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Evaluation and Comparison of 300-yd and 500-yd Shallow Water Run Tests as Predictors of Aerobic Power

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The purposes of the study were to assess and compare the validity of both 300-yd and 500-yd shallow water run (SWR) tests to predict peak aerobic power (VO_{2peak}). Participants included 18 women and 18 men who performed a graded exercise treadmill test to predict VO_{2peak} and then performed a 300-yd and 500-yd SWR for time. In addition to SWR times, other independent variables included age, gender, body weight, height, leg length, percent body fat, and 300-yd and 500-yd SWR heart rate and rating of perceived exertion. Correlation coefficients with measured VO_{2peak} were $r = -.84$ and -.87 for the 300-yd and 500-yd SWR times, respectively. Multiple regression analyses revealed that prediction of VO_{2peak} from 300-yd SWR time improved by including gender and body weight ($R = .919$; $SEE = 0.360$ L·min^{-1}). Similarly, prediction of VO_{2peak} improved from 500-yd SWR time by including gender, body weight, and leg length ($R = .940$; $SEE = 0.316$ L·min^{-1}). Equations were also developed for use in pools of varying water depths. In conclusion, the 300-yd and 500-yd SWR tests can provide accurate and valid estimates of aerobic power.

Recently, aquatic exercise has become a popular method of training and conditioning. Individuals of all fitness levels and health conditions are discovering that water exercise provides a relatively injury-free environment from physical injuries associated with land-based exercise. Specifically, aquatic exercise reduces the likelihood of injuries from high-impact, overuse, and heat-related problems typically associated with land-based exercise (Koszuta, 1986). Shallow water running, the most common mode of aquatic exercise (Midtlyng & Nelson, 1991), has become a simple alternative and/or supplement to land-based running programs.

Aerobic power is related to the risk of cardiorespiratory diseases, circulatory diseases, and all-cause mortality in men and women (Blair et al., 1989). Aerobic power determines the peak amount of oxygen that can be used by the body during moderate- to high-intensity exercise lasting longer than four or five minutes. The direct measurement of peak oxygen uptake rate (VO_{2peak}) during a graded exercise test is the most accurate assessment of aerobic power (Shepard, 1968; Taylor et

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al., 1955); however, the direct measurement of VO_{2peak} has limited practical utility.

Direct measurements of VO_{2peak} are primarily reserved for the laboratory because of costly equipment and the need for trained technicians. Despite high levels of accuracy, direct measurements of VO_{2peak} are time consuming and impractical measurements for large numbers of individuals at one time. Instead, submaximal exercise field tests have been devised to predict aerobic power. An extensive review of the literature confirms the specific need to develop a safe and valid SWR field test that is shorter and more practical than the 500-yd SWR test to predict aerobic power in men and women that can be compared with the previously developed 500-yd SWR test developed by Kaminsky et al. (1993).

Submaximal field tests have been developed for different modes of exercise, such as bench stepping, cycle ergometry, and track walking and running. The selection of a field test to quantify aerobic power, based on the effects of a specific training program, should reflect the specific mode of exercise performed during training. The practical utility of submaximal field tests may be evaluated on the basis of four considerations: (a) the accuracy and validity of the prediction, (b) the ease and convenience of the testing protocol, (c) the relative low risk of injury to the subject, and (d) the generalized application to a broad population (Kline et al., 1987).

Investigations of various submaximal exercise tests have been developed to predict aerobic power, including running (Balke, 1963; Cooper, 1968), walking (A. Jackson, Solomon, & Stusek, 1992; Kline et al., 1987), jogging (George, Vehrs, Allsen, Fellingham, & Fisher, 1992; George, Vehrs, Allsen, Fellingham, & Fisher, 1993), swimming (Conley et al., 1991, 1992), cycling (Astrand & Ryhming, 1954), aerobic dance (Rogers-Johnson, Heyward, Schau, & Cagle, 1992), bench stepping (Margaria, Aghemo, & Rovelli, 1965), deep water running (Sherman, Michaud, & Ryan, 1993), and shallow water running (Kaminsky et al., 1993). Distance runs, walks, and other land-based forms of exercise are widely used field tests because they are easy to administer and have high reliability and validity as indicators of treadmill VO_{2peak}.

In addition, the review of previous research that developed field tests to predict VO_{2peak}, determined from a maximal graded exercise test (GXT), indicated that many studies (Cooper, 1968; Doolitte & Bigbee, 1968; Getchell, Kirkendall, & Robbins, 1977; Hermiston & Faulkner, 1971; Maksud & Coutts, 1971) did not report the standard errors of estimate and/or total errors, which limits the interpretation of accuracy when using the equations to predict VO_{2peak} in other populations. Finally, many field tests have not taken into account individual differences in age, body weight, height, leg length, percent body fat, rating of perceived exertion (RPE), skill, fitness levels, and/or environmental conditions.

Some submaximal field tests have been reported to be accurate and valid predictors of VO_{2peak} whereas other field tests have been found to be poor predictors of VO_{2peak}. For example, the popular Cooper's 12-min land-based walk/run test had high validity ($r = .90$) as an indicator of treadmill VO_{2peak} in men aged 17–52 yr (Cooper, 1968). Subsequently, other investigators found the correlation coefficient between 12-min run time and VO_{2peak} ranged from .49 (moderate) to .91 (high) in college-aged females (Custer & Chaloupka, 1977; Johnson, Oliver, & Terry, 1979; Katch, Pechar, McArdle, & Weltman, 1973; Maksud, Cannistra, & Dublinski, 1976).

If no contraindications (specifically health concerns) prevent test subjects from participating in these activities, these land-based tests have been generally proven sufficient and accurate predictors of VO_{2peak}. In contrast, the 12-min swim test has been reported to have low validity as a predictor of VO_{2peak}. Cooper (1977) proposed that the 12-min swim could still be used as an alternative to the 12-min run to classify VO_{2peak}. Cooper (1977) designed and modified fitness categories based on age groups from running data, but the validity of the classifications were not evaluated immediately.

Jackson, Jackson, and Frankiewicz (1979) investigated the construct and concurrent validity of a 12-min swim as a field test of swimming endurance in 42 young males experienced in aquatic skills who ranged from 18 to 27 years of age. The participants were administered three tests: (a) a multistage endurance tethered swim test, (b) stroke count for two lengths, and (c) a 12-min swim for distance with total distance and distance covered each minute recorded for each subject. The authors concluded that 12-min swim performance was highly correlated ($r = .90$) with tethered swim work capacity; however, swim VO_{2peak} was not measured. The standard errors of estimate also were not reported.

In an attempt to validate Cooper's proposal that the 12-min swim could be used as an alternative predictor of aerobic power, Conley et al. (1991) compared the validity of the 12-min swim with that of the 12-min run. The investigators also hypothesized that a more accurate estimate of tethered swim VO_{2peak} would be obtained from the 12-min swim than from the 12-min run; and furthermore, a more accurate estimate of treadmill running VO_{2peak} would be obtained from the 12-min run than from the 12-min swim. Participants were 36 young men who were recreational swimmers. Participants completed a 12-min run and swim for distance, as well as maximal swimming (tethered) and running (treadmill) tests. Correlation coefficients and *SEE* for predictions of tethered swim VO_{2peak} from the 12-min swim ($r = .40$, *SEE* = 5.7 $ml^{-1} \cdot kg^{-1} \cdot min$) and run ($r = .74$, *SEE* = 4.2 $ml^{-1} \cdot kg^{-1} \cdot min$), and for prediction of treadmill run VO_{2peak} from the 12-min swim ($r = .38$, *SEE* = 5.1 $ml^{-1} \cdot kg^{-1} \cdot min$) and run ($r = .88$, *SEE* = 2.6 $ml^{-1} \cdot kg^{-1} \cdot min$), indicated that the 12-min run was a more accurate predictor of VO_{2peak} than the 12-min swim test, regardless of whether VO_{2peak} was measured during swimming or running. Conley et al. (1991) concluded that the 12-min swim has relatively low validity as a predictor of the tethered swim ($r = .40$) and treadmill run ($r = .38$); and therefore, should not be considered an equally valid alternative to the 12-min run in young male recreational swimmers.

In a more recent attempt to validate Cooper's proposal that the 12-min swim could be used as an alternative predictor of aerobic power, Conley et al. (1992) extended their earlier investigation of the validation of the 12-min swim as a field test of aerobic power. Methodology was similar to the previous study; however, the participants were 34 young women. Correlation coefficients and *SEE* for predictions of swimming VO_{2peak} from the 12-min swim ($r = .42$, *SEE* = 4.5 $ml^{-1} \cdot kg^{-1} \cdot min$) and run ($r = .58$, *SEE* = 4.1 ml.kg.min-1) and for predictions of treadmill run VO_{2peak} from the 12-min swim ($r = .34$, *SEE* = 6.0 $ml^{-1} \cdot kg^{-1} \cdot min$) and run ($r = .87$, *SEE* = 3.2 $ml^{-1} \cdot kg^{-1} \cdot min$) were very similar to their previous results with males and again indicated that the 12-min run test was a better predictor of VO_{2peak} than the

12-min swim test regardless of whether VO_{2peak} was measured during swimming or running. Conley et al. (1992) revealed that some of the less skilled and less economical swimmers achieved a high VO_{2peak}, but did not swim very far on the 12-min swim test. Accounting for differences in swimming skills or economy, using the stroke-technique indicators did not sufficiently improve the accuracy of estimating VO_{2peak}. Based on the results of both of the Conley et al. (1991, 1992) studies, it may be appropriate and necessary to test the feasibility of a shallow-water run test in an effort to more accurately predict VO_{2peak} in an aquatic environment.

Although norms have been previously established for the 500-yd shallow water run (SWR; Robbins, Powers, & Burgess, 1991), the use of the 500-yd SWR as a submaximal field test of aerobic power was not established until recently (Kaminsky et al., 1993). Kaminsky et al. (1993) reported that 500-yd SWR time was a valid predictor of VO_{2peak} ($R = .79$, *SEE* = 5.14 ml^{-1}·kg^{-1}·min) in men and women, particularly when percent body fat and height were taken into consideration ($R = .93$, *SEE* = 3.19 ml^{-1}·kg^{-1}·min). The assessment of an individual's percent body fat to use the prediction equations developed by Kaminsky et al. (1993) limits its practical utility in a large population. Prediction equations that used body weight rather than percent body fat would be easier to administer and possibly may be just as accurate. Caution should be considered in the selection of additional covariates, as some may limit the practical utility of the submaximal test for a large group, such as an aquatic exercise class.

Furthermore, the Kaminsky et al. (1993) study used a pool that sloped from a depth of 3.5–5 ft, in which the subjects completed the SWR at a water depth midway between the navel and nipple line. Many shallow water runners use a pool with a constant water depth and, consequently, it is not always possible to select a water depth level that corresponds to the level of the water described in the Kaminsky et al. (1993) study. Therefore, shallow water runners who use a pool with a constant water depth may be unable to use the Kaminsky et al. (1993) equations. Perhaps height and/or leg length would be stronger predictor variables than previously identified in the equations used to predict VO_{2peak}. In addition, it should be noted that the Kaminsky et al. (1993) study used a pool that was 11.5-yd in length, requiring the subjects to turn at a wall 42 times. If subjects were tested in a 25-yd pool, 19 turns would be required which would perhaps limit errors attributed to turning frequency.

Unfortunately, the 500-yd SWR field test may be too strenuous and impose potential hazards to specific populations. Thus, the development of a field test with a protocol of shorter duration, such as a 300-yd SWR, may potentially pose less hazard and risk, reduce testing time, and yet still be of sufficient duration to predict VO_{2peak} (Astrand & Saltin, 1961; Katch et al., 1973). Therefore, the main purposes of the study were to (a) devise and evaluate the validity of a 300-yd shallow water run test to predict aerobic power and (b) improve the practical utility of the recently developed 500-yd shallow water run test. In doing so, the 300-yd and 500-yd SWR tests may serve as practical assessment tools in the classification of an individual's fitness level based on broad categories, such as poor, fair, good, and excellent.

Method

Participants

The participants in the study were 36 apparently healthy adult volunteers; 18 women and 18 men who ranged widely in age from 21.25 to 48.42 yr. Apparently healthy subjects within this age range were generally considered representative of the population most likely to use the field tests. The presence of a physician was not required for administering either the SWR tests or the maximal GXT. Although the selected sample size ($N = 36$) was somewhat lower than the sample size used in the Kaminsky et al. (1993) study ($N = 43$), it did meet the minimal criterion of subjects per independent variable that has been recommended for regression analysis (Jackson, 1984).

Apparatus

Height and leg length were measured using a Broca plane and a wall scale; all participants were barefoot during measurement. Body weight was measured using a platform scale; subjects were again barefoot. Skinfold thicknesses were assessed using the Lange skinfold calipers. Peak oxygen uptake rate, or peak aerobic power, was determined from a maximal GXT, which used a MedGaphics Cardiopulmonary Exercise System CPX/D. A Nihon Kohen Cardiofax V electrocardiograph was used to monitor heart rate and ECG rhythms continually during the GXT. During the GXT, all subjects wore running shoes and shorts; the women wore a supportive bra and/or a t-shirt.

The 300-yd (12 laps) and 500-yd (20 laps) shallow water runs were timed in a constant water depth of 106.68 cm (3.5 ft or 42 in.) in a 25-yd swimming pool of 28 °C (82 °F). Borg's scale of perceived exertion was used to measure RPE during the last 5 s of the SWR tests and at the end of each minute of the GXT; the numerical ratings on the scale ranged from *very, very light* (7) to *very, very hard* (19). Postrun heart rate was recorded upon completion of both SWR tests with a Polar Vantage XL heart rate monitor that each subject wore around the chest. Both SWR tests were performed barefoot and while wearing a swimsuit.

Procedures

Before Testing Methodology. Each participant read and signed a consent form and completed a health/medical history questionnaire, which was approved by the Human Subjects Institutional Review Board of San Jose State University, before testing. The order of testing was explained to each subject. Initially, participants had laboratory assessments of body composition and size and performed the maximal GXT. In an effort to control for learning effects, participants practiced both the standardized SWR technique and use of the RPE scale. Within a week after the laboratory/practice session, the participants completed the testing by performing "best effort" 300-yd and 500-yd shallow-water runs in a random order on different days.

Testing Methodology. The testing of the participants was divided into the measurement of body composition (percent body fat) and size (height, leg length, and body weight), a maximal GXT, and two different submaximal exercise test conditions (one 300-yd and one 500-yd SWR). Before the GXT, each participant was measured for body composition and size. The GXT was followed by a random order of the two submaximal exercise test conditions to control for a learning effect.

Body Composition and Size. Body density was estimated from skinfold measurements using the equations published by Pollock et al. (1980). The Siri (1961) equation was used to calculate percent body fat from the estimated body density. Height and leg length (measured from the greater trochanter to the floor) were measured with a wall scale utilizing a Broca plane. Height and leg length were expressed in centimeters (cm). Leg length was averaged from the measurements of both right and left legs. Body weight was measured in kilograms (kg) on a platform scale.

Maximal Graded Exercise Test. Maximal graded exercise testing was conducted on each participant using the modified Bruce protocol (Bruce, Kusumi, & Hosmer, 1973). The treadmill protocol began at 1.7 mph and at a 10% grade for three minutes and continued with workload increases in speed and grade, which approximated one metabolic equivalent (3.5 ml·kg^{-1}·min^{-1}) every three minutes until voluntary exhaustion. This protocol was selected because Pollock et al. (1976) reported that VO_{2peak} measured using the modified Bruce protocol was approximately 5% higher than VO_{2peak} determined from a protocol using a graded treadmill walk. Hence, the modified Bruce protocol elicited a higher oxygen uptake rate that is more reflective of peak oxygen uptake rate.

Participants performed the GXT in a pair of socks and athletic shoes, as well as appropriate exercise clothing. Each participant was fitted with a mouthpiece and nose clip. The participants inhaled room air continually throughout the maximal GXT. A Medgraphics Cardiopulmonary Exercise System CPX/D collected expired air samples breath-by-breath for the measurements of expired ventilation rate, oxygen uptake rate, carbon dioxide production rate, and respiratory exchange ratio values during the maximal GXT.

A Nihon Kohen Cardiofax V electrocardiograph was used to monitor heart rate and ECG rhythms continually during the GXT. The ECG lead placement during the maximal test consisted of five surface electrodes that were placed at the participant's right and left arms, right and left legs, and V5. The leads monitored all cardiac electrical patterns and obtained heart rate during the last ten seconds of each minute of the test.

Peak oxygen uptake rate (VO_{2peak}) was determined during the maximal GXT as the highest VO_2 value obtained using the "mid 5 of 7" breath method described in the MedGraphics Cardiopulmonary Exercise Testing System (CPX/D) User's Manual (1993). All participants met at least one of the following criteria indicating a maximal effort: (a) heart rate was within 10 b·min^{-1} of age-predicted maximal heart rate, (b) respiratory exchange ratio was above 1.0, and/or (c) VO_2

reached a plateau (< 2.0 ml·kg^{-1}·min^{-1}) or decreased with increasing workloads (McArdle et al., 1991). Peak heart rate (HR$_{peak}$) was determined as the highest heart rate reached during the maximal GXT.

The GXT test was terminated for any of the following reasons: (a) the participant requested to terminate the test, (b) failure of the heart rate to increase with increasing workloads, (c) pain or fatigue as indicated by decreased coordination or pallor, (d) abnormalities on the ECG reading, or (e) equipment failure (American College of Sports Medicine, 1991). For the purpose of this study, each participant voluntarily terminated the test after giving a "last-minute" signal.

Shallow-Water Run Tests. Both submaximal exercise test conditions similarly adhered to the following methodologies. Before performing the shallow water runs, participants were given instructions describing the RPE scale. Each participant wore a swimsuit and a Polar Vantage XL Heart Rate monitor that recorded heart rate (HR) every five seconds during and immediately following the shallow water runs. The average of the recorded heart rates during the first 15 s of recovery immediately following completion of the runs was identified as the 300-yd SWR and 500-yd SWR heart rates. Before the actual SWR tests, each participant was required to adequately warm-up by water walking and jogging for two to three minutes followed by stretching. The SWR tests began with the participant's hand touching the pool wall.

Each participant was instructed to run forward in the pool at as fast of a pace as possible for 12 and 20 laps to complete the 300-yd and 500-yd SWR, respectively. Throughout the test, each runner remained in a designated marked "lane" at each end of the pool. Each participant was tested individually. During the SWR, the participants were given verbal encouragement to do the best they could. One lap was designated at each turn. Participants were required to touch the wall with one hand before the lap was counted. A person designated as a lap counter sat at the end of the pool revealing and recording the number of laps each participant completed. In addition, the lap counter recorded RPE and the time at completion of every two laps. The RPE values that were recorded during the last 5 s of each SWR were identified as either the 300-yd SWR RPE or 500-yd SWR RPE.

The participants' arm movements were similar to the arm actions used to swim the front crawl. Specifically, the "recovery" portion of the arm stroke was performed through the air and the "propulsive" phase was performed as the fingertips entered the water and continued to sweep the submerged hand and arm past the hips. The level that the arm was submerged depended on the participant's height, motivation, need for balance, and possible swimming skills. In fact, a "feel for the water" may have brought an element of balance necessary to water running, without significantly affecting the skill component in swimming field tests as mentioned by Conley et al. (1992).

The time of the SWR was recorded by a designated investigator in the study at the completion of 300-yd (12 laps) and 500-yd (20 laps) in minutes (min) and seconds (s) from the time the participant left the pool wall until the wall of the final lap was touched with one hand. A run was terminated early if a participant exhibited dizziness, pain, or fatigue as indicated by decreased coordination or pallor.

Analysis of Data. Descriptive statistics, means, and standard deviations were used to describe the characteristics of age, body weight, height, leg length, percent body fat, VO_{2peak}, 300-yd SWR time, 300-yd SWR HR, 300-yd SWR RPE, 500-yd SWR time, 500-yd SWR HR, and 500-yd SWR RPE in the male and female participants, as well as the total group of participants . Independent *t* tests were used to compare the characteristics of the male and female data. For the data of the total group, Pearson product-moment correlations (*r*) were used to examine the relationships between the descriptive characteristics of age, gender, body weight, height, leg length, percent body fat, VO_{2peak}, 300-yd SWR time, 300-yd SWR HR, 300-yd SWR RPE, 500-yd SWR time, 500-yd SWR HR, and 500-yd SWR RPE. Stepwise multiple regression analyses were used to develop regression equations predicting the criterion variable of VO_{2peak} from the predictor variables of: age, gender, body weight, height, leg length, percent body fat, 300-yd SWR time, 300-yd SWR HR, 300-yd SWR RPE, 500-yd SWR time, 500-yd SWR HR, and 500-yd SWR RPE. To develop equations that could be used in swimming pools that differed from the 106.68 cm (i.e., 42 in.) water depth used in the current study, forward multiple regression analyses were calculated. Forward multiple regression analyses were used to add the calculated variable of height/water depth into each of the developed equations from stepwise multiple regression analyses. In addition to the calculation of multiple correlation coefficients (*R*), standard errors of estimate (*SEE*) were also calculated from the multiple regression analyses.

Results

Analysis of the Descriptive Characteristics and Gender Comparisons

The descriptive characteristics, means and standard deviations of the 36 subjects, were calculated for the 18 male and 18 female participants, as well as for the total group of 36 participants . The descriptive statistics of age, body weight, height, leg length, percent body fat, VO_{2peak}, 300-yd SWR time, 300-yd SWR HR, 300-yd SWR RPE, 500-yd SWR time, 500-yd SWR HR, and 500-yd SWR RPE are summarized in Table 1. The mean (*M* ± *SD*) age for the total group was 27.95 ± 6.43 yr. Mean body weight for the overall group was 70.07 ± 14.23 kg. Participants' height averaged 170.15 ± 9.29 cm with a mean leg length of 87.48 ± 5.46 cm. The mean percent body fat was 17.38 ± 7.12%. The mean VO_{2peak} value was 3.29 ± 0.87 L·min^{-1}, or expressed relative to body weight, 46.88 ± 7.76 ml·kg^{-1}·min^{-1}. As expected, the mean time in the 300-yd SWR (4.88 ± 0.66 min) was somewhat faster than the mean time in the 500-yd SWR time (8.38 ± 1.10 min) and the mean heart rate value in the 300-yd SWR (178.12 ± 11.90 b·min^{-1}) was somewhat lower than the HR values in the 500-yd SWR (180.52 ± 8.84 b·min^{-1}). Likewise, the mean 300-yd SWR RPE (17.47 ± 1.94) was somewhat lower than the 500-yd SWR RPE (18.12 ± 1.98).

Independent *t* tests were calculated to compare the previously identified descriptive characteristics of female and male data and are presented in Table 1. Significant differences ($p \leq .05$) were revealed between the mean female and male

Table 1 Descriptive Characteristics and Gender Comparisons of the Subjects

Characteristics	Total Group N = 36	Females n = 18	Males n = 18	t-Value
Age (yr)	27.95 ± 6.43	28.58 ± 7.41	27.32 ± 5.40	0.58
Body Weight (kg)	70.07 ± 14.23	61.17 ± 11.38	78.98 ± 10.94	-4.79*
Height (cm)	170.15 ± 9.29	162.62 ± 5.72	177.69 ± 4.98	-8.43*
Leg Length (cm)	87.48 ± 5.46	83.83 ± 4.42	91.12 ± 3.72	-5.36*
Percent Body Fat (%)	17.38 ± 7.12	22.44 ± 5.55	12.33 ± 4.43	6.04*
$VO_{2\,Peak}$ ($L \cdot min^{-1}$)	3.29 ± 0.87	2.58 ± 0.32	4.00 ± 0.63	-8.50*
300-yd SWR Time (min)	4.88 ± 0.66	5.34 ± 0.57	4.41 ± 0.32	6.06*
300-yd SWR HR ($b \cdot min^{-1}$)	178.12 ± 11.90	173.68 ± 11.40	182.57 ± 10.96	-2.39*
300-yd SWR RPE	17.47 ± 1.94	17.03 ± 2.32	17.92 ± 1.42	-1.39
500-yd SWR Time (min)	8.38 ± 1.10	9.16 ± 0.89	7.59 ± 0.63	6.10*
500-yd SWR HR ($b \cdot min^{-1}$)	180.52 ± 8.84	178.16 ± 9.77	182.88 ± 7.33	-1.64
500-yd SWR RPE	18.12 ± 1.98	17.78 ± 2.34	18.47 ± 1.52	-1.06

Note. Values are $M \pm SD$. *$p \leq .05$.

data in the variables of body weight (61.17 ± 11.38 vs 78.98 ± 10.94 kg), height (166.62 ± 5.72 vs 177.69 ± 4.98 cm), leg length (83.83 ± 4.42 vs 91.12 ± 3.72 cm), percent body fat (22.44 ± 5.55 vs 12.33 ± 4.43%), VO_{2peak} (2.58 ± 0.32 vs 4.00 ± 0.63 L·min^{-1}), 300-yd SWR time (5.34 ± 0.57 vs 4.41 ± 0.32 min), 300-yd SWR HR (173.68 ± 11.40 vs 182.57 ± 10.96 b·min^{-1}), and 500-yd SWR time (9.16 ± 0.89 vs 7.59 ± 0.63 min).

No significant differences were revealed between the female and male mean data in the variables of age (28.58 ± 7.41 vs 27.32 ± 5.40 yr), 300-yd SWR RPE (17.03 ± 2.32 vs 17.92 ± 1.42), 500-yd SWR RPE (17.78 ± 2.34 vs 18.47 ± 1.52), and 500-yd SWR HR (178.16 ± 9.77 vs 182.88 ± 7.33 b·min^{-1}).

Summary and Discussion of the Descriptive Characteristics and Gender Comparisons

Participants in the study were generally considered young adults (27.95 ± 6.43 yr); however, the ages ranged widely from 21.25 to 48.42 yr. Participants' percent body fat levels were evaluated by the classification standards described by Wilmore and colleagues (1986). In general, the mean percent body fat of the females (22.44 ± 5.55%) was considered to be in the range classified as either optimal fitness (16–25%), or health (18–30%); however, the lower, average percent body fat of the males (12.33 ± 4.43%) fell within ranges classified as either most athletes (5–13%), or optimal fitness (12–18%). The ranges of percent body fat within each gender were again varied as percent body fat levels for the females and males ranged from 15.96 to 36.71% and 5.82–22.57%, respectively.

The mean value of aerobic power (VO_{2peak}) that was achieved by each gender during the graded exercise test was classified according to standards set by Heyward (1984). Based on the mean age of each gender, the mean female VO_{2peak} value (42.88 ± 6.10 ml·kg^{-1}·min^{-1}) was classified as good (43–52 ml·kg^{-1}·min^{-1}); however, even though the mean male VO_{2peak} value (50.89 ± 6.85 ml·kg^{-1}·min^{-1}) was somewhat higher than that of the females, the value was classified as average (43–52 ml·kg^{-1}·min^{-1}). It is also interesting to note that the ranges of VO_{2peak} values within each gender were diverse for both females (32.1–51.3 ml·kg^{-1}·min^{-1}) and males (36.4–58.8 ml·kg^{-1}·min^{-1}).

As previously discussed, the mean times for the total group of participants in the 300-yd and 500-yd SWR were 4.88 ± 0.66 and 8.38 ± 1.10 min, respectively. The mean 500-yd SWR times for each gender were compared with the classification standards published by Robbins et al. (1991). The mean female 500-yd SWR time (9.16 ± 0.89 min) was classified within the average category (8.60–9.42 min); however, the male mean 500-yd SWR time (7.59 ± 0.63 min) was classified within the poor category (7.58–7.85 min).

Interestingly, there were conflicts in the classifications of fitness levels in the males and females when the average 500-yd SWR time and VO_{2peak} value were compared with the normative data published by Robbins et al. (1991) and Heyward (1984). The high correlation ($r = -.87$) found in the current study between the 500-yd SWR times and the VO_{2peak} values suggests that the classifications of fitness levels should be somewhat similar when, in fact, the rankings were quite different within each gender. Specifically, the mean female VO_{2peak} value ranked

good; yet, the mean female 500-yd SWR time ranked average. Likewise, the mean male VO_{2peak} value ranked average; yet, the mean 500-yd SWR time ranked poor.

In addition to the contradictory fitness classification standards noted within each gender, the rankings were also contradictory between genders. Specifically, the average female SWR time was significantly slower than the male SWR time $(9.16 \pm 0.89$ vs 7.59 ± 0.63 min); yet, the average female SWR time was classified as average; and rather astonishingly, the male SWR time was classified as poor. The discrepancies found both within and between the gender comparisons of fitness categories, based on SWR times and VO_{2peak} values, suggests that the norms established by Robbins et al. (1991) for the 500-yd SWR may not be valid, and perhaps should not be used until further research is completed.

Finally, it has been noted by the American College of Sports Medicine (1991) that the RPE numeric scale correlates closely with land-based heart rate. It is interesting that the mean HR values for the 300-yd $(178.12 \pm 11.90$ b·min$^{-1})$ and 500-yd SWR $(180.52 \pm 8.84$ b·min$^{-1})$ corresponded closely to the average RPE values for the 300-yd SWR (17.47 ± 1.94) and the 500-yd SWR (18.12 ± 1.98). This close correspondence occurred despite the fact that in-water heart rate values typically fall 10–13 bpm lower than on land.

Analysis of the Correlation Coefficients for the Descriptive Characteristics of the Participants

For the data of the total group, Pearson product-moment correlations were calculated to examine the relationships between the descriptive characteristics of age, body weight, height, leg length, percent body fat, VO_{2peak}, 300-yd SWR time, 300-yd SWR HR, 300-yd SWR RPE, 500-yd SWR time, 500-yd SWR HR, and 500-yd SWR RPE. A matrix of the correlation coefficients for the descriptive characteristics of the subjects is presented in Table 2.

Of interest were significant $(p \leq .05)$ correlations revealed between VO_{2peak} and the 300-yd SWR time $(r = -.84)$ and 500-yd SWR time $(r = -.87)$. In addition, there was a significant correlation between VO_{2peak} and the 300-yd SWR HR $(r = .34)$; and, a nonsignificant relationship between VO_{2peak} and the 500-yd SWR HR $(r = .26)$. In addition, VO_{2peak} was significantly correlated to percent body fat $(r = -.56)$, leg length $(r = .68)$, body weight $(r = .76)$, and height $(r = .82)$.

As previously noted, the 300-yd and 500-yd SWR times correlated highly to VO_{2peak} $(r = -.84$ and $-.87$, respectively). In addition, the 300-yd and 500-yd SWR times had high correlations with height $(r = -.87$ and $-.86$, respectively) and leg length $(r = -.81$ and $-.80$, respectively). The 300-yd and 500-yd SWR times had moderate correlations with body weight $(r = -.63$ and $-.63$, respectively) and percent body fat $(r = .56$ and $.54$, respectively). The highest correlation coefficient was between both of the SWR times $(r = .97)$.

Summary and Discussion of the Correlation Coefficients for the Descriptive Characteristics of the Participants

The correlations between VO_{2peak} and the 300-yd $(r = -.84)$ and 500-yd $(r = -.87)$ SWR times meets the minimum criterion of $r = .80$ for establishing validity on tests of physical fitness (Bruce et al., 1973; Baumgartner & Jackson, 1991).

Table 2 Matrix of Correlation Coefficients for the Descriptive Characteristics of the Subjects

Variable	1	2	3	4	5	6	7	8	9	10	11	12
Age	1.00											
Body Weight	.06	1.00										
Height	.09	.69*	1.00									
Leg Length	.04	.63*	.87*	1.00								
Percent Body Fat	.29	-.10	-.61*	-.45*	1.00							
$VO_{2\,Peak}$	-.03	.76*	.82*	.68*	-.56*	1.00						
300-yd SWR Time	.06	-.63*	-.87*	-.81*	.56*	-.84*	1.00					
300-yd SWR HR	-.31	.21	.29	.18	-.36*	.34*	-.35*	1.00				
300-yd SWR RPE	-.05	.23	.20	.10	-.05	.20	-.25	.30	1.00			
500-yd SWR Time	.04	-.63*	-.86*	-.80*	.54*	-.87*	.97*	-.32	-.24	1.00		
500-yd SWR HR	-.25	.19	.25	.17	-.22	.26	-.31	.87*	.46*	-.27	1.00	
500-yd SWR RPE	-.09	.25	.16	.09	.07	.08	-.09	.24	.75*	-.10	-.21	1.00

*$p \leq .05$.

Therefore, both the 300-yd and 500-yd SWR should be considered valid field tests for the prediction of aerobic capacity in young adults. Consequently, both SWR field tests should be considered valid alternatives to the 12-min swim (Conley et al., 1991; Conley et al., 1992) for accurately predicting aerobic power in young adults.

The significant, yet weak correlation between VO_{2peak} and the 300-yd SWR HR ($r = .34$), as well as the lack of a relationship between VO_{2peak} and the 500-yd SWR HR ($r = .26$), were perhaps attributed to individual differences, and/or the unique heart rate responses during water exercise compared with land-based exercise (i.e., such as a nonlinear relationship between heart rate and oxygen uptake rate). Interestingly, Kaminsky et al. (1993) also found a weak relationship between VO_{2peak} and 500-yd HR ($r = .06$). The lack of strong correlations in both studies between both the 300-yd and 500-yd SWR HR and VO_{2peak} suggests that post exercise heart rate may not be a valid method to predict VO_{2peak} during SWR field tests.

In contrast, the 300-yd and 500-yd SWR times had high correlations with height ($r = -.87$ and $-.86$, respectively) and leg length ($r = -.81$ and $-.80$, respectively); and as previously mentioned, height was also highly correlated to leg length ($r = .87$). The strong correlations suggest that leg length and/or height should be variables to consider when SWR testing. The shorter stature participants appeared to generally encounter more water resistance than the participants with greater heights/leg lengths. The 300-yd and 500-yd SWR times were moderately correlated with body weight ($r = -.63$). Again, shorter and heavier participants generally tended to encounter more water resistance than taller and lighter participants during the SWR tests. Therefore, in addition to height and leg length, body weight is also an important variable to account for when SWR testing.

Of further interest was the strongest correlation found between the 300-yd and 500-yd SWR times ($r = .97$). The extremely strong relationship between the two SWR tests indicated that the 300-yd SWR test can be another valid, more practical, and safer field test than the 500-yd SWR test to predict aerobic power in men and women.

Multiple Regression Analyses

Stepwise multiple regression analyses were used to develop regression equations predicting the criterion variable VO_{2peak} from the predictor variables of: age, gender, body weight, height, leg length, percent body fat, 300-yd SWR time, 300-yd SWR HR, 300-yd SWR RPE, 500-yd SWR time, 500-yd SWR HR, and 500-yd SWR RPE. To develop equations that could be used in pools that differed from the water depth used in the current study, forward multiple regression analyses were calculated which were used to add the calculated variable of height/water depth into each of the developed equations from stepwise multiple regression analyses. In addition to the calculation of multiple correlation coefficients (R), standard errors of estimate (*SEE*) were calculated from the multiple regression equations.

The multiple regression equations for predicting VO_{2peak} from the 300-yd SWR time are presented in Table 3. Interestingly, the basic Equation 1 produced a high correlation ($R = .840$; $SEE = 0.480$ L·min⁻¹) for predicting VO_{2peak} from the

Table 3   Multiple Regression Equations for Predicting Peak Oxygen Uptake Rate (VO$_{2peak}$) from 300-yd Shallow Water Run (SWR) Time

Equation Values	Equation for VO2peak Prediction
Equation 1 (R = .840; *SEE* = 0.480 L·min^{-1})	VO$_{2peak}$ (L·min^{-1}) = 8.741–1.118(300-yd SWR Time)
Equation 2 (R = .898; *SEE* = 0.396 L·min^{-1})	VO$_{2peak}$ (L·min^{-1}) = 6.214–.680(300-yd SWR Time) + .785(Gender)
Equation 3 (R = .919; *SEE* = 0.360 L·min^{-1})	VO$_{2peak}$ (L·min^{-1}) = 4.501–.550(300-yd SWR Time) + .611(Gender) + .017(Body Weight)
Equation 4 (R = .861; *SEE* = 0.457 L·min^{-1})	VO$_{2peak}$ (L·min^{-1}) = .373–.669(300-yd SWR Time) + 3.875(Height/Water Depth)
Equation 5 (R = .898; *SEE* = 0.402 L·min^{-1})	VO$_{2peak}$ (L·min^{-1}) = 5.676–.659(300-yd SWR Time) + .766(Gender)
Equation 6 (R = .920; *SEE* = 0.364 L·min^{-1})	VO$_{2peak}$ (L·min^{-1}) = 6.006–.607(300-yd SWR Time) + .661(Gender) + .017(Body Weight)—.809(Height/Water Depth)

Note. The 300-yd SWR time was measured in min; gender was coded as female = 0 and male = 1; body weight was measured in kg; and height and water depth were measured in cm.

300-yd SWR time, indicating that the 300-yd SWR time accounted for 70.6% of the variance in VO_{2peak}. The highest correlation (R = .920; SEE = 0.364 L·min^{-1}) was achieved in Equation 6 when the variables of gender, body weight, and height/water depth were included with the 300-yd SWR time. Hence, gender, body weight, height/water depth, and 300-yd SWR time combined to account for 84.6% of the variance in VO_{2peak}.

The multiple regression equations for predicting VO_{2peak} from the 500-yd SWR time are presented in Table 4. Again, a high correlation (R = .865; SEE = 0.443 L·min^{-1}) existed in the basic Equation 1 for predicting VO_{2peak} from the 500-yd SWR time, revealing that the 500-yd SWR time accounted for 74.8% of the variance in VO_{2peak}. When the variables of gender, body weight, and leg length were included with the 500-yd SWR time, the highest correlation and lowest SEE were achieved in Equation 4 (R = .940; SEE = 0.316 L·min^{-1}). Thus, gender, body weight, leg length, and 500-yd SWR time combined to account for 88.4% of the variance in VO_{2peak}. In Equation 8, the addition of height/water depth to the variables of gender, body weight, and leg length for predicting VO_{2peak} resulted in a R = .940 and SEE = .320 L·min^{-1}. Hence, height/water depth, gender, body weight, leg length, and 500-yd SWR time combined to account for 88.4% of the variance in VO_{2peak}.

The effect of footwear on the 500-yd SWR time has been tested, and a correction factor for the 500-yd SWR equations has been developed to convert 500-yd SWR footwear (FW) time in minutes to 500-yd SWR barefoot (BF) time in minutes (Clemens & Cisar, 2006). The correction equation is BF_{time} = .897 (FW_{time}) + 1.12 (r = .97, SEE = 0.1785 min). This equation provides a method to adjust 500-yd SWR run times for males and females who wear footwear during the 500-yd SWR test.

Summary and Discussion of the Multiple Regression Analyses

Similar to the results of previous research (e.g., George et al., 1993; Jackson et al., 1992; George et al., 1992; Kline et al., 1987), test time was identified as an appropriate variable in the development of regression equations to predict VO_{2peak} in the current study. In fact, the most simple equations in the current study required either a specific 300-yd or 500-yd SWR time, and produced high correlations and reasonable standard errors of estimate for predicting VO_{2peak} from both the 300-yd SWR (R = .840; SEE = 0.480 L·min^{-1}) and 500-yd SWR (R = .865; SEE = 0.443 L·min^{-1}) times. In other words, the 500-yd SWR time accounted for slightly more (4.2%) of the variance in VO_{2peak} than the 300-yd SWR time (74.8 vs 70.6%, respectively).

The highest correlation (R = .920; SEE = 0.364 L·min^{-1}) for the 300-yd SWR time was achieved in Equation 6 when the variables of gender, body weight, and height/water depth were included. The identified predictor variables in Equation 6 combined to account for 84.6% of the variance in VO_{2peak}. Gender and body weight were previously identified as appropriate variables to include in the development of regression equations to predict VO_{2peak} (e.g., George et al., 1992, 1993; Jackson et al., 1992; Kline et al., 1987).

Table 4   Multiple Regression Equations for Predicting Peak Oxygen Uptake Rate (VO_{2peak}) from 500-yd Shallow Water Run (SWR) Time

Equation Values	Equation for VO2peak Prediction
Equation 1 (R = .865; *SEE* = 0.443 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 9.033–.685(500-yd SWR Time)
Equation 2 (R = .912; *SEE* = 0.368 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 6.675–.447(500-yd SWR Time) + .717(Gender)
Equation 3 (R = .931; *SEE* = 0.333 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 5.051–.374(500-yd SWR Time) + .552(Gender) + .016(Body Weight)
Equation 4 (R = .940; *SEE* = 0.316 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 8.980–.482(500-yd SWR Time) + .609(Gender) + .018(Body Weight)—.037(Leg Length)
Equation 5 (R = .880; *SEE* = 0.427 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 2.336–.475(500-yd SWR Time) + 3.093(Height/Water Depth)
Equation 6 (R = .912; *SEE* = 0.374 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 7.045–.455(500-yd SWR Time) + .731(Gender)—.192(Height/Water Depth)
Equation 7 (R = .932; *SEE* = 0.335 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 7.354–.424(500-yd SWR Time) + .632(Gender) + .017(Body Weight)—1.247(Height/Water Depth)
Equation 8 (R = .940; *SEE* = 0.320 L·min⁻¹)	VO_{2peak} (L·min⁻¹) = 8.158–.467(500-yd SWR Time) + .572(Gender) + .018(Body Weight)—.041(Leg Length) + .692(Height/Water Depth)

Note. The 500-yd SWR time was measured in min; gender was coded as female = 0 and male = 1; body weight was measured in kg; and, leg length, height and water depth were measured in cm.

Likewise, when the variables of gender, body weight, and leg length were included with the 500-yd SWR time, the highest correlation and lowest *SEE* were achieved in Equation 4 (R = .940; *SEE* = 0.316 L·min^{-1}). In Equation 8, height/water depth was added to the variables of gender, body weight, and leg length for predicting VO$_{2peak}$ from the 500-yd SWR time, which resulted in R = .940 and *SEE* = 0.320 L·min^{-1}. The predictor variables previously identified in both Equations 4 and 8 to predict VO$_{2peak}$ both combined to account for 88.4% of the variance in VO$_{2peak}$.

Stepwise multiple regression analyses revealed that in addition to the 300-yd SWR time, gender and body weight improved the prediction of VO$_{2peak}$ as the multiple correlation coefficients increased from .840 to .919 and the standard errors of estimate decreased from 0.480 to 0.360 L·min^{-1}. It is interesting to note that the variance accounted for in VO$_{2peak}$ improved by 13.9% when the 300-yd SWR time, gender, and body weight were combined as compared with using only the 300-yd SWR time to predict VO$_{2peak}$. From a practical standpoint, the addition of the calculated variable of height/water depth into a developed equation may increase the usefulness of the equations in swimming pools that differ from the 106.68 cm (3.5 ft or 42 in.) water depth used in the current study.

Similarly, the addition of gender, body weight, and leg length improved the prediction of VO$_{2peak}$ from the 500-yd SWR time, as the multiple correlation coefficients increased from .865 to .940 and the standard errors of estimate decreased from 0.443 to 0.316 L·min^{-1}. In fact, the variance accounted for in VO$_{2peak}$ improved by 13.6% when the 500-yd SWR time, gender, body weight, and leg length were combined as compared with using only the 500-yd SWR time to predict VO$_{2peak}$. In summary, forward multiple regression analyses that added height/water depth to the equations generally tended to improve the prediction of VO$_{2peak}$, and improvements in the variance accounted for in VO$_{2peak}$ for comparable equations utilizing similar variables.

Conclusions

The purposes of the current study were to evaluate and compare the validity of both the 300-yd and 500-yd shallow water run field tests to determine peak aerobic power (VO$_{2peak}$). The participants included 18 men and 18 women, aged 21.25–48.42 yr, who had laboratory assessments of height, leg length, body weight, and percent body fat; followed by a graded exercise treadmill test to determine VO$_{2peak}$. Within a week of the laboratory assessments, the participants completed a 300-yd and 500-yd SWR for time. VO$_{2peak}$ was highly correlated to 300-yd and 500-yd SWR times. In addition, both height and leg length were highly correlated to both SWR times. The strongest correlation was found between the 300-yd and 500-yd SWR times.

Multiple regression analyses revealed that the prediction of VO$_{2peak}$ from the 300-yd SWR time improved by including gender and body weight accounting for 84.5% of the variance in VO$_{2peak}$. Similarly, the prediction of VO$_{2peak}$ improved from the 500-yd SWR time by including gender, body weight, and leg length accounting for 88.4% of the variance in VO$_{2peak}$. Equations were also developed for use in pools of water depths that differed from the depth used in the current

study. In conclusion, the 300-yd and 500-yd SWR tests, especially if used with the discussed variables, can provide accurate and valid estimates of aerobic capacity in adult men and women.

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