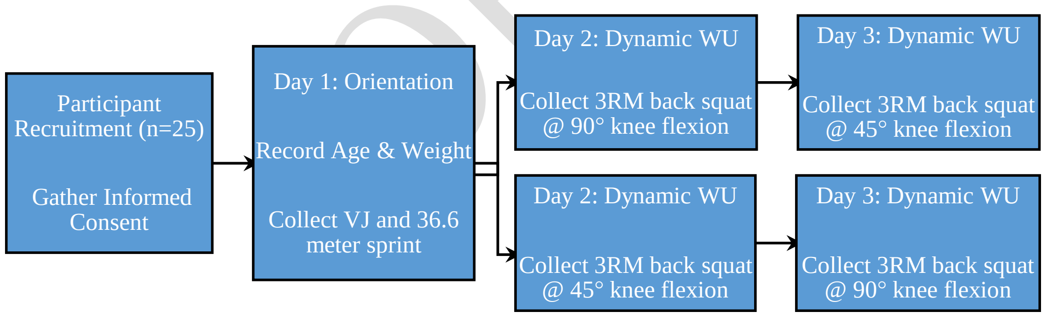
2.3.1 Day 1: Participants in both groups were tested in both the 36.6M sprint and the VJ. Before testing, participants were asked their age, weighed in on a scale (Tanita digital scale) and measured for their standing reach. The participants then performed a dynamic warm-up that included jogging, calisthenics (i.e. knee grabs, lunges, high knees, etc.), and instructed on the two tests (36.6M sprint and VJ). The participants were given 3-4 10 meter starts before testing in the 36.6M sprint, using their own preferred start stance. The 36.6M sprint was performed on a synthetic turf football field at a high school in southern California. Each subject performed two trials and the best score was used for analysis.

Roughly 8-10 minutes following the sprint tests the participants were instructed on proper VJ testing technique for the Vertec system prior to testing. The VJ test was conducted in the high school's weight room. Each subject performed two trials separated by 2-3 minutes and the best score was used for analysis.

2.3.2 Day 2 and 3: Each participant performed a 3RM back squat at 90 and 45 degrees of knee flexion. On day two of testing half of the participants performed a 3RM back squat at 90 degree knee flexion while the other participants performed the back squat at 45 degree knee flexion. On Day 3 the participants crossed over with respect to performing the 3RM back squat at the opposing knee flexion angle. Each squat testing session was proceeded by completing a dynamic warm up which included light jogging and calisthenics (as described above).

Before participants performed their back squats, the test administrator used a basic goniometer to assess the proper knee flexion angle needed. Participants were asked to hold an isometric air squat while the test administrator measured their knee angle (see Figure 1a.). While the knee angle was being attained, a resistance band was tied around the bottom of the squat rack at the depth needed for the participant to reach. The band was tied just below the gluteals of the participant. The band provided a physical cue for the participant, which signaled them to ascend out of the bottom of the squat. Participants were given 3-5 warm up sets before they attempted their 3RM back squat at the given knee flexion angles. Participants took between 3 and 5 minutes of rest between each set. Participants were given a maximum of 5 attempts to record a 3RM.

Figure 2: Study time line overview of events, WU-warm-up



2.4 Reliability

The VJ and sprints were collected as described by Baechle (2008). The test-retest reliability of short sprints has been reported to range from r=0.89-0.97 (Miller, 2012). The VJ as measured by devices such as the Vertec have demonstrated a reliability coefficient of ICC=0.95 (Nuzzo, Anning, & Scharfenberg, 2011). Repetition maximums of resistance training exercises are commonly used to predict 1-RM measures of strength (Hoffman, 2006). Further, the reliability of the back squat has been reported as ICC=0.91-0.99 (McMaster, Gill, Cronin, & McGuigan, 2014).

2.5 Design and Analysis

Data was collected for each participant in the 36.6M sprint, VJ, and 3RM back squat at both 90 degree knee flexion and 45 degree knee flexion. A Pearson correlation coefficient was calculated between the results of the VJ and 36.6M sprint, 3RM squat at 90 degrees knee flexion and 36.6M sprint, 3RM squat at 90 degrees knee flexion and VJ, 3RM squat at 45 degrees knee flexion and 36.6M sprint, 3RM squat at 45 degrees knee flexion and VJ in order to determine what squat depth was more strongly correlated with sprint and VJ performance. These same relationships were again analyzed based on 3RM squat strength to body mass ratios. The statistical significance for this study was set at $\alpha \leq 0.05$. Statistical analysis was conducted with Microsoft Excel (2013).

3. RESULTS

Participants for this study were recruited from a high school in San Diego County, CA. Twenty-five football players from the high school volunteered to participate in the study but two athletes had to withdraw from the study due to sickness and injury unrelated to the study. Data was collected from the remaining 23 participants and their demographics are reported in Table 1. The participants were all male football players from the high school aged 14-17. The average age of the participants was just over 15 years of age. The average body mass of the participants was 77.0 kgs. The average standing reach (vertical stance, eyes forward, with arm extended overhead) was 231.0 centimeters.

Table 1: Participant descriptive information

Variable	Mean±SD
Age (years)	15.1±0.9
Body Mass (kgs)	77.0±13.2
36.6M sprint (seconds)	5.23±0.26
VJ (cms)	59.6±6.6
3RM BS @ 90º (kgs)	116.1±21.0
3RM BS @ 45º (kgs)	132.1.±22.2

BS-back squat, 36.6M-36.6 meter sprint time, VJ-vertical jump, 90°-90 degrees knee flexion, 45°-45degrees knee flexion.

A fairly strong correlation was found between the 36.6M sprint times and VJ height (r=-0.65: p<0.01). There was low correlations between 3RM back squat at 90 degree knee flexion and 36.6M sprint (r=-0.33: p<0.01) as well as VJ (r=0.33: p<0.01). There was also low correlations between 3RM at 45 degree knee flexion and 36.6M sprint (r=-0.31: p<0.01) as well as VJ (r=0.33: p<0.01). There was low correlations between 3RM back squat at 90 and 45 degree knee flexion and VJ compared to strength to mass ratio (r=0.27, r=0.26: p<0.01). However, there were significant moderate correlations between the 3RM back squats (strength to body mass ratio) and 36.6M sprint times at both knee flexion angles (r= -0.46) (table 2).

Table 2: Pearson correlation coefficients (*r*)

Knee Angle	VJ 3RM SQ	36.6M 3RM SQ	VJ 3RM SQ/mass	36.6M 3RM SQ/mass
45	0.33	-0.31	0.26	-0.46
90	0.33	-0.33	0.27	-0.46

All r were significant p<0.01. VJ-vertical jump, 36.6M-36.6 meter sprint, mass-body mass, SQ-back squat.

4. DISCUSSION

The purpose of this study was to investigate if there is a correlation between varying back squat depths and explosive measure tests (i.e. 36.6M sprint times and VJ) in North American high football players. The study was attempting to provide an indication as to what depth for the back squat would be deemed optimal. The motive behind the study was to help football coaches and strength and conditioning coaches develop a strength program that would be more effective and beneficial to their athlete's performance.

The researchers hypothesized that the 90 degree knee flexion depth would correlate with lower 36.6M sprint times and higher VJ scores as opposed to the 45 degree knee flexion depth. The correlations were similar at both knee flexions, ranging from r=-0.31 to 0.33 for both 36.6M sprint and VJ. While these correlations were significant they are considered low (Safrit & Wood, 1995). These low correlations at both knee flexion angles were inconclusive with regards to the research hypothesis (i.e. which of the two squat depths is more closely associated with speed and power).

However, a Pearson correlation test revealed a significant correlation between the 36.6M sprint time and VJ performance (r=-0.65, r<0.01), which is considered high (Safrit & Wood, 1995). This relation seems to validate the interchangeable use of both the 36.6M sprint and VJ as test measures for football players. When comparing strength to mass ratios, correlations between the 3RM back squat/body mass at both 90 and 45 degree knee flexion and the 36.6M sprint times were considered moderate (90r=-0.46, 45r=-0.46), (Safrit & Wood, 1995).

The VJ scores collected in this study were reflective of 60%ile 10th grade football players VJ scores reported by Hoffman (2006). The 36.6M sprint scores recorded in this study were reflective of 55%ile (14-15 years old) football players 36.6M sprint scores (Hoffman, 2006). Based on the Brzycki (1993) 1-RM prediction equation the mean back squat scores in this study for the back squat at 90 degrees of knee flexion was 139.9 kg. Hoffman (2006) reported back squat norms for 14-45 year old high school football players with 139.0 kgs being the 60%ile. Given the Hoffman reported norms, we feel the measures of VJ, 36.6M sprint times and back squat strength collected during this study were representative of North American high school football players in general.

Results of the current study are consistent with a previous study done by Keiner, Sander, Wirth, Hartmann and Yaghobi (2014). Keiner *et al*. (2014) examined the relationship between squat depths at three separate angles (60, 90, and 120 degrees of knee flexion) and 30m sprint times in adolescent soccer players. Using a Pearson correlation test, the results revealed significant moderate correlation values of 1RM60r=-0.48, 1RM90=-0.45, and 1RM120r=-0.47; almost identical to the current study (Keiner *et al*., 2014).

Although the current study proved moderate significant correlations between back squat strength ratios and sprint times, several other studies have produced higher correlations with similar study protocols. Wisloff *et al*. (2004) reported a strong correlation (r=-0.94) between 1-RM back squat and 10m sprint performance at 90 degree knee flexion depth in elite level soccer players. McBride *et al*. (2009) also reported moderate-high correlations when comparing 1-RM back squat relative to participant's body mass performed at 70 degree knee flexion at both 9.15 and 36.6 meter sprint times (9.15r= -0.54, 36.6r= -0.60). The combined results of these studies (including the current study) suggest that using the back squat is still the one of the most beneficial exercises for developing lower body strength as it pertains to sprinting performance. The depth that is most optimal is still yet to be determined and may be dependent on the individual's body mechanics and training experience. Current research suggests that somewhere between 70 and 120 degrees knee flexion would best suit most athletes (Wisloff *et al*. 2004; Keiner *et al*. 2014; McBride *et al*., 2009).

The moderate relationship between 3RM squat/body mass performance and 36.6M sprint times (at both 90 degree and 45 degree knee flexion) suggests that strength training the lower body musculature via the back squat could increase sprint performance. A recent meta-analysis by Seitz, Reyes, Tran, de Villarreal and Haff, (2014) confirms this notion and concluded that there is a positive transfer of lower-body resistance training (RT) to sprint speed. Further, that the extent of sprint ability improvement is impacted by an individual's level of practice, body mass, number of RT sessions per week, and the rest intervals that separate the RT exercises.

The stronger the athletes become in the lower body musculature, the more potential they create for generating higher ground reaction forces (GRF's) which could subsequently increase sprint performance and vertical jump performance (Keiner *et al.*, 2014). Weyand, Sternligh, Bellizzi and Wright (2000) suggest faster sprinting performance to be more closely correlated to force exertion against the ground via the foot rather than rapid gait cycle. Comfort, Stewart, Bloom, and Clarkson (2014) reported high correlations between 20m sprint times (r=-0.67) and counter movement VJ (r=0.76) when compared to both relative and absolute strength (1RM back squat) in adolescent soccer players. Most research still supports the back squat as a prime exercise for increasing strength for the lower body muscles responsible for sprinting (Seitz *et al.*, 2014), however the optimal knee flexion angle has yet to be determined.

This study used athletes who've been strength training between 6 months and 3 years. Some of the athletes were therefore more trained than others and had a better grasp on the proper technique needed to perform the back squat. Likewise, some athletes have better technique in the testing measures of 36.6M sprint and VJ testing. Inexperience may have caused some athletes to have poor technique in the take-off phase of the 36.6M sprint or VJ along with differences in running form. Future studies may incorporate participants that are experienced lifters. Additionally, future studies examining a longitudinal strength training program, properly periodized, with an emphasis on lower body development (with back squat depth as an independent variable) may provide a more definitive answer as to if there is an optimal squat depth for developing running speed and muscular power output.

5. CONCLUSIONS

This study found that there are moderate correlations between back squat 3RMs (strength to mass) and 36.6M sprint times at 90 and 45 degrees of flexion. While only low correlations were found between the back squat 3RMs and VJ at both knee flexion angles. Further, a high correlation was found between VJ and 36.6M sprint times. Athletes and strength and conditioning coaches could use this information to aid in program design. If longitudinal studies demonstrate that back squatting at either 45 or 90 degrees of knee flexion led to equivalent gains in sprint speed and VJ performance, then one could choose to perform the back squat at either depth. This could allow for individual preference of back squat depth and program variability. For example, taller individuals often times have trouble achieving deep knee flexion back squats. In such cases the coach could have the individual use a shallower knee flexion angle back squat without sacrificing potential gains in sprint speed. Additionally, the high relationship between VJ and sprint speed suggests that these two measures could be used interchangeably. Hence suggesting that you may only need to assess either measure (but not both) to gain an understanding of the individual athletes' current level of ability.

6. ACKNOWLEDGMENTS

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