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

by

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A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved June 2018 by the
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ARIZONA STATE UNIVERSITY

August 2018

ABSTRACT

The purpose of this study was to investigate the relationship between strength and power measures with sprint freestyle performance in Division 1 collegiate swimmers. Ten male subjects with an average age of 20.1 years (*SD* = 2.2) and eight female subjects with an average age of 19.4 years (*SD* = 1.3**)** participated in the study. The subjects performed a maximal-effort 45.72-meter freestyle swim test, a one-repetition-maximum (1-RM) weighted pull-up test, a non-countermovement jump (NCMJ), and a barbell back squat velocity test. The data distributions were normalized by creating Z-scores for each variable measured and the sum of the three-dryland tests The data were analyzed using Pearson product-moment correlation analysis. The results showed an inverse association between the sum of the three-dryland performance Z-scores and the 45.72-meter sprint swim time (r = -0.77, $p < 0.05$) in male subjects. The results showed an inverse association between the sum of the three-dryland performance Z-scores, the relative pull-up Z-scores, the back squat velocity Z-scores, and the NCMJ height Z-scores with the 45.72-meter sprint swim time (r = -0.86, r = -0.66, r = -0.67, r = -0.75; $p < 0.05$) in female subjects. The findings of this study show the importance of possessing both strength and power characteristics on land for successful sprint swimming performance.

ACKNOWLEDGMENTS

I would like to thank my committee chair, Dr. Barbara Ainsworth, for guiding me through my Master's thesis. She provided constructive guidance and taught me lessons that I will take with me for the rest of my career. I would also like to thank my committee members Joe Marsit and Jesse Vezina for the advice they gave me throughout the entire process. Their level of understanding of sports performance training allowed me to view the study from different perspectives. Last, I am very grateful for the entire coaching staff and athletes of the Arizona State University Men's and Women's Swimming Teams for allowing me the opportunity to conduct research on a topic which I am very passionate.

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Chapter 1

INTRODUCTION

Overview

Dryland training is a modality of training completed on land and implemented by most swim coaches and athletes. Some ambiguity exists behind the relationship between different dryland training modalities and swimming performance. A systematic review of strength training and swimming performance concludes, "low-volume, high-velocity/force resistance training programs are optimal" for transfer to swimming performance (Crowley, Harrison, & Lyons, 2017). However, the authors did not identify specific exercises to improve performance.

Several studies have investigated the relationship between sprint swimming performances and squat-jump bar velocity (García-Ramos et al., 2016), pull-up (Pérez-Olea, Valenzuela, Aponte & Izquierdo, 2017) and jumping performances (García-Ramos et al., 2016), but none have studied the combined association of the three-dryland tests and a 50-yard 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. (2016) 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. No studies have investigated the relationship between concentric back squat barbell velocity and sprint swimming performance. In the same study, the authors investigated the relationship between freestyle swimming start performance and the parameters (e.g., peak force and peak power) of a countermovement jump (CMJ) and non-countermovement jump (NCMJ), but did not investigate the height of the jumps. The study found significant relationships between parameters (i.e., relative peak power and take-off velocity) of the CMJ with 5-meter and 10-meter freestyle swimming start performance, but not with the 15-meter swimming start performance. There were significant relationships between parameters (i.e., relative peak power and take-off velocity) of the NCMJ and 5-meter swimming start performance, but not with the 10-meter and 15-meter swimming start performances.

While there is evidence supporting the efficacy of improving the parameters of a NCMJ to improve 5-meter swimming start times, there is a lack of evidence to support the efficacy of improving NCMJ height to improve swimming start performance in Division 1 collegiate swimmers. As of 2018, there are no studies published that investigate the relationship between 1-RM weighted pull-up and sprint swimming performance. With a similar exercise, Pérez-et al. (2017), investigated the relationship between the parameters of one maximum effort BW pull-up (PU) with 50-meter freestyle swimming performance. The parameters of the PU included 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). The authors also investigated several parameters of pull-ups until failure (PUF). The parameters of PUF included number of pull-ups correctly performed (PUFR), mean velocity (PUFV), and mean velocity loss during the first and second half of the test (PUFVL). The study found significant relationships between these exercises and 50-meter freestyle times. While there is evidence supporting the efficacy of increasing the velocity of a single pull-up and velocity of pull-ups until failure to improve sprint swimming performance, 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.

Purpose of Study

The purpose of this study was to investigate the relationship between strength and power measures with sprint freestyle performance in Division 1 collegiate swimmers.

Research Aim

The aim of this study was to contribute to the literature by enhancing the current knowledge of dryland strength training for swimmers. The results of the study may help coaches and athletes make educated decisions about the efficacy of their dryland training programs.

Hypothesis

The first hypothesis stated that there will be an inverse association between the dryland test score and the 50-yard sprint swim time. The second hypothesis stated that there will be an inverse association between the sum of the three-dryland performance Z-scores and the 50-yard sprint swim time. The third hypothesis stated that the associations between dryland test scores and the 50-yard sprint swim time will be stronger in women than in men.

Definition of Terms

Akimbo: A position where the individual's places their hands on their hips with the elbows in a flexed position.

Barbell back squat: An exercise performed with a barbell placed across the trapezius muscles. The individual begins in a standing position and then flexes their knees and hips to descend to a predetermined depth. Upon reaching the predetermined depth, the individual then extends their knees and hips to return to the standing position.

Countermovement Jump (CMJ). An exercise where an individual begins in a standing position and quickly flexes their hips and knees to a self-selected depth. Upon reaching the self-selected depth, the individual immediately extends their knees and hips and plantar flexes their ankles to jump off the ground. The movement is complete when the individual comes back down to the ground with their feet.

Dryland: Any modality of exercise performed on land.

Freestyle: One of the four stroke disciplines in the sport of competitive swimming. The stroke discipline allows individuals to swim in any style. The most common style used is the front crawl.

Non-countermovement Jump (NCMJ). An exercise where an individual begins in a standing position and flexes their hips and knees to descend to a self-selected depth. Upon reaching the self-selected depth, the individual pauses in the squat position for a predetermined amount of time. After the predetermined amount of time has expired, the individual immediately extends their knees and hips and plantar flexes their ankles to jump off the ground. The movement is complete when the individual comes back down to the ground with their feet.

Pull-up: An exercise where an individual begins by hanging with their hands from a bar that is parallel to the floor. The movement starts with the individual's elbows in complete extension. The individuals complete the movement by pulling themselves upward, until their chin reaches above the bar.

Chapter 2

REVIEW OF LITERATURE

Overview

This chapter describes the sport of competitive swimming, the positive and negative studies conducted on strength training and competitive swimming, and correlates of successful performance in competitive swimming.

The Sport of Competitive Swimming

Competitive swimming has been an Olympic sport since the 1896 Athens Olympic Games. The Athens Olympic swim program consisted of four events for men only including the 100-meter freestyle, 500-meter freestyle, and 1200-meter freestyle. The program also included a 100-meter freestyle for Greek sailors only. The 1908 Olympic Games debuted the use of a swimming pool instead of rivers and lakes. In the 1912 Olympic Games, electronic timing in swimming pools was used to time the swim events (Daland, 2009). Today, the sport of competitive swimming has grown to become one of the most popular Olympic sports.

Swimming takes place in a body of water with swimmers competing in lakes, oceans, seas, and swimming pools. The length of the swimming pool used for competition and swim training varies between countries and times of the year. Pool lengths for competitive swimming include 25-yard (short course), 25-meter (short course), and 50-meter distances (long course). Competitive swimming consists of five different stroke disciplines including the butterfly, backstroke, breaststroke, freestyle, and individual medley. For the butterfly, backstroke, and breaststroke, competitive distances include the 50-, 100-, and 200-meter and yard distance races. The individual medley requires a swimmer to swim the butterfly, backstroke, breaststroke, and freestyle in consecutive order. Competitive distances for the individual medley include the 200- and 400-meter races. The freestyle races include the 50-, 100-, 200-, 400-, 800-, and 1500-meter distances. The United States is the only country that implements the 25-yard pool, as well as the 25-meter and 50-meter distances for competition.

Major international swimming competitions include the Short Course World Championships, the Long Course World Championships, and the Olympic Games. The Short and Long Course World Championships take place separately every two years and the Olympic Games takes place every four years.

Collegiate swimming in the United States takes place nationally, most notably, in the National Collegiate Athletic Association (NCAA). According to the NCAA ("Estimated Probability", 2017), 12,356 female and 9,455 male swimmers participated in the 2015-2016 season. The NCAA places college and university swim programs into three divisions. The three divisions have conferences consisting of five-to twelve universities per conference. The collegiate swim season begins in September and concludes in March. Universities and colleges typically finish their swim season with a Conference Championship. Swimmers and their respective teams who swim qualifying times, are eligible to compete at the National Championships typically held in March.

Positive Studies in Strength Training and Competitive Swimming

Five studies have used randomized controlled trials to investigate the effects of dryland strength training on swimming performance. Strass (1986) investigated the effects of a 6-week dryland training protocol on 25- and 50-meter freestyle performance in 10 male competitive swimmers with an average age of 16.6 years ($SD = 1.2$). The author did not indicate if the subjects were randomly assigned to a group. The intervention group performed their swim training program and trained arm extensor muscles using approximately 90% to 100% of their 1-RM and their arm flexor and trunk muscles for four sessions a week (training intensities not reported). The control group performed their swim training program only. The intervention and control groups performed the same swim training program. The independent variable was a six-week strength training program. The dependent variables were a 25- and 50-meter freestyle swimming performances. The author did not specify their method of data analysis. The intervention group improved their 50-meter freestyle mean speed by 2.1 ± 0.4% ($p < 0.001$). The control group showed no significant improvements their swimming speed ($p > 0.05$). The author concluded that the subjects' neuromuscular adaptations to produce maximal explosive force might have been responsible for the improvements in sprint swimming performance.

Girold et al. (2007) used a randomized controlled trial to investigate the effects of a 12-week dryland training program on 50-meter freestyle swimming performance in 21 regional to national level swimmers with an average age of 16.5 years (*SD* = 3.5). The intervention group performed their swim training program and performed dryland training that exercised the upper limbs, core, and lower limbs at 80% to 90% of their maximal load twice a week for 45 minutes each. The control group performed a 90-minute aerobic cycling session twice a week. The independent variable was a 12-week dryland training program. The dependent variable was a 50-meter freestyle swimming performance. The intervention and control group performed the same swim training program. The study analyzed the data using a two-way repeated-measures ANOVA. The results showed a 2.8 ± 2.5% ($p < 0.05$) improvement in 50-meter freestyle swimming performance in the intervention group. The control group showed no significant improvements in swimming performance ($p > 0.05$). The authors concluded that combining strength training and swim training is more efficient at improving 50-meter freestyle performance than swim training alone.

In another study, Girold et al. (2012) used a randomized controlled trial to investigate the effects of a four-week high-intensity dryland training program on 50-meter freestyle swimming performance in national-level swimmers with an average age of 21.8 years (*SD* = 3.9). The intervention group performed their swim training program and trained the pull-up and draw exercise for a maximum of three sets of six repetitions, three sessions a week. The control group performed their swim training program only. The intervention and control groups performed the same swim training program. The independent variable was a four-week high-intensity dryland training program. The dependent variable was a 50-meter freestyle swimming performance. The study analyzed the data using a two-way repeated-measures ANOVA. The results showed a 2.0 ± 1.3% ($p < 0.05$) improvement in 50-meter freestyle swimming performance in the intervention group. The control group showed no significant improvements in swimming performance ($p > 0.05$). The authors concluded that strength training increased muscle strength and swimming stroke length and therefore, implementing strength training into swim training is more efficient for improving 50-meter freestyle performance than swim training alone.

Aspenes et al. (2009) investigated the effects of an 11-week combined strength and endurance-training program on 50-, 100-, and 400-meter freestyle swimming performance in 26 subjects older than the age of 14 years. The authors did not indicate if the subjects were randomly assigned to a group. The intervention group performed strength training to train the upper body musculature and endurance freestyle training in the pool consisting of a 4 x 4 minute high-intensity interval-training program. The control group performed their swim training program only. The independent variable was an 11-week combined strength and endurance-training program. The dependent variable was a 50-, 100-, and 400-meter freestyle swimming performances. The study analyzed the data between and within groups with a Mann-Whitney *U* test and a Wilcoxon matched-pairs signed-ranks test. The study analyzed the correlations with a Spearman rank-difference correlation. The intervention group significantly improved their 400-meter freestyle swimming performance ($p < 0.05$), but not in the 50- and 100-meter freestyle swimming performance ($p > 0.05$). The control group showed no significant improvements in swimming performance ($p > 0.05$). While the study observed improvements in 400-meter swimming performance in the intervention group, the swimming training program between groups were not controlled. Therefore, the effect of strength and endurance training on swimming performance is unclear in this study. The authors concluded that strength training may be important to improve middle-distance swimming.

Trappe and Pearson (1994) used a quasi-randomized trial to investigate the effects of a six-week weight-assisted dryland strength-training program (WAT) versus a free-weight training program (NWAT) on 22.9- and 365.8-meter swimming performances in ten male collegiate swimmers with an average age of 20.1 years ($SD = 1.2$). The WAT group performed dips and pull-ups on a weight-assisted device twice a week for six weeks, while the NWAT group performed latissimus pull-downs, leg extensions and curls on a machine, dumbbell elbow extensions and curls, and bent arm horizontal adductions twice a week for six weeks. The independent variables were a six-week WAT and NWAT program. The dependent variables were a 22.9-meter freestyle and 365.8-meter freestyle swim test performed at the fourth and twelfth week of the study. The results showed a significant improvement in the 22.9-meter freestyle time from week zero to week twelve in the WAT group only ($p < 0.05$). Both groups showed a significant improvement in the 365.8-meter freestyle swim time from week four to week twelve ($p < 0.05$). The study observed no differences between groups in the 22.9-meter or 365.8-meter swim tests ($p > 0.05$). While improvements in swimming performances were observed for both groups, the potential effects of strength training on swimming performance is not clear as the strength training program was conducted from weeks one to six and swim tests were conducted during weeks four and twelve. The authors concluded a weight-assisted dryland strength-training program does not provide an obvious advantage over a traditional free-weight training program.

In summary, Strass (1986), Girold et al. (2007), Girold et al. (2012), and Aspenes et al. (2009) reported improvements in their respective strength measurements following the intervention and concluded improvements in swimming performance may be related to the improvements in strength.

Two studies presented results of systematic reviews of the association between weight training and swimming performance. Aspenes and Karlsen (2012) conducted a systematic review of exercise-training intervention studies in competitive swimming. The review included five publications that studied the effects of dryland strength training on swimming performance. The review included intervention studies with- and without control groups. The researchers did not limit the search to randomized controlled trials due to the limited amount of randomized controlled trials in the literature. The systematic review found strength training of three sets of six repetition maximums in relevant muscle groups to have a large effect size on 50-meter freestyle performance (d = 1.05). The review concluded that heavy strength training (one- to five repetition maximums) might improve swimming performance. However further randomized controlled trials are necessary to study the effects of strength training on swimming performance.

Crowley, et al., (2017) conducted a systematic review of exercise-training intervention studies in competitive swimming. The review included ten publications that studied the effects of traditional weight training using exercises, such as latissimus pull-down, bench press, pull-ups, squats, and other exercises on swimming performance. The authors concluded that performing strength training modalities requiring high force and velocity with low training volumes transfers optimally to improving swimming performance. The authors also concluded that further research is necessary to investigate the effects of long-term strength training on swimming performance. Based on the results, the authors hypothesized that the lower training volumes and higher intensities accumulate less neuromuscular fatigue and greater strength and neuromuscular improvements.

In summary, the systematic reviews highlighted the potential importance of performing strength training with heavy loads, but further research is necessary to provide coaches and athletes with optimal training guidelines.

Negative Studies in Strength Training and Competitive Swimming

This section reviews two controlled trials on strength training interventions that have no effect on swimming performance.

Tanaka et al. (1993) used a quasi-randomized trial to investigate the effects of an eight-week dryland training program on 22.9- and 365.8-meter swim performances in 12 Division 1 collegiate swimmers with an average age of 17 years ($SD = 0.32$). The intervention group performed their swim training program and performed dryland training three days a week, using the triceps dip, chin-up, latissimus pull-down, elbow extensions, and bent arm horizontal adduction exercises for three sets of 8-12 repetitions. The control group performed their swim training program only. The independent variable was an 8-week dryland training program. The dependent variables were 22.9- and 365.9-meter swimming performances. The data were analyzed with a two-way ANOVA with repeated measures. The results showed no significant changes in 22.9-meter and 365.8-meter swim times ($p > 0.05$). The authors concluded that the strength training program had no effect on swimming performance in this sample despite the increase in strength observed in the intervention group. The authors suggested that the results were due to the lack of transfer between strength and swimming performance may be a result of the strength training program not being specific to the complex mechanics of swimming.

Manning et al. (1986) used a single case experimental design to investigate the effects of a nine-week dryland training circuit program on 45.72-, 91.44-, and 182.88-meter freestyle swimming performances in seven male swimmers with an average age of 16.5 years ($SD = 0.81$). The dryland training focused on upper-body, lower-body, and core exercises. The subjects performed the exercises in their circuits at 30-50% of their 1-

RM with maximum velocity for one minute to mimic the duration of their swim races. The study did not include a control group. The independent variable was a nine-week dryland training circuit program. The dependent variables were a 45.72-, 91.44-, and 182.88-meter freestyle swimming performance. The study found no significant improvements in 45.72-, 91.44-, and 182.88-meter swimming times ($p > 0.05$). While the pre and post values of the swimming performance results were not statistically significant, the study observed average improvements of -0.75 seconds, -2.38 seconds, and -5.70 seconds in the 45.72-, 91.44-, and 182.88-meter swimming performances respectively. Therefore, the authors concluded that a high-velocity dryland circuit program might be effective in improving swimming performance.

In summary, the lack of an improvement in swimming performance following strength training as observed by Tanaka et al. (1993) and Manning et al. (1986) may be due the high volume of dryland training. The authors speculated that the strength training could contribute to an increase in muscle-mass, therefore increasing drag and decreasing the BW to force output ratio (Crowley, et al., 2017). Additionally, the high volume of dryland training may have caused an increase in fatigue in the subjects, therefore inhibiting the recovery necessary for improved swimming performance (Crowley, et al., 2017). The lack of improvement in swimming performance following strength training interventions highlights the importance of the specificity of strength training and the potential negative effects of strength training on swimming performance.

Correlates of Successful Performance in Competitive Swimming

Eleven studies have reported an association between physical performance measures such as jump height, leg strength, and upper-body strength performed on land with successful swimming performance.

In 2011, West, Owen, Cunningham, Cook, & Kilduff used a correlational study design to evaluate strength and power tests on the 15-meter swim performance in 11 male British international-level sprint swimmers with an average age of 21.3 years (*SD* = 1.7). The strength and power tests included were a three-repetition maximum (3-RM) squat and the CMJ. The study estimated the subjects' 1-RM squat using the subjects' 3-RM squat test. The CMJ measured the subjects' jump height, peak power, relative power, and rate of force development (RFD). The swim test consisted of a 15-meter swim test where subjects maximally swam a "distance further than 15-meters". A video camera placed perpendicular to the subject's body measured the swim time to 15-meters. Portable force plates attached to the starting blocks measured the subjects' peak vertical force (PVF) and peak horizontal force (PHF). The study analyzed the data using Pearson's product moment correlation. The results showed significant relationships between the 1-RM squat strength, jump height, peak power, and relative power ($r = -0.74$, $r = -0.69$, $r = -0.85$, $r = -0.66$; $p < 0.05$, respectively) and swim time to 15-meters. The 1-RM squat strength was also correlated to jump height ($r = 0.69$), power ($r = 0.78$), PVF ($r = 0.62$), PHF ($r = 0.71$) ($p < 0.05$). There was no relationship between RFD and sprint swimming time to 15-meters ($r = -0.56$, $p > 0.05$). The authors concluded that lower body strength and power is an important factor for improving swimming time to 15-meters in international-level sprint swimmers.

García-Ramos et al. (2016) used a correlational study design to investigate the relationship between the CMJ, NCMJ, squat jump with additional weights, and maximum voluntary isometric contractions (MVIC) during leg flexion and extension with 5-, 10-, and 15-meter swimming start performances in 20 female international-level swimmers with an average age of 15.3 years (*SD* = 1.6). The study measured variables of the NCMJ, CMJ, and NCMJs with additional weights including peak force, peak relative force, peak power, peak relative power, take-off velocity, and peak velocity. The subjects performed NCMJs on a Smith machine with additional resistance equivalent to 25-, 50-, 75-, and 100% of their BW. The study analyzed the data using Pearson's linear correlation coefficients. Correlations were highest between the bar velocity during the NCMJ with additional weight and sprint swimming times. The correlation coefficients ranged from large to very large in the four relative loads and 5-, 10-, and 15- meter distances ($r = -0.57$ to -0.66 at 25% BW; $r = -0.57$ to -0.72 at 50% BW; $r = -0.59$ to -0.68 at 75% BW; $r = -0.50$ to -0.64 at 100% BW, $p < 0.05$). The relative peak power during the CMJ showed a significant relationship with 5-meter and 10-meter swimming start performance ($r = -0.61$, $p < 0.01$; $r = -0.55$, $p < 0.05$, respectively). The take-off velocity during the CMJ showed a significant relationship with the 5-meter and 10-meter swimming start performance ($r = -0.62$, $p < 0.01$; $r = -0.549$, $p < 0.05$, respectively). The relative peak power and take-off velocity during the NCMJ showed a significant relationship with the 5-meter swimming start performance only ($r = -0.57$, $p < 0.01$; $r = -0.56$, $p < 0.05$, respectively). The MVIC during leg flexion and extension did not show a significant relationship with the swimming start performance ($p > 0.05$). The authors concluded that peak velocity reached during a squat jump with external load is a good predictor of the swimming start performance in female international-level swimmers.

Gola, Urbanik, Iwańska, and Madej (2014) used a correlational study design to investigate the relationship between upper and lower extremity strength with 25-meter and 50-meter front crawl swim times. The subjects were 16 physical education university students with a mean competitive swimming career of two years with an average age of 23.0 years (*SD* = 1.2). The strength tests included measurement of torque produced during an isometric contraction in four upper body and four lower body movements. The study analyzed the data using correlation analysis. The results showed a significant relationship between the relative sum of the upper body muscle torque values and swimming velocity in the 25-meter and 50-meter distances ($r = 0.60$, $p = 0.01$; $r = 0.54$, $p = 0.02$, respectively). When upper body and lower body muscle groups were evaluated individually, a significant relationship was found between the relative sum of elbow flexor muscle torque values and swimming velocity in the 25-meter and 50-meter distances ($r = 0.52$, $p = 0.04$; $r = 0.49$, $p = 0.05$, respectively). The relative sum of shoulder extensor muscle torque values had a significant relationship with 25-meter swimming velocity ($r = 0.58$, $p = 0.02$). There were no significant relationships between swimming velocity and muscle torque values in the lower body, shoulder flexor, and elbow extensor muscle groups ($p > 0.05$). The authors concluded that swimmers should train the elbow flexor and shoulder extensor muscle groups to generate a propulsive force during the front crawl-swimming stroke.

Keiner et al. (2015) used a correlational study design to investigate the relationship between maximal strength performance of upper and lower extremities and trunk muscles with swim sprint performances in 21 regional level swimmers with an average age of 17.5 years (*SD* = 2.0). The subjects performed the swim testing in an indoor 25-meter pool. The strength and power tests included a 1-RM back squat, 1-RM deadlift, 1-RM bent over row, 1-RM bench press, 1-RM sit-up, CMJ, and a NCMJ. The swim tests included three different strokes including the freestyle, breaststroke, and backstroke. The freestyle testing included a 15-, 25-, 50-, and 100-meter freestyle. The breaststroke testing included a 15-meter breaststroke with arms only, 25-meter breaststroke kick only, a 25-meter breaststroke with arms only, and a 50- and 100-meter breaststroke. The backstroke test included a 50- and 100-meter backstroke. The study analyzed the data using Pearson's correlation analysis. The 1-RM back squat showed a significant relationship with all 11 swim tests ($r = -0.33$ to $r = -0.76$, $p < 0.05$). The NCMJ showed a significant relationship with all 11 swim tests ($r = -0.36$ to $r = -0.94$, $p < 0.05$). The CMJ showed a significant relationship with all 11 swim tests ($r = -0.37$ to $r = -0.92$, $p < 0.05$). The 1-RM bench press showed a significant relationship with all 11 swim tests ($r = -0.37$ to $r = -0.85$, $p < 0.05$). The 1-RM bent-over row showed a significant relationship with all 11 swim tests ($r = -0.39$ to $r = -0.86$, $p < 0.05$). The 1-RM deadlift showed a significant relationship with all swim tests except the 100-meter backstroke test ($r = -0.51$ to $r = -0.68$, $p < 0.05$). The 1-RM sit-up showed a significant relationship with all swim tests except the 25-meter freestyle and 100-meter backstroke tests ($r = -0.26$ to $r = -0.51$, $p < 0.05$). The authors concluded that maximal strength in the upper and lower extremities and maximal trunk strength are good predictors for sprint swimming in adolescent swimmers in different strokes and distances.

Pérez-Olea et al. (2017) used a correlational study design to investigate the validity of the CMJ and the pull-up exercise as a predictor of swimming performance in young male swimmers with an average age of 19.0 years (*SD* = 3.0). The dryland tests included one BW pull-up with maximal speed during the concentric phase (PU), maximal number of pull-ups until failure (PUF), a CMJ, and the mean height of 30 consecutive CMJs (CMJMH). The study investigated parameters of PU including 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). The study investigated parameters of PUF including number of pull-ups correctly performed (PUFR), mean velocity (PUFV), and mean velocity loss during the first and second half of the test (PUFVL). The study defined parameters of the CMJMH as a relative loss in jump height between the first 15 and last 15 jumps (CMJHL). The swim test consisted of a 50-meter freestyle from the starting blocks. The subjects performed the swim test in a 50-meter swimming pool. The study analyzed the data using Pearson product-moment correlation coefficients. For the PU parameters, PUV, PUAP, PURP, and PURF had significant relationships with 50-meter freestyle times ($r = -0.80$, $r = -0.76$, $r = -0.80$, $r = -0.77$; $p < 0.05$ respectively). The results showed no significant relationship between PUAF, PUPV, and PUTPV and 50-meter freestyle time ($p > 0.05$). For the PUF parameters, PUFV and PUFVL had significant relationships with 50-meter freestyle times ($r = -0.88$, $r = 0.64$; $p < 0.05$ respectively). The results showed no significant relationship between PUFR and 50-meter freestyle time ($p > 0.05$). The results showed no significant relationships between the CMJ tests and 50-meter freestyle ($p > 0.05$). The authors concluded that only the parameters of a single maximal effort pull-up is a good predictor in sprint swimming performance.

Garrido et al. (2010) used a correlational study design to investigate the effects of leg strength and lower body power on swimming performance in 28 young national level swimmers with an average age of 12.0 years (*SD* = 0.56). The leg strength test consisted of a six repetition maximum (6-RM) leg extension test. The lower body power test consisted of a CMJ test. The swim test consisted of a 25- and 50-meter maximal effort swim in an indoor 25-meter pool. The 25- and 50-meter swim tests used an in-water start. The study analyzed the data using Spearman correlation rank coefficients. The results showed a significant relationship between the 6-RM leg extension test and 25- and 50-meter swim test ($\rho = -0.69$, $p < 0.001$; $\rho = -0.62$, $p < 0.01$, respectively). There were no significant relationships between the CMJ test and 25- and 50-meter swim tests ($p > 0.05$). The authors concluded that dryland strength is moderately associated to sprint swimming performance in young national-level swimmers.

Cronin et al. (2007) used a correlational study design to investigate the relationship between three jump tests and tumble-turn velocity in 67 elite male swimmers with an average age of 17.4 years (*SD* = 0.5). The three jump tests included a NCMJ on a modified Smith machine with loads of 20 kilograms (SJ20) and 30 kilograms (SJ30), a countermovement jump with arms akimbo (JHt), and a vertical jump with the use of the arms (VJ). The measures investigated for the jump tests were power in watts and velocity at take-off (VATO) for NCMJ, and jump height for the JHt and VJ. The tumble-turn velocity test consisted of subjects swimming 15-meters into the wall, tumble-turning, and swimming 15-meters in the opposite direction. The measures investigated for the tumble-turn were swimming velocity between two and four meters (V2-4), four and six meters (V4-6), six and eight meters (V6-8), and eight and ten meters (V8-10). The study analyzed the data using Pearson correlation coefficients. The results showed significant relationships between SJ20, SJ30, JHt, VJ, and VATO ($r = 0.29$, $p = 0.01$; $r = 0.36$, $p = 0.00$; $r = 0.40$, $p = 0.00$; $r = 0.33$, $p = 0.00$; $r = 0.38$, $p = 0.00$, respectively) with V2-4. The results showed significant relationships between SJ20, SJ30, JHt, VJ, and VATO ($r = 0.27$, $p = 0.02$; $r = 0.27$, $p = 0.03$; $r = 0.27$, $p = 0.02$; $r = 0.33$, $p = 0.00$; $r = 0.26$, $p = 0.03$, respectively) with V4-6. The results showed no significant relationships between SJ20, SJ30, JHt, VJ, and VATO with tumble-turn velocity at V6-8 and V8-10 ($p > 0.05$). Due to the low-to-moderate correlations, the authors concluded that jumping exercise may improve propulsive forces in the lower body, but training other parameters such as drag reduction and supine jump training in the horizontal plane using an apparatus may provide greater improvements and transfer to swimming turn performance.

García-Ramos et al. (2015) investigated the relationship between NCMJ height on a Smith machine and swimming start performance in 15 male swimmers from the Spanish junior national team with an average age of 17.1 years (*SD* = 0.8). The study implemented a repeated-measures design and the subjects performed the swim and dryland tests before and after a 17-day-high-altitude-training-camp. The subjects completed their normal swim training programs prescribed by their coaches and performed 10 dryland sessions (4 circuit-style training and 6 strength-power training). For lower-limb training, the subjects performed the half-squat (3-4 sets of 6-8 repetitions with 70-90% of BW) with maximal concentric speed and the lunge (3-4 sets of 6-12 repetitions with 30% of BW) with moderate concentric speed. The swimming start performance test consisted of subjects performing a swimming start from the starting blocks and performing only underwater undulatory kicking to a “distance further than 15-

meters". An underwater camera recorded the time to 5-, 10-, and 15-meters. The dryland test consisted of subjects performing NCMJs on a Smith machine with loads equivalent to 0%, 25%, 50%, 75%, and 100%. The study analyzed the swimming start performances using a two-way repeated-measures ANOVA. The study analyzed the relationship between the changes in NCMJ height and swimming start performance using Pearson's product-moment correlation. The two-way repeated-measures ANOVA conducted on swimming start performance revealed significant main effects for test (F [1, 14] = 19.9, p < 0.001, η^2_p= 0.587) and distance (F [1.1, 15.1] = 2800.5, p < 0.001, η^2_p = 0.995). The interaction between test and distance was also significant (F [1.3, 17.9] = 11.2, p = 0.001, η^2_p = 0.444). The percent change in in CMJH at 0% and 50% of BW showed a significant relationship with percent change in swimming performance time to 5-meters (r = -0.53 and r = -0.59, respectively). The percent change in CMJH at 0-, 75-, and 100% of BW showed a significant relationship with percent change in swimming performance time to 10-meters (r = -0.55, $p \leq 0.05$; r = -0.67, and r = -0.63, $p < 0.01$, respectively). The percent change in CMJH at 100% of BW showed a significant relationship with percent change in swimming performance time to 15-meters (r = -0.57, $p \leq 0.05$). The authors concluded that a 2-week altitude training camp may enhance vertical jump height and swimming start ability and that swimmers with a higher unloaded and loaded vertical jump height will have a better start performance.

Morouço et al. (2011) used a correlational study design to investigate the relationship between dryland strength and power measures with swimming performance in ten male national level swimmers with an average age of 14.9 years (*SD* = 0.74). The dryland tests included a CMJ, bench press, squat, and latissimus pull-down. The study estimated maximal height in meters and work in joules for the CMJ. The subjects incrementally increased their weight for the bench press, squat, and latissimus pull-down until their mean propulsive velocity (MPV) got lower than 0.6 $m.s^{-1}$, 0.9 $m.s^{-1}$, and 0.6 $m.s^{-1}$, respectively. The study calculated maximum propulsive power for the bench press, squat, and latissimus pull-down. The swim test included three different 30 second maximal-effort tethered swims, consisting of a whole-body, arms-only, and legs-only tests. The study measured tethered swims in Newtons of force. The subjects also performed a maximal effort 50-meter freestyle on the second day of testing. The study analyzed the data using Spearman correlation coefficients. The results showed significant relationships between work in the CMJ and average swimming force during whole-body and legs-only swimming ($r = 0.75$ and $r = 0.76$, $p = 0.01$, respectively). Maximal propulsive power during the squat showed significant relationships with swimming force during whole-body, arms-only, and legs-only swimming ($r = 0.73$, $p = 0.02$; $r = 0.60$, $p = 0.07$; $r = 0.64$, $p = 0.04$, respectively). Maximal propulsive power during the bench press showed significant relationships with swimming force during whole-body, arms-only, and 50-meter freestyle velocity ($r = 0.65$, $p = 0.04$; $r = 0.73$, $p = 0.02$; $r = 0.60$, $p = 0.07$, respectively). Maximal propulsive power during latissimus pull-down showed significant relationships with swimming force during whole-body, arms-only, and 50-meter freestyle velocity ($r = 0.65$, $p = 0.04$; $r = 0.69$, $p = 0.03$; $r = 0.68$, $p = 0.03$, respectively). The authors concluded that maximal propulsive power during the latissimus pull-down is the most related dryland test to swimming performance.

Hawley et al. (1992) used a correlational study to design to investigate the relationship between lower and upper body power with swimming in 12 male and ten female subjects. The average age of the male subjects was 13.6 years (*SD* = 1.2) and the average age of the female subjects was 13.2 years (*SD* = 1.9). The dryland test included a Wingate Anaerobic Test for the lower body and a maximal sustained power output test for the upper body. The swim testing included a 50-meter and 400-meter freestyle test. The study analyzed the data using Pearson product moment correlations and multiple linear regression analyses. The results showed significant relationships between mean power of the arms ($r = 0.63$, $p < 0.01$) and legs ($r = 0.76$, $p < 0.001$) with 50-meter freestyle swim performance. The results also showed a significant relationship between peak sustained workload of the upper body and 400-meter freestyle swim performance ($p < 0.001$). The authors concluded that significant relationships exist between laboratory measures of muscle power and swimming performance in the 50-meter and 400-meter freestyle.

Sharp et al. (1982) used a correlational study design to investigate the relationship between upper body power and 22.86-meter freestyle performance in 18 males and 22 females. The average age of the male subjects was 15.83 years (*SD* = 0.39) and the average age of the female subjects was 14.73 years (*SD* = 0.33) The study measured maximal arm power and fatigability on a Biokinetic Swim Bench. Data were analyzed using correlation analysis. The results showed a high correlation between arm power and 22.86-meter freestyle velocity ($r = 0.90$). The results showed no statistically significant correlation between fatigability on the Biokinetic Swim Bench ($r = 0.01$) and 22.86-meter freestyle velocity and. The authors concluded that arm power, as defined in the study, might be useful as an objective assessment for successful sprint swimming performance.

This section reviewed 11 studies with varied study designs and subjects to test the effects of dryland strength on swimming performance. Overall the studies, showed positive relationships between dryland strength and swimming performance. Most showed positive relationships in dryland strength parameters that were similar to the swimming performance tested, therefore highlighting the importance of specificity between dryland strength training and swimming performance.

Summary

Studies have shown the importance of measuring and training physical performance measures on land to elicit successful swimming performance. Studying the relationships between multiple physical performance measures allows coaches and athletes to dedicate their training time on variables that impact positively on swimming performance. Studies also have studied absolute upper body strength and lower body power in swimmers. However, no studies evaluated the combined association of upper-body strength and lower-body power on sprint swimming performance in collegiate Division 1 level swimmers.

Chapter 3

METHODS

Introduction

This chapter describes the subject characteristics, study design, description of activities, test procedures, methods to protect subjects from harm, data management, and data analysis.

Subjects

The study recruited members of the Arizona State University (ASU) Swimming Team from the 2017-2018 season. The target sample consisted of 15 healthy men and 15 healthy women aged 18- to 25 years. 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) (Appendix C), and (c) current injuries exacerbated during the testing activities as determined by a health history screening form (Appendix D). Prior to enrollment in the study, subjects read and completed an informed consent (Appendix A) approved by the ASU Office of Research and Integrity. The study recruited subjects through a private social media group page using a recruitment brochure (Appendix B). The subjects received an incentive ($15 Visa gift card) after the completion of all testing activities.

Study Design and Overview of the Study Tests

The purpose of the study was to determine the relationship between physical performance measures on land (dryland testing) consisting of a one-repetition-maximum (1-RM) weighted pull-up, NCMJ height, and back squat barbell velocity with sprint swimming ability (50-yard freestyle). Using a correlational study design, subjects completed one study visit lasting approximately two-to-three hours. The study tested subjects in three groups after the completion of their collegiate swim seasons. Each group included 2-10 subjects.

Description of the Dryland Test Activities. The subjects completed the following three tests to identify lower-body power and upper-body strength used during swimming performance. A description of the tests is located in the procedures section.

1-RM weighted pull-up. The 1-RM weighted pull-up tests upper-body vertical pulling strength. Vertical pulling is a movement that involves moving the upper-arm closer to the torso in the frontal and sagittal plane. Upper-body pulling is a predominant movement used during swimming. Theoretically, the greater weight one is able to pull up, the better the swimming performance. To complete the test, subjects wore a belt to suspend weight-training plates in kilograms from the waist. The subjects began the test by hanging from a bar with their hands while wearing the maximum weight possible with their elbows completely extended. The test was complete when the subject’s chin reached above the pull-up bar. The test was incomplete if the subject generated momentum with the legs, torso, or neck to complete the pull-up. Figure 1 presents an illustration of the exercise.

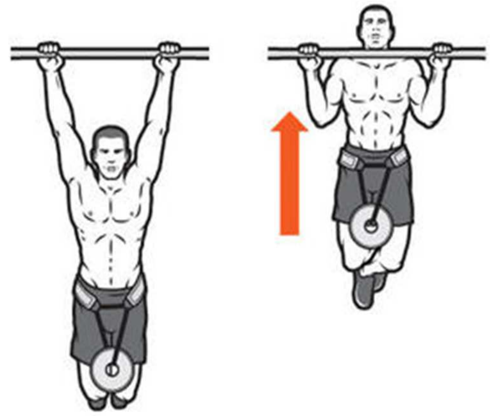

Figure 1. 1-RM Weighted Pull-up

Non-countermovement jump. The NCMJ tests lower body power. Because the sport of swimming contains no plyometric movements, the study used a NCMJ instead of a traditional CMJ, to remove the plyometric response. When a muscle stretches rapidly, a plyometric response occurs, forcing the muscle to contract rapidly. Theoretically, the higher one is able to jump vertically, the better the swimming start off the block. To complete the jump, subjects' placed their arms akimbo by placing their hands on their hips. The subjects' descended to a self-selected depth and paused for one second before initiating the concentric phase of the jump. A jump mat placed under the subjects' feet measured vertical jump height in inches. The jump mat converted the subject's in-flight time into inches. Figure 2 presents an illustration of the exercise.

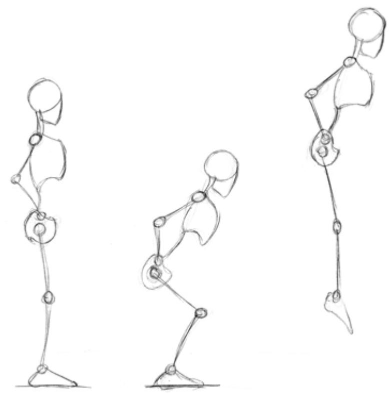

Figure 2. Non-Countermovement Jump

Back squat barbell velocity. Explosive hip and knee extension is required in swimming during the start from the blocks and during the push-off after a flip turn. The squat velocity measures the rate of force development during hip and knee extension. Theoretically, the faster the rate of force development in the lower limbs, the better the swimming start and push-off after a flip turn. To complete the test, subjects performed the barbell back squat. The weight of the barbell was determined by using half of the subjects' BW in pounds. The subjects descended to a standardized depth and ascended as fast as possible. Figure 3 presents an illustration of the exercise.

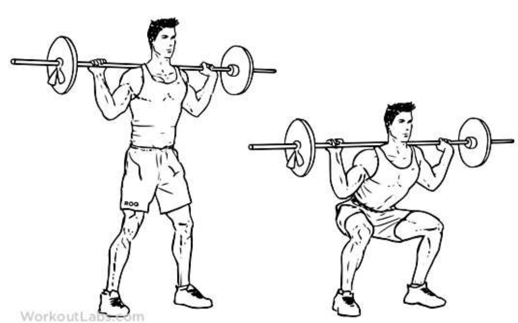

Figure 3. Back Squat

Randomization of Dryland Testing Activities. A randomization schedule for the dryland testing randomly assigned the subjects a testing order, as presented in Table 1.

Table 1

Order of Dryland Testing Sequences

Sequence	Test 1	Test 2	Test 3
1	Squat	Jump	Pull-up
2	Jump	Pull-up	Squat
3	Pull-up	Squat	Jump

Description of the Swim Test. The study utilized a 50-yard freestyle swim to test sprint swimming ability. The test took place in a 25-yard pool. The subjects dove into the pool from a Kiefer Freestyle Starting Block (Kiefer, IL, USA) and swam as fast as possible. The study randomly assigned subjects a testing order for their first and second trial.

Procedures

The study activities took place on the ASU Tempe campus and lasted approximately two-to-three hours. The subjects reported to the Mona Plummer Aquatic Center in their swimwear for pool testing and to the Ed and Nadine Carson Student-Athlete Center for dryland testing. The study procedures operated in the following order:

Informed Consent. The subjects read and completed an informed consent (Appendix A) form developed for this study. All participation was voluntary. The study allowed subjects to withdraw from the study at any time without prejudice to their status on the ASU swim team. The informed consent explained the study purpose, purpose and explanation of the tests, subject risks and discomfort, steps taken to minimize the risks and discomfort, responsibilities of the subject, benefits to be expected, and information about inquiries and confidentiality.

PAR-Q and Health History Screening. The subjects read and completed the PAR-Q (Appendix C) and a health-history screening form (Appendix D) developed for the study. The PAR-Q determined the subjects' readiness for exercise by identifying any adverse health conditions. The health-history screening form determined the subjects' readiness for the swimming, 1-RM pull-up, NCMJ, and back squat barbell velocity tests and ruled out any injuries that may worsen with these activities.

Protection of Subjects from Injury and/or Harm. The study excluded subjects from participation in the study if they answered "yes" to any questions listed on the PAR-Q or health-history screening form or until they received a physician's approval. A Certified Strength and Conditioning Specialist and paid lifeguards on staff at the Mona Plummer Aquatic Center monitored the subjects at all times.

Demographic and Swim Training Data. The subjects read and completed a demographic and swim training questionnaire (Appendix E) developed for the study. The questionnaire identified the subjects' age in years, gender, academic, and athletic year. The questions for swimming experience included stroke and distance specialty, average frequency of training in sessions per week, 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, frequency of pull-ups, squats, and jumping exercises performed in days per week, and estimated 1-RM for a weighted pull-up in kilograms. A Weight Watchers Digital Glass Scale (Model WW401GD, Conair Corporation, CT, USA) measured the subjects' BW in kilograms. A tape measure attached to a wall measured the subjects' height in centimeters.

Swim Testing. 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. The warm-up took approximately 15-minutes. To measure the swim performance, subjects completed two 50-yard 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 did not wear a textile fabric-racing suit used in competition. Instead, they wore a swimsuit worn during their daily swim training that did not extend beyond the hip flexor region. A research assistant recorded each swim time from the timing system onto a paper data collection form developed for this study. The study used the fastest score of the two attempts for data analysis. The swim testing lasted approximately 30 minutes per group of approximately 2-10 subjects.

Dryland Testing. Following the swim testing, subjects reported to the dryland testing center. The subjects performed the three-dryland tests in a randomized circuit order (see Table 1). Based on the randomization schedule, subjects reported to their first testing station to receive instructions on how to perform the practice repetition and complete the test. Following each test, subjects reported to their next test session for a similar procedure until they complete all three tests. The subjects completed a two-minute rest period between each test monitored by the research assistants. Prior to testing at each station, the research assistants described each test to the subjects. The subjects completed two practice repetitions before testing the NCMJ and the back squat barbell velocity test. A research assistant administered a rest period of 30 seconds between each practice repetition. The dryland testing lasted approximately one hour.

One-repetition-maximum weighted pull-up. The subjects completed a warm-up using a latissimus pull-down machine (Power-Lift, Iowa, USA) consisting of five repetitions at 80% of their BW and one repetition at 100% of their BW. The subjects also performed 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 (Appendix E). 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. After completion of the heaviest pull-up, the research assistant recorded the maximum weight in kilograms onto a paper data collection form developed for this study. To account for differences in BW between subjects, investigators a relative pull-up score for data analysis by using the formula: ((BW + total weight pulled)/BW).

Non-countermovement vertical jump. The subjects' feet remained on the jump-mat until initiation of the jump. The arms remained akimbo during the duration of the jump. The subjects descended to a self-selected depth by flexing their hips and knees (eccentric phase). Once they reached their self-selected depth, the subjects paused for one second, before initiating the concentric phase of the jump. A research assistant counted aloud a one-second-pause when the subject reached their self-selected depth. The subjects jumped off the ground after the one-second-pause. The hip and knees remained extended, during the duration of the flight phase. A Just Jump System Jump-Mat (Perform Better, RI, USA) placed under the subjects' feet measured the vertical jump height in inches. A research assistant recorded each attempt onto a paper data collection form developed for this study. The research assistant administered a one-minute rest period between each attempt. The investigators converted to centimeters for data analysis. The study used the highest score of the two attempts for data analysis.

Back squat barbell velocity. 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 approximately 60 centimeters off the ground behind the subject. The subjects were required to touch the rope with their buttocks to ensure a standardized squat depth. A Tendo Power Analyzer (Tendo Sports Machines, Trencin, Slovak Republic) was attached to the barbell to measure barbell velocity in meters per second. A research assistant recorded each attempt onto a paper data collection form developed for this study. The research assistant administered a one-minute rest period between each attempt. A Tendo Power Analyzer (Tendo Sports Machines, Trencin, Slovak Republic) recorded the average concentric barbell velocity in meters per second. The study used the fastest score of the two attempts for data analysis.

Data Management

All data were recorded onto a paper document developed for the study and entered into a password-protected computer. In order to maintain confidentiality, the study de-identified the data by the use of an ID number and the master list linking the name to ID number that was stored separate from the data. The documents were stored in a locked file box during transit from the data collection facilities to the lead investigators office where they were stored in a locked cabinet. Only the lead investigator and co-investigator have access to the documents. The signed consents were stored away from the data in a separate locked cabinet. The data will be stored for one year.

Data Analysis

Data distributions were normalized by creating Z-scores for each variable measured and the sum of the three-dryland tests. Pearson product-moment correlation analysis was used to analyze the bivariate correlations between the Z-scores of the dryland measures and the Z-score of the 50-yard freestyle swimming time in seconds. Correlations were computed by sex (males, females) and for the combined sample. All descriptive statistics were averaged using means and standard deviation. Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences, Version 24, IBM Corporation, NY, USA)

Chapter 4

RESULTS

The purpose of this study was to investigate the relationship between strength and power measures with sprint freestyle swim performance in Division 1 collegiate swimmers. The study sample was recruited from the Arizona State University men's and women's swimming team from the 2017-2018 season. Eight men and ten women volunteered for the study and all subjects fit the inclusion and exclusion criteria. All 18 subjects completed each test.

The subject demographic data for swimming are presented in Table 2. Males and females were similar in age, years in competitive swimming, years performing dryland activities, and average meters swam in the previous six months. As compared with females, males weighed more, were taller, and performed more days of pull-ups, jumping exercises, and back squats per week.

Table 2

Subject Demographics

	Males (N=8)		Female (N=10)		All (N=18)	
	MEAN	SD	MEAN	SD	MEAN	SD
Age (years)	20.1	2.2	19.4	1.3	19.7	1.7
Height (cm)	185.4	7.2	170.3	7.4	177.0	10.5
Weight (kg)	80.8	8.1	65.0	6.9	72.0	10.8
Years in competitive swimming	12.7	3.9	12.1	2.1	12.4	2.1
Years performing dryland activities	7.0	2.7	5.5	2.4	6.1	2.6
Average meters swam in previous 6 months	5875.0	834.5	6500.0	849.8	6222.2	878.2
Frequency of pull-ups performed in last 6 months (days/week)	3.0	0.5	1.5	0.7	2.2	1.0
Frequency of jumping exercises performed in last 6 months (days/week)	2.5	1.7	1.4	0.7	1.9	1.3
Frequency of barbell back squat performed in last 6 months (days/week)	1.6	0.9	1.0	0.0	1.3	0.7

The subject characteristics for swimming experience are presented in Table 3. Most swimmers were 182.88-meter and freestyle specialists. The sample was primarily freshman and most participated in nine swim practice sessions per week.

Table 3

Subject Characteristics for Swimming Experience

	Males (N=8)		Female (N=10)		All (N=18)	
	N	%	N	%	N	%
Distance Specialty (meters)						
45.72	4	50	4	40	8	44.4
91.44	5	62.5	3	30	8	44.4
182.88	2	25	7	70	10	55.6
457.20	2	25	6	60	8	44.4
1508.76	2	25	4	40	6	33.3
Stroke Specialty						
Butterfly	1	12.5	3	30	4	22.2
Backstroke	2	25	2	20	4	22.2
Freestyle	6	75	9	90	15	83.3
Individual medley	2	25	2	20	4	22.2
University Enrollment Status						
Freshman	3	37.5	5	50	8	44.4
Sophomore	3	37.5	3	30	6	33.3
Junior	0	0	2	20	2	11.1
Senior	0	0	0	0	0	0
Graduate	2	25	0	0	2	11.1
Swim Training Sessions/Week						
8	0	0	1	10	1	5.6
9	7	87.5	8	80	15	83.3
10	1	12.5	0	0	1	5.6
10+	0	0	1	10	1	5.6

The swim and dryland performance scores are presented in Table 4. As compared with females, males had faster swim times, higher relative pull-up scores, jumped higher, and had faster back squat velocities.

Table 4

Swim and Dryland Performance Scores

	Males (N=8)		Female (N=10)		All (N=18)	
	MEAN	SD	MEAN	SD	MEAN	SD
50-yard freestyle time (seconds)	21.6	0.8	24.8	0.8	23.4	1.8
NCMJ Height (cm)	53.0	4.0	41.2	7.0	46.5	8.3
Relative Pull-up Score ((BW+Weight Pulled)/BW)	1.3	0.1	0.9	0.5	1.1	0.4
Back Squat Velocity (meters/second)	1.1	0.1	0.9	0.1	0.97	0.2

The graphical depiction of the correlations between dryland strength and power measures with sprint freestyle performance for male subjects is presented in Figure 4. The correlations between each individual dryland test and the 45.72-meter freestyle time ranged from $r = -0.54$ to $r = -0.64$. The only significant correlation observed was between the sum of the three-dryland performance Z-scores and the 45.72-meter freestyle time Z-scores ($p < 0.05$). The remaining correlations were not significant ($p > 0.05$).

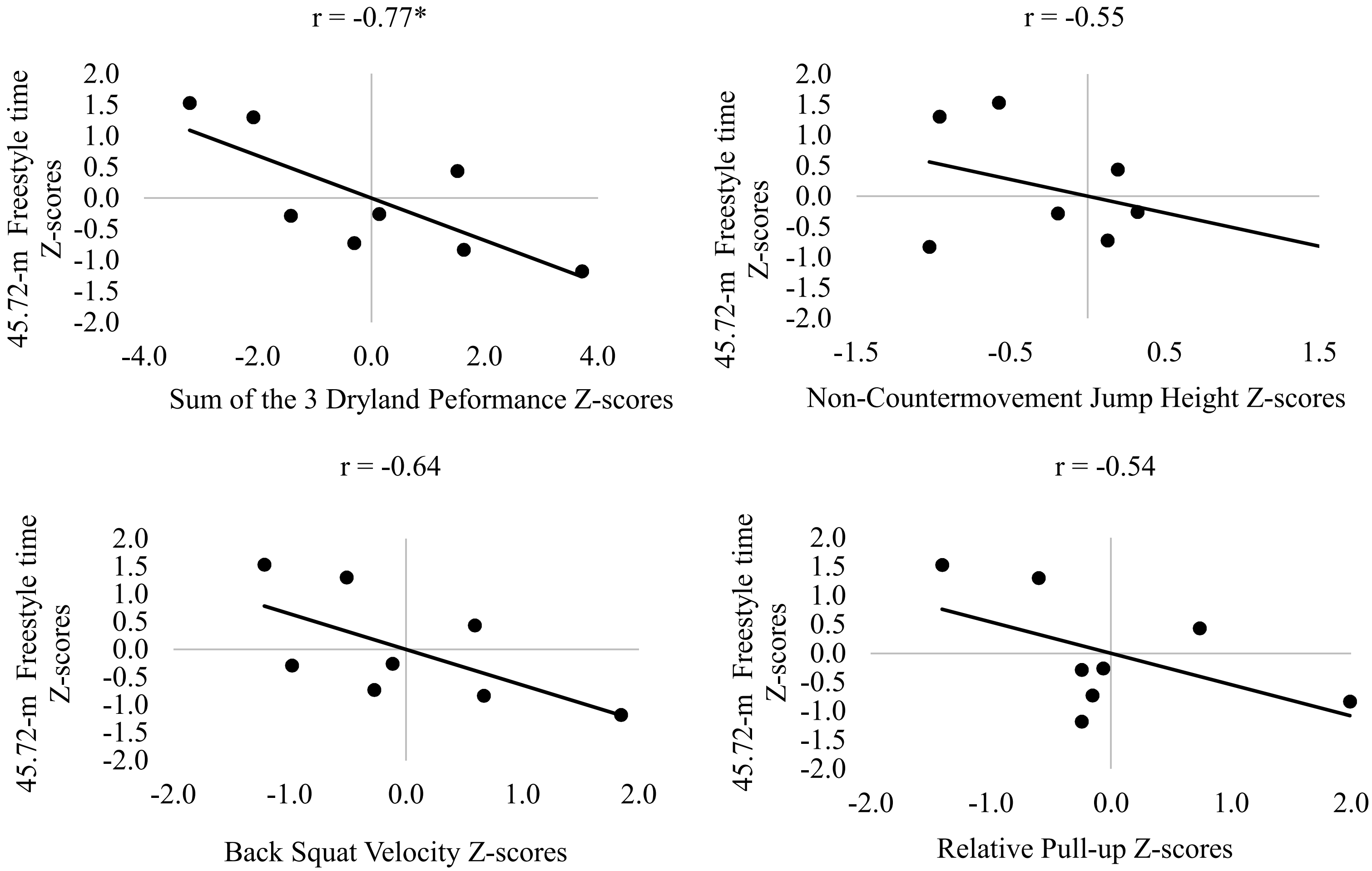

Figure 4. The Pearson correlation coefficients between the Z-score of the dryland scores and the Z-score of the 45.72-meter freestyle time in male subjects. * $p < 0.05$

The graphical depiction of the correlations between strength and power measures with sprint freestyle performance for female subjects is presented in Figure 5. The correlations between each individual dryland test and 45.72-meter freestyle time ranged from $r = -0.66$ to $r = -0.75$. Correlations were significant correlations for the NCMJ height, back squat velocity, relative pull-up scores, and Z-scores of the sum of the three-dryland performances with the 45.72-meter freestyle time Z-scores ($p < 0.05$).

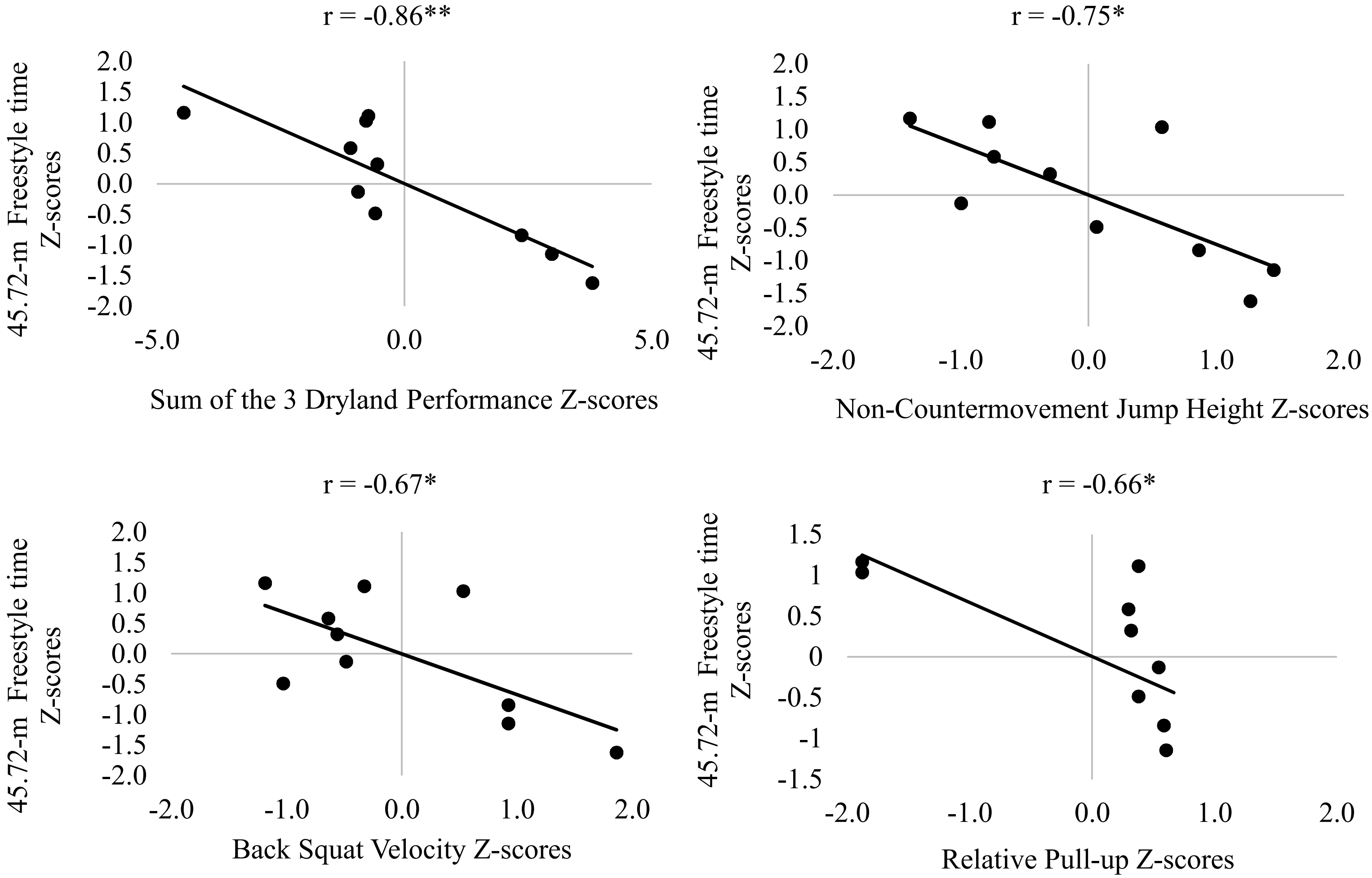

Figure 5. The Pearson correlation coefficients between the Z-score of the dryland scores and the Z-score of the 45.72-meter freestyle time in female swimmers. * $p < 0.05$. ** $p < 0.01$

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 6. The correlations between each individual dryland test and 45.72-meter freestyle time ranged from r = -0.61 to r = -0.66. Correlations were significant correlations for the NCMJ height, back squat velocity, relative pull-up scores, and Z-scores of the sum of the three-dryland performances with the 45.72-meter freestyle time Z-scores ($p < 0.05$).

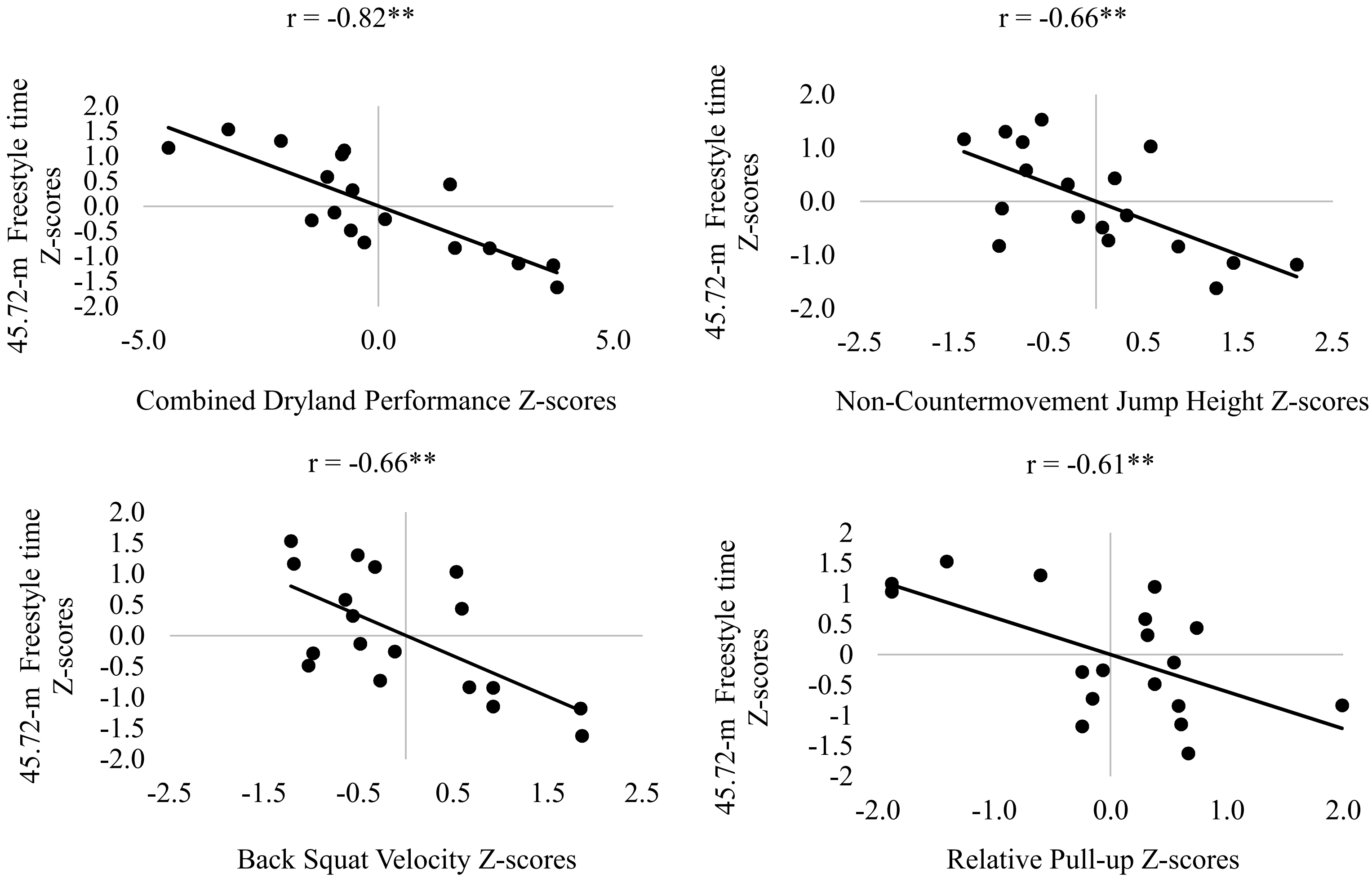

Figure 6. The Pearson correlation coefficients between the Z-score of the dryland scores and the Z-score of the 45.72-meter freestyle time in all swimmers. ** $p < 0.01$

Chapter 5

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 Z-score of 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 no significant correlations for males (r = -0.54 to -0.64, $p > 0.05$). It is possible, that the male results did not reach significance due to the low sample size (N = 8).

The significant correlation between the Z-score of the sum of the dryland performances 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. (2015), 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) and significant correlations between NCMJ and CMJ heights with sprint swimming performance in different strokes (r = -0.36 to r = -0.94).

Males, females, and the combined sample showed the lowest correlation between pull-up score and swimming performance. It is possible that maximal upper-body pulling strength is not as important as other strength and power measures due to the properties of water. In an aquatic environment, water resistance increases as velocity of the body relative to the water increases (Zatsiorsky and Kraemer, 2006). During a typical swimming stroke, the muscle does not produce maximal force (Zatsiorsky and Kraemer, 2006), therefore a higher level of maximal strength may not be an asset to swimming performance as there is an optimum range. Because the correlation between the relative pull-up score and swimming performance for male subjects was not significant, training faster velocities during pull-ups may play a critical factor in improving swimming performance (Pérez-Olea et al., 2017). Pérez-Olea et al. (2017) found the velocity of a BW pull-up to be a good predictor of sprint swimming performance. Additionally, Morouço et al. (2011) found the maximal propulsive power during the latissimus pull-down to be associated with 50-meter freestyle velocity (r = 0.68), which suggests the importance of both force production and velocity during upper-body pulling movements.

For swimmers, once a baseline of maximal strength is established, training power characteristics may become more important than training strength characteristics for swimming performance. The discrepancy in maximal upper body strength between the male and female subjects may explain why the pull-up score reached significance for the female subjects and not for the male subjects. It is possible that the male subjects reached baseline strength levels that did not additionally maximize swimming performance, while the female subjects had not yet reached their maximal strength range. The gender differences in pull-up scores from this study also illustrate the importance of working on the technical and physiological aspects of the swimming stroke, once one reaches certain levels of strength. Further research will clarify the relationship between maximal pull-up strength and BW pull-up velocity with swimming performance to identify optimal training objectives for swimmers.

The correlation between the NCMJ height and swimming performance for the combined genders is in agreement with Keiner et al. (2015) who found the NCMJ to be correlated with 50-meter swimming performance (r = -0.82), males and females with an average age of 17.5 years (SD = 2.0). A higher NCMJ height may contribute to improved start performance as seen in García-Ramos et al. (2015) and García-Ramos et al. (2016) and with improved turn performance as seen in Cronin et al. (2007).

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 (Bishop et al., 2013). In contrast, West et al. (2011) found significant relationships between CMJ height and 15-meter swimming start times (r = -0.69) in male subjects with a similar age (M = 21.3, SD = 1.7). The lack of relationship between the NCMJ and swimming performance in male subjects is similar to the results of Garrido et al. (2010), who found no significant relationships between CMJ and 50-meter freestyle performance in young national-level swimmers with an average age of 12.0 years (SD = 0.56). 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

(Cureton & Collins, 2007). It is also possible that the male subjects in the current study possessed greater leg strength due to their training experience. Researchers have observed squatting strength to be higher in athletes with greater strength training experience (Izquierdo, Häkkinen, Gonzalez-Badillo, Ibáñez, & Gorostiaga, 2002). Although not statistically significant, the male subjects in this study reported higher mean values than females in years of performing dryland activities and the frequency of jumping exercises and back squats performed per week. 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. 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. (2016). García-Ramos et al. (2016) found significant correlations between the bar velocity during a NCMJ on a Smith machine with additional resistance equivalent to 25-, 50-, 75-, and 100% of their BW and parameters of the NMCJ with swimming start performances (5-, 10-, 15-meters) 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. (2010) studied 28 young national-level swimmers with an average age of 12.0 years (*SD* = 0.56) 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. (2015), studied 21 regional level swimmers with an average age of 17.5 years (*SD* = 2.0) 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. (2010), and Keiner et al. (2015) may explain the importance of training strength characteristics in youth swimmers with no strength training experience, training strength and power characteristics in teenage swimmers (age 17-19 years) with little strength training experience, and training power characteristics in swimmers with high levels of strength training experience.

Study Limitations

This study had four limitations that may have influenced the results. First, the small sample size may have caused a type 2 error in the male subjects (N = 8) that obscured significant relationships. Second, the study characteristics differed between male subjects and female subjects. The male subjects reported having more dryland training experience than the females. Additionally, 25% of male subjects were 457.2-meter specialists, while 60% of female subjects were 457.2-meter specialists. Short- and long distance swimmers have different muscle fiber type compositions and leg strength and power values (Gerard, Caiozzo, Rubin, Prietto, & Davidson, 1986) which may have influenced the results. Third, the study sample consisted of only one swim team. Additional studies should attempt to reproduce the results in teams with different training methodologies and swim skills. Fourth, there were two outliers in the female's 1-RM weighted pull-up test. Two female subjects were unable to do a weighted pull-up, thus giving them a score of 0 kilograms. This may have influenced the correlation between relative pull-up score and swimming performance in female subjects. Future studies should investigate the relationship between strength and power measures with swimming performance in larger samples with varied strength and swimming abilities.

Practical Application

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 to optimize the swimmers performance. Once optimal strength and power characteristics are developed, swimming specific training should become the priority over dryland training. In conclusion, further research can establish optimal strength and power value norms for swimmers. Coaches also should assess swimmers individually and develop training program based on their specific strength and power characteristics.

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APPENDIX A
INFORMED CONSENT FORM

ID#______
Date ______

Strength, Power, and Swimming Study

CONSENT FORM

INTRODUCTION
The purpose of this form is to reveal information regarding your participation as a research subject. The information provided may affect your decision to participate in the study.

RESEARCHERS
Barbara Ainsworth Ph.D. (Professor, ASU) and Sean Kao (Graduate Student, ASU) have invited your participation in a Master's thesis research study.

STUDY PURPOSE
The purpose of this study is to study the relationship between strength and power measures with sprint freestyle performance in Division 1 collegiate swimmers.

PURPOSE AND EXPLANATION OF THE TEST
If you decide to participate, then you will join a study involving research of the relationship between lower body power and upper body strength with sprint freestyle swimming performance in Division 1 collegiate swimmers. One visit of approximately two-to-three hours will be required.

As an incentive for participation, you will receive a $15 Visa gift card upon completion of the study. You must be ages 18-25 to participate.

Activities performed during the visit will consist of the following in this order.

1. Read and sign informed consent form.

2. Complete the 2017 PAR-Q and health screen questionnaire to determine eligibility for the study.

3. Complete demographic information form.

4. Have your height and weight measured. Your weight will be measured with a digital glass scale. Your height will be measured with a tape measure taped against the wall.

5. *Swim a 50-yard freestyle test*

A 50-yard freestyle will be used to test your sprint swimming ability. You will dive into the pool and swim as fast as possible. The swim will take place in a 25-yard pool. You will be required to dive from the starting blocks, sprint 25-yards, flip turn, then sprint another 25-yards. You will be randomly assigned a testing order for your first and second trial. The faster of the two trials will be used for data entry.

6. *Perform 3 dryland strength tests*

You will complete three dryland tests in a randomized order

1RM weighted pull-up: This tests upper body vertical pulling strength related to pulling the body through the water in swim strokes. Prior to the test you will warm-up by performing five repetitions on a latissimi dorsi pull-down machine. To complete the test, you will wear a belt to suspend kilogram weight training plates from the waist. You will begin by hanging from a bar with your hands while wearing a weight with

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Date ______

80% of your self-estimated 1 repetition maximum pull-up weight; your elbows will be completely extended. The test will be deemed complete when your chin reaches above the pull-up bar and incomplete if you generate momentum with the legs, torso, or neck to complete the pull-up. You will incrementally increase the weight, starting at 80% of your 1 repetition maximum, until you are no longer able to complete a pull-up with proper technique. The maximum weight completed with proper technique will be used for data analysis.

Non-countermovement vertical jump: This tests lower your body power needed for pushing off the blocks. Because the sport of swimming contains no plyometric movements (creating repeated maximum force in short intervals of time), the non-countermovement vertical jump will be used instead of a traditional countermovement jump to remove the plyometric response. A countermovement jump is a jump where the eccentric phase (bending your knees in a squat position) is followed immediately by the concentric phase (leaping into the air as high as you can go). To complete the jump, you will place your hands on your hips with hips and knees extended and descend to a self-selected depth and pause for one second before initiating the concentric phase of the jump. You will perform two jumps with a one-minute rest period between each jump. The highest jump of the two will be used for data analysis.

Barbell back squat velocity test: This test measures your lower body power needed for pushing off the starting blocks. The squat velocity tests measures your rate of force development during hip and knee extension. To complete the test, you will place a barbell on your shoulders (trapezius muscle). The weight of the barbell will be half of your body weight. You will descend in a squat to a standardized depth and raise up as fast as possible. You will perform two squats with a one-minute rest period between each jump. The fastest squat of the two will be used for data analysis.

PARTICIPANT RISKS AND DISCOMFORT

A. 50-yard freestyle test
You may feel an increase in heart rate and blood pressure. The test may feel strenuous to you and you may feel some fatigue or exhaustion. There is the remote chance that you may sustain a muscle strain or joint injury, however the likelihood of this happening is very low. To reduce the risks you can stretch your muscles as needed before moving. You will warm-up with a 500-yard freestyle swim at your own pace followed by 4 x 25 yard swims consisting of 12.5 yards of maximum speed and 12.5 yards of slow swimming. You will rest 30 seconds between each 25-yard swim. The warm-up will end with you taking one practice start off the starting blocks. The warm-up will take an approximate 15 minutes. You also will have at least 5 minutes to rest between swim trials.

B. 1 repetition maximum weighted pull-up test
You may feel an increase in heart rate and blood pressure. You may feel some discomfort around the lower back and hands from the weight-belt and pull-up bar, respectively. The test may feel strenuous to you and you may feel fatigue or exhaustion. There is the remote chance that you may sustain a muscle strain or joint injury, however the likelihood of this happening is very low. To reduce the risks you can stretch your muscles as needed before movement. You will warm up on a on a latissimus dorsi pull-down machine by performing 5 repetitions at 80% of your BW and 1 repetition at 100% of your BW. You will have a 30-second rest period between each practice repetition. You also will rest for 1 minute between trials and have 30 seconds to one minute of rest between trials. You can take rest breaks as needed.

ID#______
Date ______

C. Non-countermovement jump
You may feel an increase in heart rate and blood pressure. The test may feel strenuous to you and you may feel fatigue or exhaustion. There is the remote chance that you may sustain a muscle strain or joint injury, however the likelihood of this happening is very low. To reduce these risks you can stretch your muscles as needed. You will warm-up for each test by taking two practice repetitions. You also will rest for 30 seconds between each test and you can take rest breaks as needed.

D. Back squat barbell velocity
You may feel an increase in heart rate and blood pressure. You may feel some pressure around the trapezius muscle from the barbell. The test may feel strenuous to you and you may feel fatigue or exhaustion. There is the remote chance that you may sustain a muscle strain or joint injury, however the likelihood of this happening is very low. To reduce these risks, you can stretch your muscles as needed. You will warm-up by taking two practice repetitions. You will rest for 30 seconds between each test and you can take rest breaks as needed.

RESPONSIBILITIES OF THE PARTICIPANT
You should disclose all previous medical history and health status. Any information not disclosed may affect your safety during the test. You should also report any pain or discomforts during the test.

BENEFITS TO BE EXPECTED
You will not physically benefit from participating in the study, but results from the tests will allow sports performance coaches to tailor their training programs for start and swimming performance.

INQUIRIES
Any questions about procedures or test results are encouraged and should be directed to Dr. Barbara Ainsworth (602-827-2291; Barbara.ainsworth@asu.edu) or Sean Kao (909-753-6499; kao_sean@yahoo.com). If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

CONFIDENTIALITY
Any results obtained from the testing will remain confidential. Test results are not to be released to any individual except the lead investigator and co-investigator. Information obtained may be used for statistical and scientific purpose with your right to privacy retained. In order to maintain confidentiality, a numerical code will be administered to each participant (i.e., 1, 2, 3). Data will be recorded onto a paper document developed for the study and entered into a password protected computer. The documents will be stored in a locked file box during transit from the data collection facilities to the lead investigators office where they will be stored in a locked cabinet. Only the lead investigator and co-investigator will have access to the documents.

I hereby consent to voluntarily have my measurements taken to better understand my strength, power, and swimming performance. I understand that I may stop the test at any point if I so desire. I have read this form, and I understand the test procedures and attendant risks and discomforts. I consent to participate in this test.

ID#______
Date ______

Date____________________

Signature of Participant____

Date____________________

Signature of Investigator ____

INVESTIGATOR'S STATEMENT
"I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the subject/participant a copy of this signed consent document."

APPENDIX B
RECRUITMENT FORM

ASU Swimmers Needed For a Study of Strength, Power, and Sprint Swimming

PARTICIPATION IS VOLUNTARY

Members of the ASU men's and women's swim team are needed to investigate the relationship between strength and power dryland measurements and swimming performance. Volunteers will complete three dryland tests (1-repetition maximum weighted pull-up, vertical jump, and squat velocity) and two 50-yard freestyle tests.

Study activities will occur in the ASU Mona Plummer Aquatic Center and Ed and Nadine Student Athlete Center. The study will require one visit lasting 2-3 hours. Volunteers will receive a $15 Visa gift card upon the completion of the study.

ELIGIBILITY CRITERIA

- Member of the ASU Swim Team from the 2017-2018 season
- Healthy men and women aged 18-25 years
- Must have no current injuries
- Must have six months of resistance training experience
- Not listed as a breaststroke specialist or breaststroke hybrid specialist on the roster

If interested, please contact Sean Kao:
(909)753-6499 kao_sean@yahoo.com

ASU IRB IRB # STUDY00007831 | Approval Period 3/1/2018 – 2/28/2019

APPENDIX C
PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

ID ____
Date ________

2017 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐ ?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ____________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

OSHF

01-01-2017

2017 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1.	**Do you have Arthritis, Osteoporosis, or Back Problems?** If the above condition(s) is/are present, answer questions 1a-1c	If **NO** ☐ go to question 2
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2.	**Do you currently have Cancer of any kind?** If the above condition(s) is/are present, answer questions 2a-2b	If **NO** ☐ go to question 3
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3.	**Do you have a Heart or Cardiovascular Condition?** *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm* If the above condition(s) is/are present, answer questions 3a-3d	If **NO** ☐ go to question 4
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4.	**Do you have High Blood Pressure?** If the above condition(s) is/are present, answer questions 4a-4b	If **NO** ☐ go to question 5
4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5.	**Do you have any Metabolic Conditions?** *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes* If the above condition(s) is/are present, answer questions 5a-5e	If **NO** ☐ go to question 6
5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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01-01-2017

2017 PAR-Q+

6.	**Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*	
	If the above condition(s) is/are present, answer questions 6a-6b	If **NO** ☐ go to question 7
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐
7.	**Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*	
	If the above condition(s) is/are present, answer questions 7a-7d	If **NO** ☐ go to question 8
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐
8.	**Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*	
	If the above condition(s) is/are present, answer questions 8a-8c	If **NO** ☐ go to question 9
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐
9.	**Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*	
	If the above condition(s) is/are present, answer questions 9a-9c	If **NO** ☐ go to question 10
9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐
10.	**Do you have any other medical condition not listed above or do you have two or more medical conditions?**	
	If you have other medical conditions, answer questions 10a-10c	If **NO** ☐ read the Page 4 recommendations
10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ____________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

OSHF

2017 PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+

Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.
3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

APPENDIX D

HEALTH HISTORY SCREENING FORM

ID# ____
Date ________

Strength, Power, and Swimming Study

HEALTH HISTORY SCREENING FORM

INSTRUCTIONS: This questionnaire asks about injuries or illness you may have that can affect your ability to participate in this study. The questionnaire must be filled out prior to your testing session. All information will be kept confidential. Please take your time and complete it carefully and thoroughly, and then review it to be certain you have not left anything out. Your answers will help us determine your state of readiness for exercise.

DIRECTIONS: Insert a number in the provided space that best represents your answer. If you have any questions, please ask Sean Kao, study leader, for clarification.

SSPTHH01 ______ 1. What is your gender?
(1) Male
(2) Female

Do you have a current injury or illness that keeps you from doing…

SSPTHH02 ______ 2. Any physical activity
(1) Yes → Specify ___________________________________
(2) No

SSPTHH03 ______ 3. Sprint swimming with maximal effort
(1) Yes → Specify ___________________________________
(2) No

SSPTHH04 ______ 4. Weighted pull-ups
(1) Yes → Specify ___________________________________
(2) No

SSPTHH05 ______ 5. Jumping exercises
(1) Yes → Specify ___________________________________
(2) No

SSPTHH06 ______ 6. Barbell back squat
(1) Yes → Specify ___________________________________
(2) No

Page 1 of 2

ID# ____
Date ________

Do you have any other health condition that may affect your ability to participate? If yes, please list in the space below.

____

APPENDIX E

DEMOGRAPHIC AND SWIM TRAINING QUESTIONNAIRE

ID#______
Date ________

Strength, Power, and Swimming Study

DEMOGRAPHIC and SWIM TRAINING QUESTIONNAIRE

SSPTDEM01 1. ________What is your age (years)?

SSPTDEM02 2. What is your gender? (Check one)

1. [ ] Male
2. [ ] Female

SSPTDEM03 3. What is your academic year? (Check one)

1. [ ] Freshman
2. [ ] Sophomore
3. [ ] Junior
4. [ ] Senior
5. [ ] Graduate

SSPTDEM04 4. What is your athletic year? (Check one)

1. [ ] Freshman
2. [ ] Sophomore
3. [ ] Junior
4. [ ] Senior
5. [ ] Graduate

SSPTDEM05 5. What is your stroke specialty? (Check all that apply)

1. [ ] Butterfly
2. [ ] Backstroke
3. [ ] Breaststroke
4. [ ] Freestyle
5. [ ] Individual Medley

Page 1 of 2

ID#______
Date _________

SSPTDEM06 6. What race distance is your specialty? (Check all that apply)

1. [ ] 50-yard
2. [ ] 100-yard
3. [ ] 200-yard
4. [ ] 500-yard
5. [ ] 1650-yard

SSPTDEM07 7. What is your average frequency of training in **sessions/week** in the last 6 months? (Check one)

1. [ ] 1-2 sessions
2. [ ] 3-4 sessions
3. [ ] 5 sessions
4. [ ] 6 sessions
5. [ ] 7 sessions
6. [ ] 8 sessions
7. [ ] 9 sessions
8. [ ] 10 sessions
9. [ ] More than 10

INSERT ONE NUMBER IN BLANK SPACE FOR NEXT QUESTIONS

SSPTDEM08 8. _______ What is the average **METERS you swam in practice** during the last 6 months?

SSPTDEM09 9. _______ How many **YEARS** have you been participating in competitive swimming?

SSPTDEM10 10. ______ At what **AGE** did you begin competitive swimming?

SSPTDEM11 11. ______ How many **YEARS** have you been participating in dryland activities defined as any extracurricular exercise on land)?

SSPTDEM12 12. ______ How many **DAYS PER WEEK** have you performed pull-ups in the past 6 months?

SSPTDEM13 13. ______ How many **DAYS PER WEEK** have you performed jumping exercises in the past 6 months?

SSPTDEM14 14. ______ How many **DAYS PER WEEK** have you performed the barbell back squat exercise in the past 6 months?

SSPTDEM15 15. ______ What is your self-estimated 1-repetition maximum weighted pull-up (maximum weight you can pull for one weight; not including body weight)? **Report in pounds or kilograms.**

APPENDIX F

DATA COLLECTION FORM

ID#________
Date ________

Strength, Power, and Swimming Study

DATA COLLECTION FORM

SSPTWTKG	_________ (kg)	(station tester's name _______________)
SSPTHTCM	_________ (cm)	

50-yard freestyle		(station tester's name _______________)
SSPTSWBEST	_________ (sec.)	
SPPTSWT1	_________ (sec.)	
SPPTSWT2	_________ (sec.)	

1RM Weighted Pull-up		(station tester's name _______________)
SSPTPUKG	_________ (kg)	_______BW (kg) _______Estimated 1RM Pull-up _______80% Estimated 1RM Pull-up

Non-Countermovement Jump		(station tester's name _______________)
SSPTJPBEST	_________ (in.)	
SPPTJPT1	_________ (in.)	
SPPTJPT2	_________ (in.)	

Back Squat Velocity		(station tester's name _______________)
SSPTSQBEST	_________ (m/s)	
SPPTSQT1	_________ (m/s)	
SPPTSQT2	_________ (m/s)	

Page 1 of 1

APPENDIX G

PERMISSION TO USE THE MONA PLUMMER AQUATIC CENTER

From:	Gregory Werner
To:	Barbara Ainsworth
Cc:	Sean Kao
Subject:	RE: fee for timing pad for Sean Kao research
Date:	Tuesday, February 27, 2018 11:32:05 AM

Barb:

Sean has our permission to conduct his thesis research at the Mona Plummer Aquatic Center.

Thanks,

Greg

Greg Werner
Aquatics Manager
Mona Plummer Aquatic Center
Arizona State University
480-965-4047 (W)
740-707-6271 (C)
Greg.Werner@asu.edu

From: Barbara Ainsworth
Sent: Monday, February 26, 2018 4:12 PM
To: Gregory Werner <Greg.Werner@asu.edu>
Cc: Sean Kao <kao_sean@yahoo.com>
Subject: Re: fee for timing pad for Sean Kao research

Excellent Greg . Thanks.

Will you send me an e-mail that gives Sean Kao permission to collect his thesis data in the pool? The IRB requires we have permission from you written in an e-mail.

Thanks.

Barb

Barb Ainsworth
Phone (480) 208-5877
E-mail: barbara.ainsworth@asu.edu
Sent from my iPhone

On Feb 26, 2018, at 2:58 PM, Gregory Werner <Greg.Werner@asu.edu> wrote:

APPENDIX H

PERMISSION TO USE THE ED AND NADINE CARSON

STUDENT-ATHLETE CENTER

From:	Sean Kao
To:	Barbara Ainsworth
Subject:	Fw: Request to use the Ed and Nadine Carson Student Athlete Center
Date:	Monday, February 26, 2018 4:22:04 PM

Dr. Ainsworth,

This email is from Gavin Walker granting permission to use the Ed and Nadine Carson Student Athlete Center. He works as a sports performance coach and works with the swim team.

Get organized with Yahoo Mail

> ----- Forwarded Message -----
> **From:** "Gavin Walker" <gwalker4@asu.edu>
> **To:** "Sean Kao" <kao_sean@yahoo.com>
> **Sent:** Mon, Feb 26, 2018 at 3:39 PM
> **Subject:** Re: Request to use the Ed and Nadine Carson Student Athlete Center
> Sean,
>
> Good to go for the study here in our facility. Let me know how I can help.
>
> Thanks!
>
> **Gavin Walker, M. ED., CSCS**
> **Assistant Coach Sports Performance**
> **Arizona State University**
>
> On Mon, Feb 26, 2018 at 3:15 PM, Sean Kao <kao_sean@yahoo.com> wrote:
>
> > Hi Gavin,
> >
> > I am requesting permission to use the Ed and Nadine Carson Student Athlete Center for data collection in the Strength, Power, and Swimming Study.
> >
> > Thank you,
> > Sean Kao
> >
> > **Sean Kao CSCS, USAW**
> > Graduate Student
> > **Arizona State University**
> > **College of Health Solutions**
> > Tempe, AZ 85282
> > **C: (909)753-6499**

APPENDIX I

BIOSCIENCE HRP-503B FORM

ASU Knowledge Enterprise Development ARIZONA STATE UNIVERSITY	BIOSCIENCE INSTRUCTIONS AND TEMPLATE		
	NUMBER	DATE	PAGE
	HRP-503b	3/4/2016	1 of 8

Instructions and Notes:

- Depending on the nature of what you are doing, some sections may not be applicable to your research. If so mark as "NA".
- When you write a protocol, keep an electronic copy. You will need to modify this copy when making changes.

1 **Protocol Title**

Include the full protocol title

The relationship between strength and power measures with sprint freestyle performance in Division 1 collegiate swimmers.

Background and Objectives

Provide the scientific or scholarly background for, rationale for, and significance of the research based on the existing literature and how will it add to existing knowledge.

- Describe the purpose, specific aims, or objectives.
- State the hypotheses to be tested.
- Describe the relevant prior experience and gaps in current knowledge.
- Describe any relevant preliminary data.

Describe the purpose, specific aims, or objectives

- The purpose of this study is to study the relationship between strength and power measures with sprint freestyle performance in Division 1 collegiate swimmers

State the hypotheses to be tested

- Null hypothesis- There is no relationship between 1-repetition maximum (1RM) weighted pull-up, back squat barbell velocity, seated vertical jump height and a combination of these measures with a 50-yard freestyle spring performance
- Alternative hypothesis- There is a relationship between 1-repetition maximum (1RM) weighted pull-up, back squat barbell velocity, seated vertical jump height and a combination of these measures with a 50-yard freestyle sprint performance

Describe the relevant prior experience and gaps in current knowledge

- There has been a recent increase in popularity of using barbell velocity tracking, but little-to-no evidence has been shown in its efficacy in swimmers. Garcia-Ramos et al. (2016) measured barbell velocity during a squat jump on a smith machine with 25%, 50%, 75%, and 100% of body weight (BW). The authors were able to show a relationship between bar velocity during a squat jump and swimming start performance. Based on a literature search, no studies have measured the relationship between the concentric back squat barbell velocity where the feet don't leave the ground and sprint swimming performance.
- There also have been no studies to investigate the relationship between a 1-repetition maximum (1RM) pull-up and sprint swimming performance. Pérez-Olea, Valenzuela, Aponte & Izquierdo (2017) investigated the relationship between a one maximum effort BW pull-up including a pull-up mean velocity (PUV), pull-up absolute power (PUAP), pull-up relative power (PURP), and a pull-up relative force (PURF) with a 50-meter freestyle sprint swimming performance. They also investigated aspects of pull-ups until failure including pull-up until failure mean velocity (PUFV) and pull-up until failure velocity loss (PUFVL). Significant relationships were found between PUV, PUAP, PURP, PURF, PUFV, and PUFVL with 50-meter freestyle times (r = -0.80, r = -0.76 r = -0.80, r = -0.77, r = -0.88, r = 0.64; p < 0.05 respectively). While there is evidence supporting a higher velocity of a pull-up and repetitions of pull-ups until failure to improve sprint swimming performance, there is a lack of evidence to support improvements in a 1RM pull-up with sprint swimming performance.
- Only one study is published to show the relationship between a non-countermovement jump and swimming start performance in Division 1 collegiate swimmers. Garcia-Ramos et al. (2016) measured a countermovement jump (CMJ) and a non-countermovement jump (SJ) in twenty international level female swimmers. To measure swimming start performance, participants dove from the starting blocks and swam "a distance further than 15-meters". Significant relationships were found between relative peak power and take off velocity during the CMJ with 5-meter and 10-meter swimming start performance (r = -0.49 to -0.62, p<0.05). Relative peak power and take off velocity during the SJ showed a significant relationship with 5-meter swimming start performance only (r = -0.57, p < 0.01; r = -0.56, p < 0.05, respectively). While there is evidence supporting the efficacy of improving a non-countermovement jump on improving swimming start times, there is a lack of evidence to support these findings in Division 1 collegiate swimmers and under full 50-yard race conditions.

Describe any relevant preliminary data

- No preliminary data have been investigated

ASU Knowledge Enterprise Development
ARIZONA STATE UNIVERSITY

BIOSCIENCE INSTRUCTIONS AND TEMPLATE		
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3 Data Use

Describe how the data will be used. Examples include:

- Dissertation, Thesis, Undergraduate honors project
- Publication/journal article, conferences/presentations
- Results released to agency or organization
- Results released to participants/parents
- Results released to employer or school
- Other (describe)

These data will be used to fulfill the requirements for a Master's Degree thesis

4 Inclusion and Exclusion Criteria

Describe the inclusion and the exclusion criteria for the study.
Describe how individuals will be screened for eligibility.
Indicate specifically whether you will target or exclude each of the following special populations:

- Minors (individuals who are under the age of 18)
- Adults who are unable to consent
- Pregnant women
- Prisoners
- Native Americans
- Undocumented individuals

This study is enrolling competitive swimmers. Inclusion criteria will consist of (a) no current injury that prohibits them from swimming or performing resistance training activities, and (b) must have at least six months of resistance training experience. Exclusion criteria will consist of (a) not currently listed as a breaststroke specialist on the team's website, (b) failure to answer "yes" to all questions listed on the Par-Q, and (c) current injuries that could be exacerbated during the testing activities. Injury status will be determined with a health questionnaire that will be administered to the participants as a screening tool prior to study enrollment. Minors, adults who are unable to consent, pregnant women, prisoners, and undocumented individuals will all be excluded from the study.

5 Number of Participants

Indicate the total number of participants to be recruited and enrolled

- Provide a rationale for the proposed enrollment number
- What percentage of screened individuals will likely qualify for the study?

Fifteen healthy men and fifteen healthy women *aged 18- to 25* from the Arizona State University Swimming team will be recruited for the study. The Arizona State men's team have 18 swimmers listed on the roster with three of them listed as breaststroke specialists. The Arizona State women's team have 21 swimmers listed on the roster with six of them are listed as breaststroke specialists. To maintain a homogenous sample, breaststroke specialists will be excluded from the study. Therefore, 15 men and 15 females will be recruited from the Arizona State University Swimming team.

6 Recruitment Methods

- Describe when, where, and how potential participants will be identified and recruited.
- Describe materials that will be used to recruit participants. (Attach copies of these documents with the application.)
- Does any member have a dual role with the study population?

Potential participants will be recruited immediately following approval of the project by the IRB application review by posting a flyer (1) on a private Facebook page designed for the ASU swim team members and (2) in the Arizona State men's and women's swimming team locker rooms.

7 Study Timelines

Describe:

- The duration of an individual participant's participation in the study.
- The duration anticipated to enroll all study participants.
- The estimated date for the investigators to complete this study (up to and including primary analyses).

Knowledge Enterprise Development
ARIZONA STATE UNIVERSITY

BIOSCIENCE INSTRUCTIONS AND TEMPLATE		
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The participants will participate in one study visit, lasting approximately two-to-three hours. Approximately two weeks is anticipated to enroll all study participants and complete data collection. The estimated date for the investigators to complete this study is the 29th of June, 2018.

8 Procedures Involved

Describe and explain the study design. Provide a description of all research procedures being performed and when they are performed.

Describe procedures including:

- The documents/ measures / devices/ records /sampling that will be used to collect data about participants. (Attach all surveys, scripts, and data collection forms.)
- What data will be collected including long-term follow-up?
- All drugs and medical devices used in the research and the purpose of their use, and their regulatory approval status.
- Describe the available compensation (monetary or credit that will be provided to research participants).
- Describe any costs that participants may be responsible for because of participation in the research.

SEE PAGE BELOW

Knowledge Enterprise Development
ARIZONA STATE UNIVERSITY

BIOSCIENCE INSTRUCTIONS AND TEMPLATE		
NUMBER	DATE	PAGE
HRP-503b	3/4/2018	4 of 8

Describe and explain the study design:
The study will use a correlational design.

Provide a description of all research procedures being performed and when they are performed.

SEE THE PROCEDURES IN A WORD DOCUMENT INCLUDED AS AN ATTACHMENT WITH THE OTHER DOCUMENTS

Attach all surveys, scripts, and data collection forms

The consent form, surveys, scripts, data collection forms, *permission to use the Mona Plummer pool and Ed and Nadine Carson weight room for data collection, and (8) study procedures from the Bioscience form are attached.*

9 Withdrawal of Participants

Describe anticipated circumstances under which participants will be withdrawn from the research without their consent.

Describe procedures that will be followed when participants withdraw from the research, including partial withdrawal from procedures with continued data collection.

Participants will be ineligible for the study if they (a) fail to answer "yes" to all questions listed on the Par-Q, and (b) if they indicate an injury on the health screening questionnaire. The Par-Q and health questionnaire and the health screening questionnaire will be reviewed by the lead investigator and co-investigator prior to all study activities. If a participant injures themselves during the study and are unable to complete the tests they will be withdrawn from the study. Injured participants will be referred to the ASU swimming Sports Medicine staff and all their data will be thrown away and destroyed. An injury report will be completed and sent to the Office of Research Integrity and Assurance. Participants who refuse to participate from any test will be withdrawn from the study and all their data will destroyed.

10 Risks to Participants

List the reasonably foreseeable risks, discomforts, hazards, or inconveniences to the participants related the participants' participation in the research. Include as may be useful for the IRB's consideration, the probability, magnitude, duration, and reversibility of the risks. Consider physical, psychological, social, legal, and economic risks. Reference this information when appropriate.

- If applicable, indicate which procedures may have risks to an embryo or fetus should the participant be or become pregnant.
- If applicable, describe risks to others who are not subjects.

All tests performed

There will be an increase in heart rate and blood pressure during the test; however this is normal with exercise. Both the heart rate and blood pressure decline to near normal levels after exercise in trained athletes. The test may feel strenuous to some participants and may induce fatigue or exhaustion that should diminish after a rest period. There is a remote chance that a participant may sustain a muscle strain or joint injury, however the likelihood of this happening is very low.

1-repetition maximum weighted pull-up test

In addition to the risks identified for all tests, participants may feel some discomfort around the lower back and hands from the weight-belt and pull-up bar, respectively; this should diminish following the rest period.

Back squat barbell velocity

In addition to the risks identified for all tests, participants may feel some pressure around the trapezius muscle from the barbell; this should diminish following the rest period.

To Mitigate Risks: For every task, participants will be allowed to warm up as described below.

Swim test – Participants can stretch their muscles as needed before movement. The swim testing will begin 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. Participants will rest 30 seconds between each 25-yard swim. The warm-up will end with participants taking one practice start off the starting blocks. The warm-up will take an approximate 15 minutes. They will have at least 5 minutes to rest between swim trials.

The 1-repetition max (RM) weighted pull-up - Participants can stretch their muscles as needed before movement. The participants will warm-up on a latissimus dorsi pull-down machine (Power-Lift, Iowa) by performing 5 repetitions at 80% of their BW and 1 repetition at 100% of their BW. A rest period of 30 seconds will be administered between each practice repetition. Participants will rest for 1 minute between trials. They also will have 30 seconds to one minute of rest between trials. They also can take rest breaks as needed.

Back squat barbell velocity and Non-countermovement jump – Participants can stretch their muscles as needed before movement. Before the test, participants can stretch their muscles as needed. The participants will warm-up for each test by taking 2 practice repetitions. They will rest for 30 seconds between each test. They also can take rest breaks as needed.

11 Potential Benefits to Participants

Realistically describe the potential benefits that individual subjects may experience from taking part in the research. Include the probability, magnitude, and duration of the potential benefits. Indicate if there is no direct benefit. Do not include compensation or benefits to society or others.

Participants will not benefit physically from the study. They may benefit from knowing the results from their tests performed for use in goal setting for swim training.

12 Setting

Describe the sites or locations where your research team will conduct the research.

- Identify where research procedures will be performed.
- For research conducted outside of the ASU describe:
  - Site-specific regulations or customs affecting the research.
  - Local scientific and ethical review structures in place.

The study activities will take place on the ASU Tempe campus. Participants will report to Mona Plummer Aquatic Center for pool testing and the Ed and Nadine Carson Student-Athlete Center for dryland testing.

13 Multi-Site Research

If this is a multi-site study where you are the lead investigator, describe the processes you will use to ensure communication among sites, such as:

- Each site has the most current version of the protocol, consent document, and HIPAA authorization.
- Required approvals have been obtained at each site (including approval by the site's IRB of record).
- Describe processes you will use to communicate with participating sites.
- Participating sites will safeguard data as required by local information security policies.
- Local site investigators conduct the study appropriately.

N/A

14 Resources Available

Describe the qualifications (e.g., training, experience, oversight) of you and your staff as required to perform your roles. When applicable describe knowledge of the local study sites, culture, and society. Provide enough information to convince the IRB that you have qualified staff for the proposed research.

Describe other resources available to conduct the research: For example, as appropriate:

- Describe your facilities.
- Describe the availability of medical or psychological resources that participants might need as a result of any anticipated consequences of the human research.
- Describe your process to ensure that all persons assisting with the research are adequately informed about the protocol, the research procedures, and their duties and functions.

Participants will be monitored at all times by a Certified Strength and Conditioning Specialist (Sean Kao) and paid lifeguards on staff at the Mona Plummer Aquatic Center.

- The Mona Plummer Aquatic Center was built in 1981 and has two pools – a 50 meter by 25-yard competition pool and a 25-yard, eight-lane warm-up pool. It also has a 25 yard by 22 yard diving well. The Ed and Nadine Carson Student-Athlete Center contains Powerlift and Hammer Strength equipment, resistance machines, and a nutrition area. The Ed and Nadine Student Athlete Center and Mona Plummer Aquatic Center are located adjacently from each other and will require participants to walk upon completion of the swim testing.
- The ASU Athletics Department has athletic trainers, sport nutritionists, and sport psychologists on staff.
- All student study staff have complete the CITI training and will practice the study screening, consent, and testing protocols prior to all testing.

15 Prior Approvals

Describe any approvals that will be obtained prior to commencing the research. (E.g., school, external site, funding agency, laboratory, radiation safety, or biosafety approval.)

Verbal approval for this study has been obtained from Bob Bowman (Arizona State Swimming Head Coach), Gavin Walker, (Arizona State Swimming Sports Performance Coach), and Greg Werner, (Mona Plummer Facilities Manager).

16 Data Management and Confidentiality

Describe the data analysis plan, including procedures for statistical analysis.

Describe the steps that will be taken to secure the data during storage, use, and transmission.

- Training, authorization of access, password protection, encryption, physical controls, certificates of confidentiality, and separation of identifiers and data

Describe how data and any specimens will be handled:

- What personal identifiers will be included in that data or associated with the specimens?
- Where and how data or specimens will be stored?
- How long the data or specimens will be stored?
- Who will have access to the data or specimens?
- Who is responsible for receipt or transmission of the data or specimens?
- How will data and specimens be transported?
- If data or specimens will be banked for future use, describe where the specimens will be stored, how long they will be stored, how the specimens will be accessed, and who will have access to the specimens.
- Describe the procedures to release data or specimens, including: the process to request a release, approvals required for release, who can obtain data or specimens, and the data to be provided with specimens.

All data will be recorded onto a paper document developed for the study and entered into a password protected computer. In order to maintain confidentiality, data will be de-identified by use of an ID number and that the master list linking name to ID number are stored separate from the data. The documents will be stored in a locked file box during transit from the data collection facilities to the lead investigators office where they will be stored in a locked cabinet. Only the lead investigator and co-investigator will have access to the documents. The signed consents will be stored away from the data in a separate locked cabinet. The data will be stored for one year.

17 Safety Monitoring

This is required when research involves more than Minimal Risk to participants. The plan might include establishing a data monitoring committee and a plan for reporting data monitoring committee findings to the IRB and the sponsor. Describe:

- The plan to periodically evaluate the data collected regarding both harms and benefits to determine whether participants remain safe.
- What data are reviewed, including safety data, untoward events, and efficacy data?
- How the safety information will be collected (e.g., with case report forms, at study visits, by telephone calls with participants).
- Who will review the data?

Participants will be required to read and sign the informed consent form prior to filling out any forms for the study.

The lead investigator and co-investigator will review the 2017 PAR-Q and health screen questionnaire form prior to any testing activities to ensure the participants meet the requirements necessary to participate in the study.

18 Consent Process

Describe the process and procedures process you will use to obtain consent. Include a description of:

- Who will be responsible for consenting participants?
- Where will the consent process take place?
- How will consent be obtained?
- If participants who do not speak English will be enrolled, describe the process to ensure that the oral and/or written information provided to those participants will be in that language. Indicate the language that will be used by those obtaining consent. Translated consent forms should be submitted after the English is approved.

Informed consent forms will be written on a paper document by the lead investigator. Participants will be required to read and sign the informed consent form prior to participation in the study. The consent process will take place on the day of the study visit at the Mona Plummer Aquatic Center.

19 Investigational New Drug or Devices

If the drug is investigational (has an IND) or the device has an IDE or a claim of abbreviated IDE (non-significant risk device), include the following information:

- Identify the hold of the IND/IDE/Abbreviated IDE.
- Explain procedures followed to comply with FDA sponsor requirements for the following:

	Applicable to:		
FDA Regulation	**IND Studies**	**IDE studies**	**Abbreviated IDE studies**
21 CFR 11	X	X	
21 CFR 54	X	X	
21 CFR 210	X		
21 CFR 211	X		
21 CFR 312	X		
21 CFR 812		X	X
21 CFR 820		X	

N/A

20 CITI

Provide the date that the members of the research team have taken the CITI training for human participants. This training must be taken within the last 4 years. Additional information can be found at: http://researchintegrity.asu.edu/training/humans

Ai Ishida: 27-Aug-2016 (aiai041816@gmail.com)
Anthony Preda: 31-Oct-2017 (apreda@asu.edu)
Joshua Nassif: 30-Aug-2016 (Joshua.nassif@asu.edu)
Sean Kao: 31-Aug-2014 (kao_sean@yahoo.com)

APPENDIX J

PROCEDURES INVOLVED FROM BIOSCIENCE HRP-503B

8. Procedures Involved

Describe and explain the study design. Provide a description of all research procedures being performed and when they are performed. Describe procedures including:

- The documents/ measures / devices/ records /sampling that will be used to collect data about participants. (Attach all surveys, scripts, and data collection forms.)
- What data will be collected including long-term follow-up?
- All drugs and medical devices used in the research and the purpose of their use, and their regulatory approval status.
- Describe the available compensation (monetary or credit that will be provided to research participants).
- Describe any costs that participants may be responsible for because of participation in the research.

Describe and explain the study design:
The study will use a correlational design.

Provide a description of all research procedures being performed and when they are performed.

Attach all surveys, scripts, and data collection forms
The consent form, surveys, scripts, and data collection forms are attached.

What data will be collected including long-term follow-up?

Location: The study activities will take place on the ASU Tempe campus and last approximately two-to-three hours. Participants will report to Mona Plummer Aquatic Center in their swimwear for pool testing and the Ed and Nadine Carson Student-Athlete Center for dryland testing. The study procedures will be performed in the following order:

Informed Consent: Participants will read and sign an informed consent form (attached) approved by the IRB. Participants will be allowed to withdraw from the study at any time without prejudice to their status on the ASU swim team.

Screening: Participants will read and complete a physical activity readiness questionnaire (PAR-Q) and a health history screening questionnaire (see attached). Participants with exclusion criteria will be dismissed. Those who have the inclusion criteria will give informed consent to participate in the study

Demographic and Swim Training Questionnaire: Participants will complete a demographic and swim training questionnaire developed for this study (attached).The questionnaire will identify the participants' age in years, stroke and distance specialty, academic and athletic year, average frequency of training in days/week, average meters swam in a usual practice session in meters/practice, frequency of pull-ups, squats, and jumping performed in days/week, estimated 1RM for a weighted pull-up in kilograms, years participating in dryland strength and power training activities, and years in competitive swimming. Body weight will be measured in kilograms with a Weight Watchers Digital Glass Scale (Model WW401GD, Conair Corporation, CT). Height will be measured in centimeters with a tape measure attached to a wall.

Swim Testing: Testing will take place in a 25-yard pool with participants in groups of 5-10. Two tests will be completed with the order they complete the two tests will be randomized. Due to the length of time required to put on a textile fabric racing suit, typically used in competition, participants will not be allowed to wear a textile fabric racing suit. Instead, the participants will wear swimwear that does not extend beyond the hip flexor region and that is worn during their daily swim training. The swim testing part of the study should take about 30 minutes per group. Participants will complete the following activities.

Warm-up. The swim testing will begin 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. Participants will rest 30 seconds between each 25-yard swim. The warm-up will end with participants taking one practice start off the starting blocks. The warm-up will take an approximate 15 minutes.

Swim Test. The 50-yard swim test will start with participants diving into the water from a starting block and swimming two lengths of the pool with a freestyle stroke as fast as possible. Each swim test will be timed using a Daktronic timing system (SD, USA). The 50-yard sprint swim will approximately last 18- to 24 seconds for men and women. Two swim tests will be performed. Each swim time will be recorded from the timing system onto a paper data collection form developed for this study (attached). The best score of the two attempts will be used for data analysis.

Recovery Swim. Following each sprint swim, participants will complete a recovery swim of 300 yards at their own pace.

Dryland Testing: Following the swim testing, participants will change their clothes and report to the dryland testing center. Participants will perform the three dryland tests in a randomized circuit order. Based on the randomization schedule, participants will report to their first testing station to receive instructions on how to perform the practice repetition and complete the test. Following each test, participants will report to their next test session for a similar procedure until they complete all three tests. Participants will rest for two-minutes between each test as monitored by the study staff. Prior to testing at each station, study staff will describe each test to the participants. Participants will be allowed two practice repetitions before testing the non-countermovement vertical jump and the back squat barbell velocity test. They will complete 5 warm-up pull-downs prior to the pull-up test. A rest period of 30 seconds will be administered between each practice repetition. The dryland testing will last approximately one hour.

The 1-repetition max (RM) weighted pull-up is a single pull-up with a maximum weight in kilograms added to a waist belt. The participants will warm-up on a latissimus dorsi pull-down machine (Power-Lift, Iowa) by performing 5 repetitions at 80% of their BW and 1 repetition at 100% of their BW. Participants will begin the 1RM weighted pull-up test by hanging from a bar with their hands with elbows completely extended and wearing a weight belt with weights that equal 80% of their self-estimated maximal weight. They will begin by performing 1 repetition at that weight. The test will require the participants to incrementally increase the weight on the belt by 2.5 kilograms for women and 5 kilograms for men after each pull-up until they are no longer able to perform a pull-up as instructed. A one-minute rest period will be administered between each attempt. The maximum weight in kilograms for 1 RM pull-up will be recorded by a research assistant onto a paper data collection form developed for this study after completion of the heaviest pull-up. The weight of the belt will be added to the total weight lifted. To account for differences in BW, a relative score will be calculated for data analysis by using the formula: ((BW + total weight pulled) / BW).

The non-countermovement jump is a vertical jump as high as possible. To start the test, the participants' feet will stay on the jump mat until initiation of the jump. The arms will remain on their hips for the duration of the jump. After the descent phase of the jump (bending the knees or eccentric phase), participants will pause for one second before leaping into the air vertically (concentric phase). A one-second-pause will be counted out loud by a study staff when the participant reaches their self-selected bent knee depth. After take-off for the vertical leap, the hip and knees will remain extended until the feet land on the mat. The vertical jump will be measured with a jump mat placed under the participants' feet. Two attempts will be performed. A one-minute rest period will be administered between each attempt. Each attempt will be recorded by a study staff onto a paper data collection form developed for this study. The jump height will be measured in inches using a Just Jump System jump mat (Perform Better, RI). Inches will be converted to centimeters for the data analysis. The highest score of the two attempts will be used for data analysis.

The back squat barbell velocity test is a weighted barbell squat performed as fast as possible with half of the participant's bodyweight. The participants will be required to descend in the squat until their hip crease is below the top of their knee. The depth of the squat will be predetermined with an elastic rope placed in the frontal plane approximately 1-to 2 feet off the ground behind the participant. The participants will be required to touch the rope with their buttocks to ensure a standardized squat depth. A Tendo Power Analyzer (Tendo Sports Machines, Trencin, Slovak Republic) will be attached to the barbell to measure barbell velocity in meters per second. Participants will perform two squat tests. A one-minute rest period will be administered between each attempt. Each test will be recorded by a research assistant onto a paper data collection form developed for this study. The average concentric barbell velocity in meters per second will be recorded with a Tendo Power Analyzer (Tendo Sports Machines, Trencin, Slovak Republic). The fastest score of the two tests will be used for data analysis.

Data Analysis. Data will be transferred from the paper forms into a spreadsheet and analyzed using SPSS. Descriptive statistics and Pearson correlations will be used to test the study hypotheses.

Describe the available compensation (monetary or credit that will be provided to research participants).
Each participant will receive a $15 Visa gift card upon completion of the study. *Funds to purchase the cards will be provided by Barbara Ainsworth's Regents' Professor Research fund ($5000 annual stipend).*

Describe any costs that participants may be responsible for because of participation in the research.
There are no costs to participants to engage in this study.