The Correlation Between Strength and Power Measures with Sprint Freestyle Performance in Division 1 Collegiate Swimmers

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ABSTRACT

The purpose of this study was to investigate the relationship between dryland strength and power measures with sprint freestyle performance in Division 1 collegiate swimmers. Ten males (Age, M = 20.1 yrs., SD = 2.2) and eight females (Age, M = 19.4 yrs., SD = 1.3) with an average of 12.4 years of competitive swimming experience participated in the study. Dryland measures were a one-repetition maximum (1-RM) weighted pull-up test in kilograms, a non-countermovement jump (NCMJ) in centimeters, and a barbell back squat velocity test in meters per second designed to test upper body and leg strength and power. The swim task was a maximal-effort 45.72-meter freestyle swim. To normalize the data, Z-scores were computed for each variable and for the sum of the three-dryland tests. The data were analyzed using Pearson product-moment correlation analysis. In males, an inverse association was observed between the sum of the three-dryland performances and the sprint swim time ($r = -0.77$, $p < 0.05$). In females, correlations were significant between the sum of the three-dryland performances, the weighted pull-up, the back squat velocity, and the NCMJ height with the sprint swim time ($r = -0.86$, $r = -0.66$, $r = -0.67$, $r = -0.75$; $p < 0.05$, respectively. The results showed the importance of dryland strength and power in male and female competitive swimmers for successful sprint swimming performance.

Introduction

Dryland training is a modality of training completed on land and implemented by many coaches and athletes. Although previous studies have observed the importance of possessing upper and lower body strength and power for successful sprint swimming performance (2, 3, 7, 8, 10, 11, 12, 13), some ambiguity exists between the relationship of different dryland training modalities and swimming performance. Crowley, Harrison, and Lyons (4) found the pull-up and squat exercise to be the most popular exercises prescribed for swimmers by elite strength and conditioning coaches, but little is known about its efficacy on swimming performance.

Several studies have investigated the relationship between squat-jump bar velocity (7), pull-up (12), and jumping performances (7) with sprint swimming performances. No studies have reported the association of the multiple dryland tests with a 45.72-meter freestyle swim performance. Further, no study has tested a one-repetition-maximum (1-RM) weighted pull-up and back squat barbell velocity on sprint swimming performance in Division 1 collegiate swimmers.

There has been an increase in the popularity of using barbell velocity tracking for improving sports performance, but little-to-no evidence has shown its efficacy in swimmers. García-Ramos et al. (7) investigated the relationship between barbell velocity during a squat jump on a Smith machine with 25-, 50-, 75-, and 100% of body weight (BW) and swimming start performances at 5-, 10-, and 15-meters in 20 international-level female swimmers. The authors found an inverse relationship between bar velocity during a squat-jump and swimming start performance.

García-Ramos et al. (7), also investigated the relationship between the freestyle swimming start performance and the parameters of a countermovement jump (CMJ) and non-countermovement jump (NCMJ). There were significant relationships between several parameters (e.g., relative peak power in watts per kilogram) of the NCMJ and 5-meter swimming start performance, but not with the 10- and 15-meter swimming start performances. While there is evidence supporting the efficacy of improving parameters of a NCMJ to improve components of a 50-meter freestyle, there is a lack of evidence to support the efficacy of improving NCMJ height to improve sprint swimming performance in Division 1 collegiate swimmers.

The 1-RM weighted pull-up measures upper body pulling strength, which may be important for propulsion in sprint swimming performance. However, no studies report the relationship between the 1-RM weighted pull-up and sprint swimming performance. Pérez-et al. (12), investigated the relationship between the parameters of a maximum effort BW pull-up (pull-up mean velocity (PUV), pull-up absolute power (PUAP), pull-up relative power (PURP), pull-up relative force (PURF), pull-up absolute force (PUAF), pull-up peak velocity (PUPV), and time to reach peak velocity (PUTPV)) with 50-meter freestyle swimming performance. Significant inverse relationships were observed between the PUV, PUAP, PURP, and PUR metrics with 50-meter freestyle times. This suggests the importance of possessing upper body pulling power for successful sprint swimming performance. While there is evidence supporting the efficacy of increasing the velocity of a single pull-up, there is a lack of evidence to support the efficacy in increasing a swimmer’s 1-RM weighted pull-up to improve sprint swimming performance.

The purpose of this study was to investigate the relationship between upper body strength and lower body power measures with sprint freestyle performance in a convenience sample of Division 1 male and female collegiate swimmers.

Methods

Participants

The study recruited members of the Arizona State University (ASU) Swimming Team from the 2017-2018 season. The inclusion criteria consisted of (a) no current injury that prohibits them from swimming or performing strength training activities, and (b) the swimmers must have had at least six months of strength training experience. The exclusion criteria consisted of (a) listed as a breaststroke specialist on the team's website, (b) failure to answer "no" to all questions listed on the Physical Activity Readiness Questionnaire (PAR-Q), and (c) current injuries exacerbated during the testing activities as determined by a health history screening form. Prior to enrollment in the study, subjects read and completed an informed consent approved by the ASU Office of Research and Integrity.

Design

A correlational study design was used to determine the relationship between physical performance measures on land consisting of a 1-RM weighted pull-up, NCMJ height, and back squat barbell velocity with 45.72-meter freestyle performance. The subjects completed one study visit and were tested in three different groups after the end of their collegiate swim seasons. The subjects completed the 45.72-meter freestyle swim prior to performing the dryland strength and power tests. A 30-minute rest period separated the swimming and dryland tests. The three-dryland tests were assigned in a randomized circuit order. The study allowed two attempts to the subjects for the swim, NCMJ, and back squat barbell velocity tests. The study used the best score of the two attempts for data analysis.

Descriptive Data

The subjects read and completed a demographic and swim training questionnaire developed for the study. The questionnaire identified the subjects' age in years, gender, academic, and athletic year. The questions for swimming experience included average meters swam in a usual practice session in meters per practice and age they began competitive swimming. The questions for dryland training experience included number of years participating in dryland activities and self-estimated 1-RM for a weighted pull-up in kilograms.

45.72-meter freestyle test

A 45.72-meter freestyle swim test was utilized to test sprint swimming ability. The subjects began the swim testing session with a warm-up consisting of a 500-yard freestyle swim at their own pace followed by 4 x 25-yard swims consisting of 12.5-yards of maximum speed and 12.5-yards of slow swimming. The subjects rested 30 seconds between each 25-yard swim. The warm-up ended with subjects taking one practice start off the starting blocks. To measure the swim performance, subjects completed two 45.72-meter sprint performances from the starting blocks. The study timed each swim test using a Daktronic timing system (SD, USA). Following each sprint swim, subjects completed a recovery swim of 300-yards at their own pace. The subjects wore their usual swimsuit used in swim practices; not a textile fabric-racing suit.

1-RM weighted pull-up

A 1-RM weighted pull-up test was utilized to test upper body pulling strength. Prior to performing the 1-RM weighted pull-up, the subjects completed a warm-up consisting of the following: five repetitions using a latissimus pull-down machine (Power-Lift, Iowa, USA) at 80% of their BW, one repetition at 100% of their BW, and one pull-up with their BW only. The subjects started the 1-RM weighted pull-up test at 80% of their self-estimated maximum-weighted 1-RM as identified on the demographic and swim training questionnaire. To complete the 1-RM weighted pull-up test, the subjects incrementally increased the weight by approximately 2.5 kilograms for women and approximately 5 kilograms for men until they were no longer able to perform a pull-up as instructed. A research assistant administered a one-minute rest period between each attempt. To account for differences in BW between subjects, investigators assigned a relative pull-up score for data analysis by using the formula: ((BW + total weight pulled)/BW).

Non-countermovement vertical jump (NCMJ)

A NCMJ was utilized to test lower body power. Prior to performing the NCMJ test, the subjects completed a warm-up consisting of two NCMJs with submaximal effort. The subjects descended to a self-selected depth by flexing their hips and knees. Once they reached their self-selected depth, the subjects paused for one second, counted aloud by a research assistant, before initiating the concentric phase of the jump. The hip and knees remained extended during the duration of the flight phase. The arms remained akimbo, during the duration of the jump. A Just Jump System Jump-Mat (Perform Better, RI, USA) placed under the subjects' feet measured the vertical jump height. The research assistant administered a one-minute rest period between each attempt.

Back squat barbell velocity

A back squat barbell velocity test was utilized to measure lower body strength and power. Prior to performing the squat test, the subjects completed a warm-up consisting of two barbell back squats with submaximal effort. The subjects were required to descend in the squat until their hip crease reached below the top of their knee. The depth of the squat was predetermined with an elastic rope placed in the frontal plane behind the subject. The subjects were required to touch the rope with their buttocks to ensure a standardized squat depth. The weight of the barbell was determined by using half of the subjects' BW in pounds. A Tendo Power Analyzer (Tendo Sports Machines, Trencin, Slovak Republic) was attached to the barbell to measure the average concentric barbell velocity in meters per second. The research assistant administered a one-minute rest period between each attempt.

Statistical Analysis

Means, standard deviations, and proportions were computed for the study variables. Tests for normality of the distribution revealed positive skew for the dryland and swim performance variables. Accordingly, Z-scores were computed for all test variables; the dryland strength and power measure scores were summed to create a combined dryland test score. Pearson product-moment correlation analysis was used to analyze the bivariate correlations between the dryland measures and the 45.72-meter freestyle swimming time in seconds. Correlations were computed by sex and for the combined sample. Statistical significance was set at $p < 0.05$. Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences, Version 24, IBM Corporation, NY, USA)

Results

The male and female subjects had a combined average of 12.4 ± 2.1 years of competitive swimming experience, an average of 6.1 ± 2.6 years of dryland experience, and swam an average of 6222.2 ± 878.2 meters per practice in the previous 6 months. The graphical depiction of the correlations between dryland strength and power measures with sprint freestyle performance for male subjects is presented in Figure 1. The correlations between each individual dryland test and the 45.72-meter freestyle time ranged from r = -0.54 to r = -0.64.

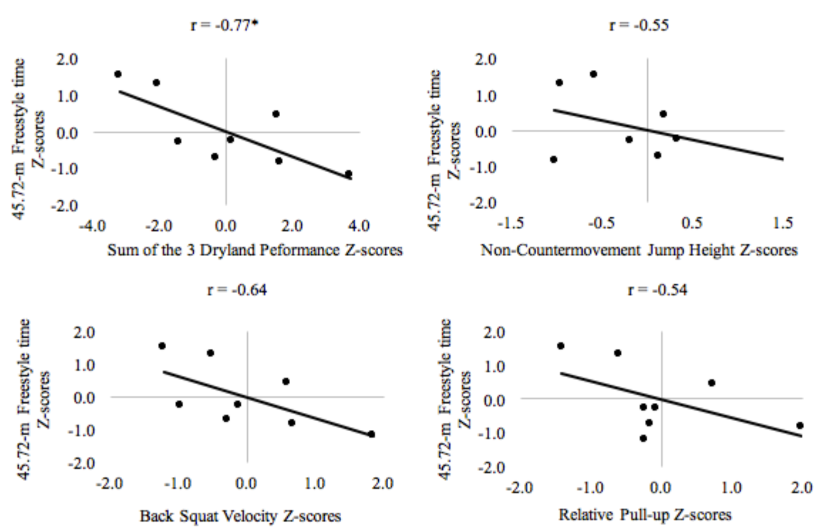

Figure 1. The Pearson correlation coefficients between the Z-score of the dryland scores and the Z-score of the 45.72-meter freestyle time in male subjects. * p < 0.05

The graphical depiction of the correlations between strength and power measures with sprint freestyle performance for female subjects is presented in Figure 2. The correlations between each individual dryland test and 45.72-meter freestyle time ranged from r = -0.66 to r = -0.75 (p < 0.05)

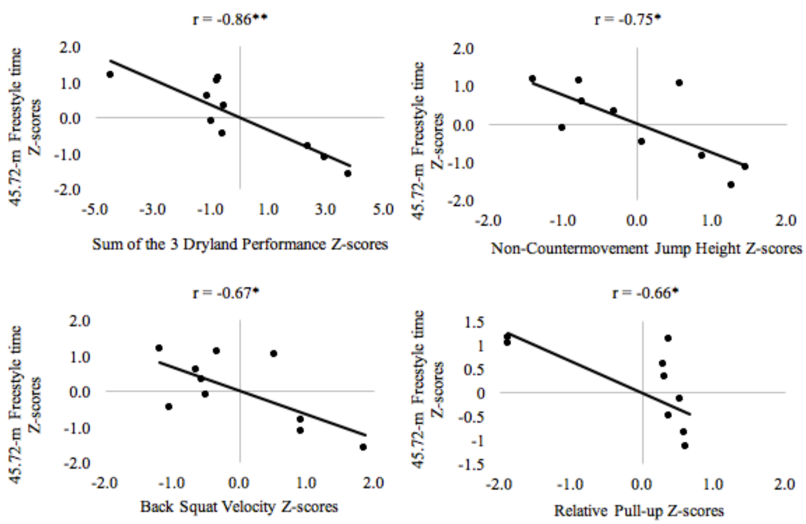

Figure 2. The Pearson correlation coefficients between the Z-score of the dryland scores and the Z-score of the 45.72-meter freestyle in female subjects. * p < 0.05. ** p < 0.01

The graphical depiction of the correlations between the strength and power measures with the sprint freestyle performance in all subjects combined is presented in Figure 3. The correlations between each individual dryland test and 45.72-meter freestyle time ranged from r = -0.61 to r = -0.66 (p < .001).

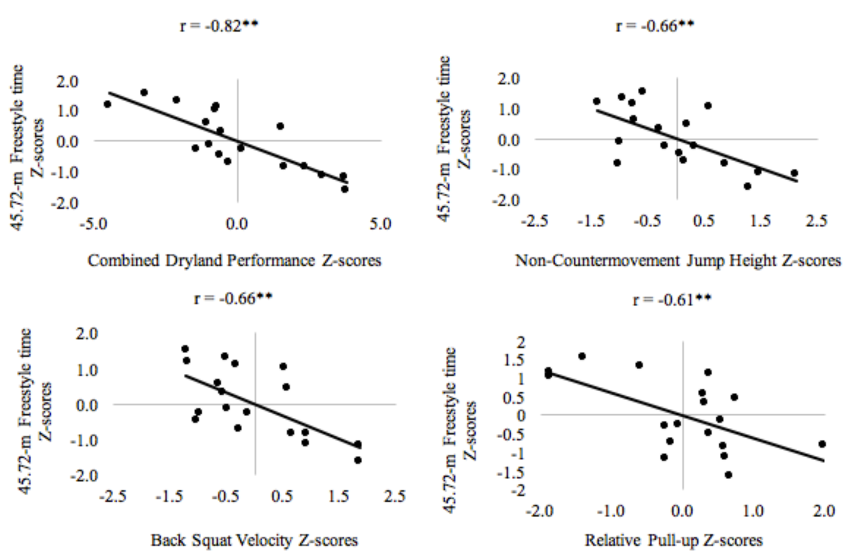

Figure 3. The Pearson correlation coefficients between the Z-score of the dryland scores and the Z-score of the 45.72-meter freestyle in all subjects. ** p < 0.01

Discussion

This study investigated the relationship between strength and power measures with 45.72-meter freestyle swimming performance. The present study found significant relationships between the sum of the dryland performances and swimming performance for both genders and combined as a single sample. The present study also found significant bivariate correlations between each individual dryland test and swimming performance for females ($r = -0.66$ to -0.75, $p < 0.05$), but not for males ($r = -0.54$ to -0.64, $p > 0.05$). The significance of the individual and the combined dryland tests in females may indicate greater variability in the dryland test performances in females as compared with males. It also is possible, that the male results did not reach significance due to the low sample size ($N = 8$).

The significant correlation between the dryland tests and swimming performance in both genders may highlight the importance of possessing both strength and power characteristics to be successful in sprint swimming. These findings are similar to the results of Keiner et al. (10), who found significant correlations between maximal strength measures in the upper body, lower body, and trunk muscles with sprint swimming performance in different strokes ($r = -0.26$ to -0.86, $p < 0.05$) and significant correlations between NCMJ and CMJ heights with sprint swimming performance in different strokes ($r = -0.36$ to $r = -0.94$, $p < 0.05$).

Correlations were lowest between the pull-up and swimming performance in males, females, and the combined sample ($r = -0.54$ to -0.66). This may be explained by the relative importance of maximal force production capabilities as compared with relative strength and power in water. Typically, a human's force capabilities increase as movement velocity decreases, but in an aquatic environment, water resistance increases as velocity of the body relative to the water increases (14). Therefore, during a typical swimming stroke, the muscle will not produce maximal force, suggesting a higher level of maximal strength may not be an asset to swimming performance. For swimmers, once a baseline of maximal strength is established, training power characteristics may become more important than training strength characteristics. Training at faster velocities during pull-ups may play a critical factor in improving swimming performance as seen in Pérez-Olea et al. (12). Additionally, Morouço et al. (11) found the maximal propulsive power during the latissimus pull-down to be associated with 50-meter freestyle velocity ($r = 0.68$, $p < 0.05$), which suggests the importance of both force production and velocity during upper body pulling movements for successful sprint swimming performance.

The correlation between the relative pull-up score and swimming performance was significant in females but not in males. Differences in maximal upper body strength between male and female swimmers may explain this observation. Males may have had sufficient baseline strength levels that did not further maximize swimming performance, while females had not yet reached their maximal strength range.

The relationship between the NCMJ height and swimming performance in females and the combined genders is in agreement with Keiner et al. (10) who found the NCMJ to be correlated with 50-meter swimming performance ($r = -0.82$, $p < 0.05$), in males and females with an average age of 17.5 ± 2.0 years. A higher NCMJ height may contribute to improved start performance as seen in García-Ramos et al. (6) and García-Ramos et al. (7) and with improved turn performance as seen in Cronin et al. (2).

The lack of relationship between the lower body measures and swimming performance in male subjects is surprising considering the start (0-15m) makes up approximately 30% of a 50-meter swim (1). West et al. (13) found significant relationships between CMJ height and 15-meter swimming start times ($r = -0.69$) in male subjects with a mean age of 21.3 ± 1.7 years. Alternatively, Garrido et al. (8), failed to show a relationship between the CMJ and 50-meter freestyle performance in young national-level swimmers with an average age of 12.0 ± 0.56 years. This null relationship may be due to the lack of transfer of lower body power to skillful movements, such as the start and turn. It is also possible that the male subjects in the present study already possessed sufficient strength and power on land that did not further improve swimming performance and they may benefit more from swimming-specific training.

Interestingly, the female subjects exhibited significantly slower back squat velocities than male subjects ($p < 0.05$). These results were unexpected because a load relative to the BW was utilized for the back squat velocity test and gender differences in relative lower body strength has been observed to be minimal in trained swimmers (5). It is also possible that the male subjects in the current study possessed greater leg strength due to their training experience. Although not statistically significant, the male subjects in this study reported higher mean values than females in years of performing dryland activities. Additionally, 50% of the female subjects were freshman, while only 37.5% of male subjects were freshman. This may have influenced the results, as swimmers typically do not begin strength training until their first year of collegiate swimming. Researchers have observed squatting strength to be higher in athletes with greater strength training experience (9). The greater training experience in male subjects may have influenced the results of this study.

The significant relationship between the NCMJ height and back squat velocity with swimming performance in female subjects are similar to the results of García-Ramos et al. (7). García-Ramos et al. (7) found significant correlations between the bar velocity during a NCMJ on a Smith machine with additional resistance and parameters of the NMCJ with swimming start performances in 20 female swimmers. In the present study, it is possible that the female subjects with higher jump heights and faster back squat velocities also displayed faster swim performances due to faster swimming starts.

For swimmers new to strength training or lacking in strength, training strength characteristics instead of power, could be beneficial for improving swimming performance. Garrido et al. (8) studied 28 young national-level swimmers with an average age of 12.0 ± 0.56 years with no strength training experience and observed a significant, inverse relationship between leg strength and 25-meter and 50-meter freestyle swimming performance. They did not observe a similar relationship for the CMJ. Keiner et al. (10), studied 21 regional level swimmers with an average age of 17.5 ± 2.0 years with little strength training experience and observed significant inverse relationships between maximal strength with sprint swimming performance in different strokes and between NCMJ and CMJ heights with sprint swimming performance in different strokes. Collectively, the results of the present study, Garrido et al. (8), and Keiner et al. (10) may explain the importance of training strength characteristics in youth swimmers with no strength training experience, training strength and power characteristics in adolescent swimmers with little strength training experience, and training power characteristics in swimmers with high levels of strength training experience.

Conclusion

Statistically significant, inverse relationships between three measures of strength and power and sprint swimming performance were observed in females but not males. A combination of the three strength and power measures were inversely related with sprint swimming performances in males and females. This suggests that possessing both upper body strength and lower body power might be important for successful sprint swimming performance, especially in females. To enhance performance coaches should monitor their swimmers' strength and power characteristics carefully and develop individual training programs based on their specific strength and power characteristics. Further research is necessary to establish optimal strength and power value norms for swimmers.

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