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The Relationship Between Relative Strength Levels to Sprinting Performance in Collegiate 100-400M Sprinters

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THE RELATIONSHIP BETWEEN RELATIVE STRENGTH LEVELS TO SPRINTING PERFORMANCE IN COLLEGIATE 100-400M SPRINTERS

BY

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This thesis is approved as a credible and independent investigation by a candidate for the Master of Science in Nutrition and Exercise Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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CONTENTS

ABBREVIATIONS

1 RM – One repetition maximum

3RM – Three repetition maximum

cm – centimeter

CMJ – Counter movement jump

DI – Division One

DII – Division Two

EMG – Electromyography

kg – kilogram

m – meter

NCAA – National Collegiate Athletic Association

NFL – National Football League

OL – Olympic lifting

PL – Power lifting

RT – Resistant training

SD – standard deviation

SRT – Sprint and resistant training

ST – Sprint training

TFRRS – Track and field results reporting system

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ABSTRACT

THE RELATIONSHIP BETWEEN RELATIVE STRENGTH LEVELS TO SPRINTING PERFORMANCE IN COLLEGIATE 100-400M SPRINTERS

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The purpose of this study was to determine the relationship between relative maximal (1RM) strength (i.e. back squat and power clean) to sprinting performance in 60-400m collegiate sprinters. A secondary purpose was to determine the distribution of athletes within the theoretical relationship between relative squat strength and performance capabilities. Fifty-six (n = 56) male and sixty-four (n = 64) female collegiate track and field sprinters were observed from DI (n = 88) and DII schools (n = 32) that participated in a year round strength and conditioning program.

Maximal strength was divided by body weight to calculate relative strength and were classified into one of three categories of strength based on relative squat strength: strength deficit (male and female = 0), strength association (male = 24, and female = 51), strength reserve (male = 23, and female = 5) based on Suchomel's theoretical model [36]. Pearson product moment correlation coefficient was calculated (JMP v.13.0, SAS Institute Inc.) to determine the relationship between relative maximal strength of the power clean and back squat with the performance times of 60-400m sprints. For female sprinters, the power clean and squat were significant correlated to 60m (clean: $r=-0.42$, $p \leq 0.017$, $r=-0.55$ squat: $p \leq 0.001$) and 100m (clean: $r=-0.55$, $p \leq 0.001$, squat: $r=-0.51$, $p \leq 0.003$) performance times with P-values approaching significant for 200m (clean: r=-

0.29, $p \leq 0.06$, squat: r=-0.29, $p \leq 0.07$) times and there was no relationship between relative strength and 400m times. For male sprinters, significant correlations were only found between the squat and 100m (r=-0.43, $p \leq 0.01$) performance and between the power clean and 200m (r=-0.36, $p \leq 0.04$) performance. Our results demonstrate an association of strength and performance in female athletes, but not in male athletes. Suchomel's theoretical [36] model demonstrating a relationship between relative back squat strength and performance may help explain the results.

Chapter 1

REVIEW OF LITERATURE

There are multiple factors influencing sprinters running velocity and the ability to increase running velocity. Some factors that may influence running velocity include genetics, biomechanics, central nervous system activation, fatigue, nutrition, motivation, training technique, psychology, motivation, and climate. Some of these factors can be enhanced through training such as fatigue and biomechanics while other factors such as genetics and nutrition cannot be changed through training. While these factors are important to consider, the focus of this study is related to sprinting performance and its relationship to relative strength and power measurements in the squat, clean, and vertical jump. The literature is presented in an organizational design highlighting the following topics: (a) speed and performance (b) training for speed (c) strength training (d) power training (e) relationship between relative strength and power to sprinting performance (f) summary.

1.1 ***Speed and Performance***

Sprinting performance in track and field sprinters takes muscular strength and power to complete a 100 or 200-meter dash. Stride frequency and stride length influence sprinting speed. Maximal sprinting speed is defined as the time to reach peak stride length and stride frequency [1, 2]. Mackala et al. [2] studied kinematics, motor abilities, and anthropometric characteristics between sprinters and active students and found a significant difference between the groups in time, peak velocity, maximum stride frequency, and stride index. Mackala et al. [2] reported that sprinters have longer strides and quicker stride frequency than non-sprinters. In addition, Weyand et al. [3] found that sprinters reach top speeds not by repositioning their limbs more rapidly in the air, but by applying greater forces to the ground. Applying force to the ground would explain why top sprinters are able to produce longer stride lengths and faster stride frequencies and thus faster times. This is significant because sprinters who desire to increase their speed will need to train to produce more force into the ground to decrease their sprint times. However, force produced into the ground is not the only factor in determining ones speed. An offensive lineman in the NFL can produce more force into the ground than a college sprinter but would never win a 100m race. Thus, the ratio between body mass and ability to produce force into the ground may be the equalizing factor for performing fast sprint times.

1.2 Training for Speed

Research has well documented the impact of training interventions to improve speed [4, 5, 6, 4, 7]. Interventions have included high-speed treadmill sprinting [4], resistance based with fixed plane exercises [5, 6], and assisted running with elastic cords [7].

1.2.1 Free Sprinting

Free sprint training can be defined as the form of human sprinting without the use of any external equipment [8]. Free sprint training has been shown to be an excellent approach to increase speed [9, 10] and especially in the early stages of a sprinters training protocol that focuses on form [9]. To better understand the benefits of free sprint training, it would be important to know the effects of free sprinting can have with a non-integrated protocol that does not use resistance or Olympic training. In a 10 week study that compared a plyometric group to a free sprinting group [10], they found that both groups improved similarly to jumping height and jumping distance but only the sprinting group significantly improved leg extensor strength (p=0.002), sprint (p=0.001) and agility (p=0.001) performance. It is important to note that there was no resistance protocol and the sprinting group increased strength testing while the plyometric group did not. The interesting finding is that the plyometric group and sprinting group found no differences in jump testing. Thus, it could be hypothesis that free sprinting training is superior to plyometric training because of the added benefits of increased strength, agility, and sprinting performance. However, research shows that an integrated approach with free sprint training that includes resistant training shows increased results.

Ross et al. [4] studied sprinting performance with three different training interventions for seven weeks in a sprint training only (ST), resistance training only (RT), and combined sprint and resistance training (SRT) group. Their findings showed a greater increase in sprinting performance in the ST and SRT when compared to the RT only group. However, only the SRT group reported an increase in treadmill sprint peak power. Thus, sprinting specificity seems to be important to improve sprinting performance [9] but strength training can enhance improvement. Interestingly enough, the reverse is also true where an increase in sprinting performance with only free sprint training can increase strength [10]. Therefore, free sprint training and resistant training compliment each other in optimizing results. This indicates that an integrated training approach of free sprinting and resistive training seems to be the most effective way to improve sprinting performance.

1.2.2 Resistant and Assistive Sprinting

There are multiple ways to add resistance or assistance to a sprinting action, such as, sled towing, parachute, and downhill uphill sprinting. Similar to resistant training, such as a load for a squat movement, resistant sprinting loads the athlete in the pattern of sprinting. The idea is that the athlete will become stronger in the sprinting movement and thus increase speed, especially during the acceleration phase. Assistive sprinting refers to the sprinting movement that enhances sprinting ability above normal capacity. Sprinters who train to improve sprint acceleration will commonly use sled towing [11]. Kawamori et al. [11] studied the effects of using a "light" and "heavy" sled-towing group. The "light" group trained with a sled that reduced 10-meter sprint velocity by approximately 10%, whereas the heavy group trained with a sled that reduce 10-meter sprint velocity by approximately 30%. The "light" and "heavy" group was based on previous research conducted by Lockie et al. [12] who had created a formula through a pilot study to accurately describe the relationship between towing loads and the resulting sprinting velocity over 15 meters [12]. Kawamori et al. [11] reported the "heavy" group significantly improved both the 5-m and 10-m sprint time by 5.7 ± 5.7% and 5.0 ± 3.5%, respectively; whereas only 10-m sprint time was improved significantly by 3.0 ± 3.5% in the "light" group [11]. This indicates that heavier sled towing may be useful for training the acceleration component of running with athletes, and particularly at the 5-meter distance.

Parachute resisted sprinting has also been found effective to adding resistance to a specific sprinting pattern that does not significantly alter running mechanics [13]. Paulson et al. [13] investigated acute effects of parachute-resisted sprinting on kinematics of 12 collegiate sprinters. The sprinters performed two separate tests in the 40-yard dash using parachute in one condition and no parachute in the other. Paulson et al. [13] suggests that parachute-resisted sprinting does not affect ground contact time, stride rate, and stride length and upper and lower extremity joint angles during weight acceptance initial ground contact time in their subjects using the parachute compared to not using the parachute. This suggest that parachute resisted training can be an effective method in adding resistance similar to sled towing resistance training.

In addition to sled towing and parachute training, combined up-hill and downhill sprinting has been found to be an effective method to add resistance and assistance to sprinting action [14]. Paradisis et al. [14] studied the effects of sprint running training on sloping surfaces (3% grade) on selected kinematic and physiological variables. Thirty-five sport and physical education students were randomized into 4 training groups of 1) uphill-downhill, 2) downhill, 3) uphill, 4) horizontal, and the addition of a non-training control group. Six weeks of training 3 times a week with 10 minutes of rest in-between sets included 6 repetitions of 80-m sprints for the combined uphill-downhill and horizontal groups and 12 repetitions of 40-m sprints in the uphill and downhill groups. Their findings showed that maximum running speed and step rate increased significantly ($p < 0.05$) in a 35-m sprint in the uphill-downhill (0.29ms; 3.5%) and the downhill (0.09ms; 1.1%) groups; whereas flight time shortened only for the combined uphill-downhill group (6ms; 4.3%). A similar study done by Upton et al. [7] determine if assisted sprint training or resistive sprint training provided a significant advantage, as compared to one another and to traditional sprint training. Upton et al. [7] discovered that after 12-weeks of training with a division one women's soccer team, the assisted sprinting group improved velocity in the initial first 5 yards the greatest and the resistive sprinting group had the highest improvement in the 15 to 25 yard segment of a 40-yard sprint. Cook et al. [15] also found improvement in the 40-yard sprint with a 3-week intervention of eccentric strength training and over speed downhill running of 25 meters at a 2-degree slope. Thus, it can be concluded that an integrated training approach of assistant speed training and resistive speed training can enhance speed performance.

1.3 Strength Training

Research indicates that strength is the foundation for power output and speed [16, 17, 18]. Experts agree that an effective periodization training intervention consists of strength training as a precursor to power training [19, 20]. Furthermore, an effective training practice to increase lower extremity strength is found in multi-joint free weight exercises such as the front squat or the back squat [21, 22, 23]. Research indicates stronger athletes have a greater ability to generate higher power outputs than weaker athletes [24, 25, 26]. Thus, strength is emphasized in the beginning of a sprinters training program to maximize the potential for power training during the track season. Although there are multiple ways to gain strength, the focus of this study is strength training.

1.3.1 *Back Squat*

Comfort et al. [22] performed a study to determine if changes in maximal squat strength were reflected in sprint performance in professional rugby players. From pre to post training, the subjects significantly (17.7%, $p < .001$) improved their squat strength from (170 ± 21.4kg) to (200.8 ± 19.0kg). The subjects also significantly ($p < .001$) improved in their sprint performance of 5 meters (7.6%), 10 meters (7.3%), and 20 meters (5.9%). Thus, it is apparent that an increase in lower body strength can enhance sprinting performance. The exercise selection however is an important determination in how to train the lower body. A study done by Wirth et al. [27] found that the back squat was more effective in improving the counter movement jump when compared to the leg press machine. This result could be explained by a study done by Fletcher et al. [28] who found that the back squat produced significantly greater ($p = 0.036$) EMG activity compared to the smith machine. Fletcher [28] explained that the back squat has a greater stability challenge applied to the torso and seems to increase muscle activation. Indicating that the back squat has less stability than the leg press and smith machine and thus has more muscle activation and potential transfer of strength to power activities that involve stability, such as sprinting and jumping. Thus, the reason why the back squat in this study was used as the measure of lower body strength.

1.4 Power Training

1.4.1 *Olympic*

Research shows that power training is an effective training method to enhance sprinters explosive power [29, 26]. Maximal power is defined as the explosive nature of force production [30]. Training for power can be accomplished by weightlifting exercises or also known as Olympic lifting. Hoffman at el. [29] studied the differences between an Olympic lifting group (OL) and powerlifting group (PL) with division III football athletes in an off-season program. The PL group focused on exercises (Deadlift, stiff leg deadlift, Romanian deadlift leg curl, calf raises, and upper body) that emphasized on maximal force production with loads between 6 to 8 reps of their 1 RM of intensity at a slow velocity of movement. The OL group focused on exercises (Snatch pulls above knee and floor, push press, clean, clean pulls, push jerks, lunges, power shrugs, overhead squats, box jumps, front squats, and upper body) that used loads between 6 to 8 reps of their 1RM but with high level of velocity movement. Both groups however had similar protocol for squat and bench as it was the athletes' testing program. The results found no significant differences in strength gains but the OL group improved 40-yard sprint times from 4.95 to 4.88 compared to PL group results of 4.94 to 4.90. In addition, the OL group had a greater result in the vertical jump. A similar study by McBride at el. [26] reported that Olympic lifters and sprinters possessed a greater peak velocity and vertical jump heights than powerlifting athletes.

In a study that compared an Olympic weightlifting program to a plyometric program, Tricoli et al. [31] reported that the Olympic weightlifting group significantly increased the 10-meter sprint while the plyometric program had no significant result. Both groups increased their counter movement jump (CMJ) significantly. However interestingly, the Olympic group had superior results in the CMJ compared to the plyometric group. Research indicates that strength training, such as the powerlifting only group (Hoffman 2004), alone is not adequate as an integrated program that includes power training to improve sprinting performance [29, 31, 26]. In addition, it appears that Olympic weightlifting with no plyometric protocol shows superior results in the counter movement jump test compared to plyometric training with no Olympic weightlifting protocol. Thus, Olympic weightlifting should be included in a strength and conditioning program to enhance sprinting and jumping performance.

1.4.2 *Plyometric*

The nature of plyometrics is the ability to reach maximal force in the shortest possible time [32]. Sprinters experience this phenomenon every time they contact the ground. Contact time in some elite sprinters can equal between 80-95 milliseconds with ground reaction forces exceeding 3-4 times their body weight in a single running stride [33]. The transitional period from eccentric to concentric contraction, stretch-shorting cycle, needs to be as short as possible. The counter movement jump simulates this action and tests the athlete in their ability to produce force and to produce that force as quickly as possible. The counter movement jump also naturally factors in bodyweight, as the athlete has to produce force against its own body mass to propel them in the air.

The counter movement jump test is also correlated to 100-meter dash performance [34, 35]. Loturco et al. [34] found a significant correlation ($r=-0.85$, $p< 0.01$) between the counter movement jump and the 100-meter dash in elite sprinters and Kale et al. [35] found a significant correlation of ($r=-0.46$, $p< 0.05$) in 21 volunteer male sprinters. Coh et al. [33] examined the relationship between explosive power variables of the counter movement jump and depth jump in elite and sub-elite sprinters and found that the height of the counter movement jump in the elite sprinters was ~8cm higher than the sub-elite group. Therefore, the sprinters degree of relative force produce into the ground and the amount of time on the ground makes up factors that influence sprinting speed.

1.5 Relationship Between Relative Strength to Sprinting Performance

Absolute strength is defined by the total weight lifted during a strength exercise. Relative strength is defined by the total weight lifted divided by body mass during a strength exercise. To calculate relative strength in this study, 1RM of the clean or squat are divided by the athlete's body mass. To categorize the level of relative strength, figure 1 shows Suchomel's theoretical relative strength model [36] that is put into three phases; Strength deficit (0-0.5), strength association (0.5-2.0), and strength reserve phase (2.0+) [36]. In this model, strength deficit is defined as those individuals whose squat 1-lift maximum is below 0.5 times their body weight. In this phase it is suggested that individuals may not be able to exploit their levels of strength to performance benefits. The strength association phase is defined as those individuals whose squat 1-lift maximum is between 0.5 and 2.0 times their body weight. This phase is characterized as having a nearly linear relationship between relative strength to performance capabilities. In the strength reserve phase, it is defined as those individuals whose squat 1-lift maximum is above 2.0 times their body weight. During this phase, athletes have significantly improved their relative strength and performance, however, continued strength gains may or may not have a linear correlation of direct performance benefits.

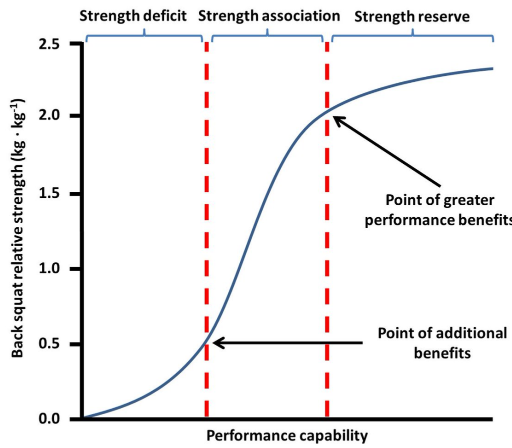

Figure 1.

When considering Newton's second law (force = mass x acceleration) and the equation for power (power = force x velocity) it is important to compare strength and power to the athlete's body mass. An athlete's force is determined by how well they can accelerate along with their body mass and power is determined by velocity and force. An elite sprinter will need to have a high level of force and power to accelerate against its own body mass to run fast times. Nuzzo et al. [37] compared relative 1RMs in both the squat and power clean to relative counter movement jump (CMJ) peak power, CMJ peak velocity, and CMJ height and found significant correlations (p=0.05). Nuzzo's findings are related to the current study because it shows that relative 1RM squat and power clean have a relationship with jumping tests which naturally factors in body mass. Another study done by Barker et al. [38] compared relative strength and its correlation to sprinting speed and discovered that all measures of strength (3RM Back Squat) and power (3RM Hang Clean) relative to body mass were significantly related to sprinting performance of 40 meters in professional ruby players [38]. Furthermore, Barker et al. [38] found that relative clean power has a strong relationship in sprinting performance resulting in a significant correlation in the 10-meter (r= -0.56) and 40-meter sprint (r= -0.72). Hori et al. [18] also studied performance in the hang power clean and its relationship to sprinting and jumping performance and reported that the highest relative 1RM hang power clean performances had significant relationships with the highest jumps (r=-0.69) and fastest sprint times (r= -0.58) in semi-professional Australian Rules football players. A recent study done by Loturco et al. [34] also found that maximum mean propulsive power relative to body mass was significantly correlated with the 100-m sprint (p=0.01). The mean propulsive power was assessed in the jump squat exercise utilizing a smith machine. In addition, the jump tests (Squat jump, counter movement jump, and horizontal jump) were also largely associated with the 100-m dash performance (p=0.01). When comparing the findings of Loturco et al. [34] that jump tests correlate with a 100-m dash and Nuzzo et al. [37] and Hori et al. [18] results findings of jump tests to be correlated with relative strength and power measurements in the squat and power clean show that jumping, power, strength, and speed all have a relationship when evaluated against body mass. It is important to note that relative strength and power have been found to have a correlation with sprint times but absolute strength and power have been found to have no correlation to sprinting performance [37,18]. Thus, body mass seems to be the equalizing factor when analyzing strength and power measurements in sprinters to assess their sprinting performance potential.

1.6 Summary

Sprinting performance takes muscular strength and power to compete at a high level in collegiate sprinting events. Studies show that there is a positive training effect on improving sprinting ability from jumping, strength, and power interventions. Studies have also shown positive training effects on improving jumping ability from strength and power interventions. An integrated training approach that targets strength, power, and speed seems to produce the greatest results for sprinting performance. Another important factor to sprinting performance is body mass. Studies have shown that the ability of the sprinter to produce strength and power against its own body mass has a significant correlation. However, few studies if any have looked at the correlation of relative strength and power to sprinting performance in actual collegiate track and field meets in the 60m, 100m, 200m and 400m dash. A study to assess the relative strength and power qualities at different levels of collegiate races may help researchers, track coaches, and strength and conditioning professionals understand the optimal body mass to strength and power ratios for sprinting performance in their athletes.

Chapter 2

INTRODUCTION

Sprinting performance in track and field sprinters takes muscular strength and power to complete a 60-400-meter dash. Sprinting is the product of stride length and stride frequency and maximal sprinting speed is defined as the time to reach peak stride length and stride frequency [1, 2]. Stride length is thought to be more important than stride frequency to increase speed [3, 39]. Weyand et al. [3] found that sprinters reach top speeds not by repositioning their limbs more rapidly in the air, but by applying greater forces to the ground. Taylor et al. [39] confirmed Weyand et al. [3] research in discovering that Olympic medalist Usain Bolt achieved the greatest velocity over the 60-80 meter split but had the longest contact time and lowest step frequency. Mackala et al. [40] concluded that maximal running speed is largely determined by how much force a sprinter can apply to the ground during each step. The more force applied the greater the potential for increasing stride length.

Athletes focus on developing strength and power during training to increase their ability to apply more force into the ground to enhance sprinting performance. Optimal training includes an integrated approach that utilizes sprinting, strength, and power training. Research shows that sprint training improves sprinting ability as well as strength [10], resistive training improves strength and sprinting ability [22], and power training (i.e. Olympic weightlifting) improves rate of force development (power), jumping ability and speed [29, 26, 31].

The ability to apply force to the ground to optimize sprinting performance seems to be equalized by body mass and strength levels. According to Suchomel's theoretical relative strength model, athletes who are in the strength association phase of being able to back squat .5 to 2 times their body weight have a nearly linear relationship between relative strength and performance capability [36]. While athletes who are in the strength reserve phase of being able to back squat more than twice their body weight may have a less of a degree of correlation of relative strength to performance. Other studies have shown that the ability of the sprinter to produce strength and power against its own body mass has a significant correlation [38, 18, 34]. Barker et al. [38] compared relative strength and power out to sprinting speed and discovered that all measures of strength (3RM Back Squat and 3RM Hang Clean) and power output (jump squat) relative to body mass were significantly related to sprinting performance. Research shows that speed, strength, and power training can enhance sprinting performance and that relative strength and power optimizes force produced into the ground. However, few studies have investigated the correlation of relative strength (1RM Back Squat) to sprinting performance in actual collegiate track and field meets in the 60m, 100m, 200m and 400m dash. A study assessing the above-mentioned correlation would assist researchers, track coaches, and strength and conditioning professionals to understand the optimal body mass to strength ratios for sprinting performance in their athletes.

Study Purpose

The purpose of this study was to determine the relationship between maximal (1RM) strength exercises commonly utilized to improve strength and performance (back squat, power clean, and vertical jump) with sprinting performance times of the 60m, 100m, 200m, and 400m sprints for collegiate male and female runners. A secondary purpose was to determine the distribution of athletes within the theoretical relationship between relative squat strength and performance capabilities based Suchomel's theoretical model [36].

Research Hypothesis

We hypothesized that there will be a strong correlation between relative strength and sprinting performance times. While the data will not provide a cause and effect relationship, it will provide evidence as to the relationship between strength and sprinting performance. Our secondary hypothesis is that the majority of athletes will be classified in the strength association or strength reserve categories.

Chapter 3

METHODS

The methods that pertain to this study are described in this chapter. For organizational purposes the methods are presented under the following topics: (a) methods (b) population (c) statistical analysis

3.1 Methods

Two data collections had been taken during this study. This study collected existing data from two different sources with both sources being directly linked. The first data collection was from collegiate strength and conditioning departments that train track and field sprinters. The first data collection contained collegiate sprinter's maximal effort in the squat, clean, and vertical jump. The data also contained height, weight, and gender. The inclusion criteria included current collegiate athlete during the 2015/16 academic calendar at an NCAA division one or division two institution, and ran a 100 or 200-meter dash. The exclusion criteria included freshmen year status, and ran above a 400-meter dash. The second collection of data stemmed from the first data collection with the utilization of known public information on the Track & Field Results Reporting System (TFRRS) website. Data collection compared the results of TFRRS in collegiate track and field meets in data collection two. Preceding data collection, approval was obtained through the South Dakota State University Institutional Review Board for the Protection of Human Subjects by submitting the Research Protocol and Informed Consent to the Human Subjects Committee.

3.2 Subjects

Subject characteristics are provided in Table 1. Subjects were from DI (n=88) and DII schools (N=32). The subjects of this study were collegiate sprinters who participated in a year round strength and conditioning program. The subjects were sophomore through seniors, including fifth-year seniors.

3.3 Statistical Analysis

Maximal strength was divided by body weight to calculate relative strength. Athletes were classified into one of three categories of strength based on relative squat strength: strength deficit, strength association, strength reserve, based on Suchomel's theoretical model [36]. Participant characteristics and measurements of strength and performance times are presented as means ± SD. A Pearson product moment correlation coefficient was calculated (JMP v.13.0, SAS Institute Inc.) to determine the relationship between relative maximal strength of the power clean and back squat with the performance times of 60m, 100m, 200m, and 400m sprints for both females and males.

Chapter 4

RESULTS

Physical characteristics as well as the performance measures of the athletes are presented in Table 1 by sex. Table 2 summarizes the Pearson correlation coefficients of the relative strength measurements and sprint performance times for female (Table 2a) and male athletes (Table 2b). For female sprinters, the power clean and squat were significant correlated to 60m and 100m performance times. P-values approached significant for 200m times and there was no relationship between relative strength and 400m times. There was also no relationship between vertical jump and performance times for any of the distances.

The relationship between relative strength of the power clean and squat for male athletes was not as evident or consistent as for the female athletes. The only significant correlation calculated was between the squat and 100m performance and between the power clean and 200m performance. There was no relationship between vertical jump and performance times.

Athlete's classification of relative strength levels are presented in Table 3. Fifty-one of the 56 female athletes were in the strength association phase, while only five were in the strength reserve phase. Of the 47 males athletes, 23 were in the strength reserve phase and 24 were in the strength association phase.

Chapter 5

DISCUSSION

The purpose of this study was to determine the relationship between maximal (1RM) strength exercises commonly utilized to improve strength and performance (back squat, power clean, and vertical jump) with sprinting performance times of the 60m, 100m, 200m, and 400m sprints for collegiate male and female runners. This study found significant correlations between power clean and squat and performance times in the 60m and 100m for females and the relationship approached significant ($p=0.07$) for the 200m. For males, there was a significant correlation between the squat and 100m performance times as well as for the power clean and 200m performance times. The relationship between strength and sprint performance times were not as evident for the male athletes as it was for the female athletes. The reason for this difference may be explained by Suchomel's theoretical model for relative strength levels shown in (Figure 1) [36]. The model provides an explanation for the relationship between strength and the performance capability of an individual. The relative strength levels consist of three phases, strength deficit, strength association, and strength reserve and assumes that individuals should be able to back squat twice their body weight for optimal performance.

The strength deficit phase suggests that individuals have not achieved optimal gains in strength which may hinder their ability to perform. Within this phase individuals are in a motor learning phase and are considered novices in strength training. Research supports by the phasic progression that indicates that central and local factors such as motor unit recruitment, fiber type, and co-contraction enhances the ability to improve maximum strength [20, 41]. Rippetoe [41] states a novice trainee as one whom the stress applied during a single workout and the recovery from that single stress is sufficient to cause an adaption by the next workout. Thus, individuals in this phase are able to generate rapid muscular and neural adaptions and able to improve strength. In our study, no subjects were found to be in the strength deficit phase. This may be explained by the study design that subjects had to be of sophomore or above to be eligible for the study. Limiting the freshmen population allowed the pool of subjects to have at least one year of training with a strength and conditioning coach to develop strength.

Almost all the women were classified in the strength association phase, which according to Suchomel's model, is characterized by a nearly linear relationship between relative strength and performance capability by being able to exploit their level of strength into performance benefits. Similar to the strength deficit phase, the main two physiological adaptations in strength association phase occurs at the protein (myofibrils) level, which allows for muscle hypertrophy and an increase in muscle cross-sectional area [42,43]. The second adaptation is related to neuromuscular improvements in motor unit recruitment and firing synchronicity [44]. The stress to cause this adaptation is done by strength training. Hoffman et al. [45], followed collegiate football players career and discovered that the football players experienced the greatest gains in strength during the first two years of college, with smaller gains in the third and fourth years. While surrogate measures of performance were utilized (vertical jump) it can be assumed that these athletes also experienced significant improvements in performance. Athletes who are novices or in the strength association phase are able to experience gains in power and performance by simply strength training [46]. In our study, the majority of the female athletes were in this phase and we observed a significant relationship between relative strength and performance times.

The majority of the male athletes were classified in the strength reserve phase, which leaves little room for improvement based on Suchomel's model. In the strength reserve phase athletes have reached a strength level where traditional strength training does not have a significant transfer effect toward performance benefits. When athletes are in this phase strength gains will be minimal compared to the strength association phase, therefore, training should emphasis high velocity or power training to stimulate additional performance benefits [47]. Previous research has shown that velocity based or power training can stimulate further performance gains in athletes who possess a reasonable level of maximal strength [47, 48, 49] and may be more beneficial to performance than traditional strength training while in the strength reserve phase. Although strength training should not be eliminated in this phase, the emphasis should be focused more on power training to improve performance.

In the present study, the lack of correlation of relative strength to performance times in the male sprinters may be explained by the fact that these athletes had a mean relative back squat of 1.95 (range 1.4 to 2.8) approaching the strength reserve phase. The high relative back squat in the male athletes indicates little room for improvement in performance from strength training [48] as they are in or close to being in the strength reserve phase [36]. In contrast, 91% of the female sprinters in the present study fell in the strength association phase with a mean of relative back squat of 1.65 (range 1.1 to 2.4). Since the average strength level of the female population falls in the strength association phase, their performance can improve by simply strength training [46]. Thus, explaining why the females in the present study had more of a relationship of strength levels to sprinting performance. It is important to note, however, that there is limited research examining the differences in performance between individuals that can squat greater then or equal to 2.5 times their body mass versus 2.0 and 1.5 times their body mass. In addition, no research has discussed the changes in performance after transitioning from a 2.0 to a 2.5 relative squat strength.

In summary, our results demonstrate an association of strength and performance in female athletes, but not in male athletes. Suchomel's theoretical [36] model demonstrating a relationship between relative back squat strength and performance may help explain the results. However, more research needs to be done to determine if athletes who are in the strength reserve phase of being able to squat double their body weight can improve performance by increasing their relative strength through training.

PRACTICAL APPLICATION

Our data suggests that relative strength levels are related to sprinting performance in female colligate sprinters. However, the data also found an inconsistent relationship with relative strength levels and sprinting performance in male colligate sprinters. We recommend strength and conditioning coaches design programs that focuses on increasing relative strength with female athletes who squat less than twice their body weight to increase sprinting performance. Once the athlete is able to squat twice their body weight, we recommend a program that emphasizes on power development while maintaining or continuing to increase relative strength levels to further sprinting performance gains.

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Figure 1. Suchomel's Theoretical Relative Strength Model

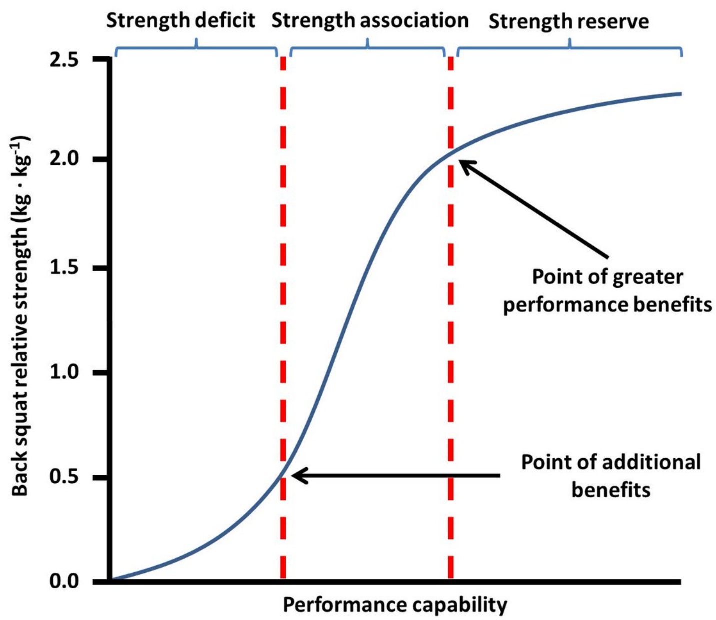

Table 1. Subject Characteristics

	Female (64)	Male (56)
Height (cm)	166.64 ± 7.74	180.27 ± 7.39
Weight (kg)	60.09 ± 6.49	76.14 ± 7.55
Clean (kg)	64.07 ± 9.57	108.15 ± 17.69
Clean (kg/bw)	1.07 ± 0.15	1.42 ± 0.19
Squat (kg)	98.40 ± 18.29	149.85 ± 32.75
Squat (kg/bw)	1.65 ± 0.29	1.96 ± 0.35
Vertical Jump (cm)	62.13 ± 6.8	79.53 ± 7.13
Johnson Peak Power	4469.45 ± 685.77	6753.91 ± 493.5
60m (sec)	7.79 ± 0.23	6.98 ± 0.24
100m (sec)	12.37 ± 0.53	10.99 ± 0.42
200m (sec)	25.27 ± 1.00	22.22 ± 0.85
400m (sec)	56.10 ± 3.32	49.98 ± 2.53
Sophomore	28	24
Junior	27	13
Senior	9	19

Table 2a. Correlation between strength and sprint times for 60m, 100m, 200m, and 400m events for female sprinters.

Female				
	60m	**100m**	**200m**	**400m**
Clean				
Number	31	31	41	24
Correlation	-0.42	-0.55	-0.29	-0.17
p-value	0.017*	0.001*	0.06	0.43
Squat				
Number	32	32	41	24
Correlation	-0.55	-0.51	-0.29	-0.33
p-value	0.001*	0.003*	0.07	0.11
VJ				
Number	19	16	25	15
Correlation	0.039	-0.05	-0.17	-0.23
p-value	0.87	0.87	0.44	0.41

Table 2b. Correlation between strength and sprint times for 60m, 100m, 200m, and 400m events for male sprinters.

Male				
	60m	**100m**	**200m**	**400m**
Clean				
Number	23	27	33	16
Correlation	-0.24	-0.28	-0.36	-0.08
p-value	0.27	0.15	0.04*	0.75
Squat				
Number	22	26	30	15
Correlation	-0.39	-0.43	-0.33	-0.10
p-value	0.07	0.01*	0.07	0.71
VJ				
Number	16	15	20	9
Correlation	-0.29	-0.25	-0.18	-0.32
p-value	0.26	0.37	0.44	0.39

Table 3. Athlete's Classification of Relative Strength Levels

Subjects	Females 56 (Tested Relative Back Squat)	Males 47 (Tested Relative Back Squat)
Strength Reserve Phase	2+ (5)	2+ (23)
Strength Association Phase	2-0.5 (51)	2-0.5 (24)
Strength Deficit Phase	<0.5 (0)	<0.5 (0)