RELATIONSHIP OF LEG STRENGTH AND SPRINTER'S STRIDE LENGTH

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Relationships between maximal squat strength, peak velocities, and relative stride lengths were examined in male and female collegiate sprinters during a 60m sprint. Runners were videotaped at 120 Hz. and stride lengths, and peak velocities were calculated using the Ariel APAS software. Sprinters' 1-RM squat strengths and leg lengths were measured. A high correlation of r=.904, (p=.09) was found between the male sprinters' leg strength and relative stride length, and the females had a low non-significant r=.515. A high significant correlational relationship of r=.988 (p=.04) was found for male leg strength and sprint velocity, and the females had a non-significant correlation r=.074. Male sprinter leg strength was a significant training factor influencing relative stride length, and sprinting velocity. While female leg strength was a not a factor for the relative stride length, and peak velocity.

KEY WORDS: sprint mechanics, stride length relationship, squat strength, sprint velocity

INTRODUCTION: Running speed is the product of stride frequency and stride length, represented in the equation of Speed = Stride Length x Stride Frequency (Weyand, Sternlight, & Bellizzi, 2000). The number of times a runner's feet contact the ground in a given period (stride frequency) combined with the displacement traveled during each stride (stride length) results in the magnitude of speed. Some of the literature contests that stride frequency is responsible for faster speeds (Čoh, Milanović, & Kampmiller, 2011) and others state that stride length is the deciding factor (Weyand et al., 2000), or that the dominant influence is undecided (Salo, Bezodis, Batterham, & Kerwin, 2011). Regardless of which is superior, neither variable should be neglected, as both play a part in producing continual progression throughout a runner's training.

The two factors must be trained in unison, as maximum velocity comes about from an optimal relationship of training, as well as individual kinematic and morphological characteristics, such as body height, leg length, strength, and flexibility (Salo et al., 2011). To over emphasize one factor may adversely affect the remaining factor, resulting in a less efficient performance (Hunter, Marshall, & McNair, 2004). Frequency has been reported as having a stronger neural emphasis, while stride length is focused on force generation (Čoh, Milanović, & Kampmiller, 2001). The greater the amounts of force that a runner can produce and apply it to the ground in an effective direction it may result in greater ground reaction forces (GRFs) and faster potential velocities that may be achieved. Young, Benton, Duthie, & Prior (2001) reported that periodized resistance training can improve the large amounts of force capacity required while sprinting at maximal velocity. Greater muscular force allows a sprinter to get on and off the ground more quickly, as less ground time is now needed to achieve the necessary amounts of force, resulting in a more efficient running performance; however the direct relationship between maximal strength and stride length is still limited in research literature. The purpose of this study was to examine the relationship of leg strength on running stride length and maximal sprinting velocity in male and female collegiate 60m sprinters.

METHODS: Participants in this study were healthy Midwestern division I collegiate sprinters (4 males and 3 females) who had completed at least 6 weeks of speed work and strength training who were between the ages of 18-24 years. Informed consents were obtained by all participants.
Strength evaluation: All participants performed a prescribed warmup including 4 sets of squat lifts starting with 40% of their 1-RM goal weight and then progressing to 90% of their initial 1-RM attempt and after 5 minute rest they attempted their maximal lift that was recorded as their maximal squat strength.

Kinematic video analysis: After a typical warmup, the runners performed two maximal 60 m sprint time trials that were videotaped at 120 Hz using a JVC GRDVL 9500 video camera that was positioned 50m down the outdoor Mondo track and perpendicular to the runway. Fourteen markers were placed on selected joints of the sprinters and they performed 2 sprint trials with at least 5 minutes of rest between trials while being videotaped.

The fastest time trial was selected for film analysis and the runners' strides completed during the final 10 m were digitized. The x, y data point coordinates were transformed using a 2D DLT into real distances using a calibration cube 50 m down the track, and the coordinates were smoothed using a Butterworth 2nd order digital filter with an 9 Hz frequency cut-off, using the Ariel APAS software. The runners' leg length represented the displacement from the floor to the greater trochanter measured to the nearest .1cm. Kinematic analyses were performed on two right and left strides occurring in the final 10m of the 60m sprint trial. The sprinters' maximal horizontal velocity, their average stride length, stride length relative to leg length, and foot contact times were calculated during the final 10m of the run.

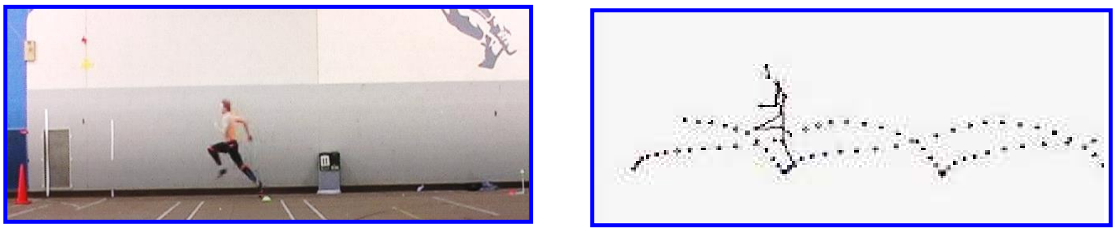

Figure 1. Sprinting field of view and sprinting gait trajectories

Independent T-tests were performed to determine if the male and female sprinters' leg lengths, stride lengths, and leg length/stride ratios were statistically similar. Then Pearson product correlations for the male and female athletes were determined between the sprinter's maximal squat strength, stride length (absolute length and relative to leg length), and peak sprinting velocity achieved during a 60 meter sprint time trial. All data were analyzed using the Statistical Package for Social Sciences (SPSS).

RESULTS: Descriptive data calculated for stride length, stride length relative to leg length, and maximal squat strength, for the male (n=4) and female sprinters (n=3) are presented in Table 1. The independent T-tests performed on the male and female sprinters' anthropometric data such as leg length, stride length and leg length/stride ratio indicated the male and female subjects were statistically similar at the .05 level.

Table 1: Descriptives for male & female sprinters' strength capacity, stride length, speed

Characteristic	M ± SD	Range
Male Squat Strength n=4	159.1 ± 12.0 kg	143.2 - 170.5 kg
Leg Length	82.4 ± 5.8 cm	77.0 - 90.5
Stride length	160.5 ± 13.3 cm	145.0 - 177.0
Leg length/Stride ratio	1.95 ± 0.07	1.88 - 2.04
Peak Sprint Velocity	7.56 ± 0.5 m*s^{-1}	6.89 - 7.92 m*s^{-1}
Foot contact time	0.107 ± .009 s	0.96 - 0.116 s
Female Squat Strength n=3	119.7 ± 16.0 kg	143.2 - 170.5 kg
Leg Length	78.5 ± 1.8 cm	77.0 - 90.5
Stride length	147.3 ± 4.9 cm	145.0 - 177.0
Leg length/Stride ratio	1.88 ± 0.06	1.88 - 2.04
Peak Sprint Velocity	6.9 ± .0.6 m*s^{-1}	6.89 - 7.92 m*s^{-1}
Foot contact time	0.116 ± .011 s	0.108 - 0.129 s

Scatterplots graphically representing the relationship of sprinter squat strength and their relative stride length are shown in Figures 2 and 3, for the males and females, respectively.

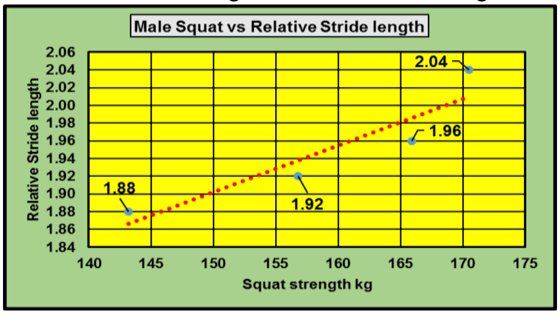

Figure 2: Male squat vs relative stride length

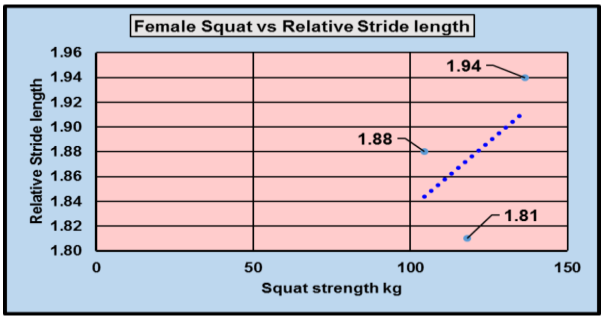

Figure 3: Female squat vs relative stride length

The plots representing the relationship between squat strength and peak sprinting velocities during the final 10m of a 60m sprint for the male and female sprints are shown in Figures 4 and 5, respectively.

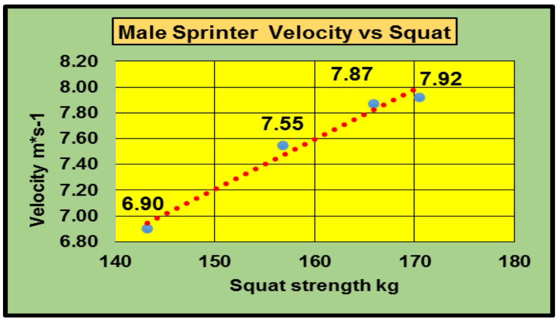

Figure 4: Male squat vs sprint velocity

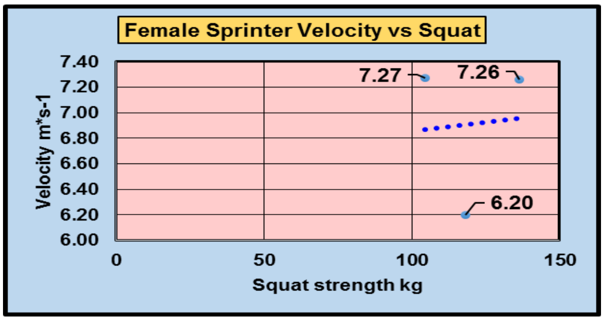

Figure 5: Female squat vs sprint velocity

Pearson product correlations were determined between the variables of relative stride length, peak velocity, contact time, and maximal squat strength. The Pearson product correlation coefficients indicating the relationship and level of significance between the selected variables are presented in Table 2.

Table 2. Pearson product correlations between selected variables

	Variable 1 vs	Variable 2	Coefficient r	Prob
Male Sprinters	Relative Stride length	Peak Velocity	r = .829	p = .12
n=4	Relative Stride length	Leg strength	r = .904	p = .09 *
	Leg strength	Peak Velocity	r = .988	p = .04 **
	Contact time	Peak Velocity	r = .538	p = .78
Female Sprinters	Relative Stride length	Peak Velocity	r = .893	p = .11
n=3	Relative Stride length	Leg strength	r = .515	p = .85
	Leg strength	Peak Velocity	r = .074	p = .98
	Contact time	Peak Velocity	r = .538	p = .78

Note: Significance *p=.10, ** p=.05

DISCUSSION: A correlation of r=.904 significant at the .10 level was found to exist for the strong relationship between squat strength and relative stride length for male sprinters. A non-significant correlation of r=.515 reflecting a weak to moderate relationship between female sprinters' squat strength and relative stride length was reported. A high significant correlation of r=.988 (p=.04) was found between squat strength and peak running velocity for the male sprinters. A non-significant coefficient of r=.074 reflected a slight relationship shown in the scatterplot between squat strength and peak sprint velocity for the female sprinters in the current study. No statistically significant differences were found between the male and female sprinter's anthropometric characteristics. However, the male sprinters' average leg lengths were 5% longer than the female sprinters, and the average male running stride lengths were

9% longer than the female sprinters. The male runners' stride length relative to their leg lengths were just 3.7% longer than the female runners. The male sprinters exhibited 60m sprinting velocities that were 9.4% faster than the females and the male sprinters' foot contact times were 8.4% faster that would result in faster stride frequencies.
The male sprinters exhibited 33% greater squat strength than the female sprinters. The increased strength may have resulted in larger and more impulsive ground reaction forces that would produce higher running velocities. The high correlation between squat strength and male sprinters' relative stride length (p=.09) was significant at the .10 level, and the high relationship between leg strength and peak velocity was significant at the .05 level, would indicate that male sprinters' leg strength is a strong influencing factor on stride length and running velocity when coaching male athletes. This finding was consistent with the results reported by Čoh, M., Milanović, D., & Kampmiller, T. (2001). The non-significant correlation between female squat strength and relative stride length was similar to the findings by Paruzel-Dyja, M., Walaszczyk, A., & Iskra, J. (2006). A significant correlation of .988 (p=.04) was found between squat strength and peak running velocity for the male sprinters and this very strong relationship was also reported by Paruzel-Dyja, M., Walaszczyk, A., & Iskra, J. (2006). Similarly, Young et al. (2001) reported that stronger male athletes achieved faster maximal running velocities. A slight non-significant relationship of r=.074 was found between squat strength and peak sprint velocity for the female sprinters in the current study. A strong but non-significant relationship of r=.893 (p=.011) was found for the females' relative stride length and peak velocity. This might indicate that the females in this study used greater relative stride lengths as a compensatory mechanism to increase their running velocity than higher leg strength and increased ground reaction forces but the limited number of subjects used in the this study hindered making powerful statistical relational conclusions.

CONCLUSION: The correlation analysis found that male sprinter leg strength was a significant factor related to the variable of stride length relative to the leg length and the male leg strength was a significant factor influencing sprinting velocity. Therefore, when coaching male sprint athletes a significant emphasis on strength training may be in order to improve sprinting velocities. Also, it was found that female sprinter leg strength had little or no relationship to the stride length relative to leg length nor did it positively influence the female sprinters peak running velocity during a 60m sprint trial. From the correlational analysis is would appear that the squat strength of male sprinters produced a larger improvement in the stride frequency/foot contact time during a 60m sprint than its influence on stride length relative to leg length when compared to female sprinters. However, the male sprinters' additional leg strength permitted them to more fully extend their legs that resulted in greater relative stride lengths and increased force generation against the ground while running. The female sprinters showed a trend to improve sprint velocity by increasing their relative stride length. But female leg strength was indicated to have little or no influence on sprinting velocity but testing of more subjects are necessary to be able to arrive at definitive relational conclusions.

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