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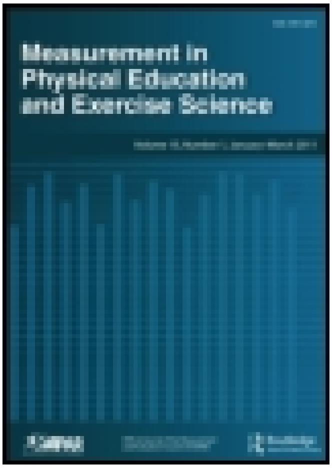

Measurement in Physical Education and Exercise Science
Publication details, including instructions for authors and subscription information:
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Published online: 18 Nov 2009.

To cite this article: Dawn Huse , Patricia Patterson & Jeanne Nichols (2000) The Validity and Reliability of the 12-Minute Swim Test in Male Swimmers Ages 13-17, Measurement in Physical Education and Exercise Science, 4:1, 45-55, DOI: 10.1207/S15327841Mpee0401_5

To link to this article: http://dx.doi.org/10.1207/S15327841Mpee0401_5

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MEASUREMENT IN PHYSICAL EDUCATION AND EXERCISE SCIENCE, *4*(1), 45–55
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The Validity and Reliability of the 12-Minute Swim Test in Male Swimmers Ages 13–17

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The purpose of this study was to examine the validity and reliability of the Cooper 12-min swim test in high school male swimmers ages 13 to 17. Thirty-three boys performed three 12-min swims and 1 maximal graded treadmill test within a 14-day period. One practice swim was conducted 1 week prior to participation in this study. VO_{2max} was assessed by indirect calorimetry with open-circuit spirometry with the Truemax 2400 metabolic cart (Consentius Technologies, Sandy, UT). Test–retest reliability of the 12-min swim assessed via 1-way analysis of variance indicated moderate reliability (R = .66, 95% confidence interval [CI] = .42–.81), whereas concurrent validity assessed via a Pearson product–moment correlation indicated a moderate relation (r = .47, 95% CI = .15–.70, r^2 = .22). Results indicate that the Cooper 12-min swimming test is only moderately reliable after 2 practice swims and does not appear to be a valid field test of aerobic capacity in high school male swimmers ages 13 to 17.

Key Words: aerobic capacity, physical fitness, swimming, oxygen consumption

Physical activity and physical fitness are important for people of all ages. Several studies (Blair et al., 1993; Fletcher et al., 1992; Powell, Thompson, Caspersen, & Kendrick, 1987) have indicated that inactivity is a primary risk factor for coronary heart disease (CHD), with consequences as serious as hypertension, hypercholesterolemia, and smoking. Furthermore, aerobic exercise can help mitigate or control diabetes, obesity, hypertension, and blood lipid abnormalities, thus decreasing the risk of CHD (Fletcher et al., 1992). It is the opinion of the American College of Sports Medicine (ACSM; 1995) that public health will continue to benefit by “getting more people more active more of the time” (p. 4).

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Recommendations about the importance of physical activity for children and youth are contained in statements by the ACSM (1988), the National Institutes of Health (1995) *NIH Consensus Statement,* and *Healthy People 2000* (Public Health Services, U.S. Department of Health and Human Services, 1991). These articles recommend at least 30 min of moderately intensive physical activity each day. Furthermore, increases in the percentage of children participating in daily physical education are advocated as one method of assisting the promotion of the public health of children and youth.

Physical fitness testing is a common method of providing information about the status of a student. Results of these tests can be used as feedback to students and parents and as feedback to teachers on any needed curricular changes that might enhance physical activity and, concomitantly, physical fitness. To ensure that scores students receive on these tests can be meaningfully interpreted, there must be evidence of their validity and reliability. Concurrent validity is generally examined by correlating scores obtained from a field test and a criterion test, whereas reliability is determined by examining the consistency of test scores across multiple trials or days.

The criterion test for cardiovascular fitness is *maximal oxygen uptake* (VO_{2max}), which is the highest rate oxygen can be taken up and utilized by the body during exercise (Cureton, 1994). However, because these tests are time consuming and require special equipment and trained personnel, investigators have searched for field tests that can be administered to large groups of people, utilizing minimal equipment in a relatively short period of time.

Several studies have examined the validity and reliability of various field tests of cardiovascular fitness in high school students. These include the 12-min run–walk test (Doolittle & Bigbee, 1968; Maksud & Coutts, 1971), the 1-mile run or walk (Buono, Roby, Micale, Sallis, & Shepard, 1991; McSwegin, Plowman, Wolff, & Guttenberg, 1998), the 20-meter shuttle run (Liu, Plowman, & Looney, 1992; van Mechelen, Hlobil, & Kemper, 1986), the 9-min run test (Safrit & Wood, 1987), and the step test (Buono et al., 1991; Metz & Alexander, 1967). In general, validity coefficients range from $r = .42$ to $r = .90$ with the majority of coefficients at about $r = .65$. Reliability coefficients ranged from $R = .61$ to $R = .92$.

Although most research has been conducted on running tests, it is important to examine the validity and reliability of other tests for those people who are not able to run or for those athletes who do not participate in running-centered events. One such alternative might be swimming. The Cooper 12-min swim test (Cooper, 1977) is a swimming field test that has been the target of limited research, with only two studies examining its measurement properties. Conley, Cureton, Dengel, and Weyand (1991) employed 36 men, ages 18 to 32, and examined validity by correlating swim distances obtained from the 12-min swim test to peak oxygen uptakes obtained from a continuous, grade-incremented treadmill running protocol. The resultant correlation was $r = .38$. A second study (Conley, Cureton, Hinson,

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Higbie, & Weyand, 1992) examined both the validity and reliability of the 12-min swim test in 34 women, ages 18 to 34. Results indicated a validity coefficient of r = .34 and a test–retest reliability (within 7 days) of R = .98.

No other studies were found that examined the validity or reliability of the 12-min swim test. Moreover, these properties, particularly validity, are population specific. Therefore, the purpose of this study was to examine the validity and reliability of the 12-min swim test in high school male swimmers.

METHODS

Participants

Thirty-three boys between 13 and 17 years of age participated in this study. These boys were recruited from high school aquatics programs in the southwestern United States and had participated in at least one season of either high school swimming or water polo. All swimmers were in the 3rd week of the high school swimming season at the start of testing. They completed the Physical Activity Readiness Questionnaire (Thomas, Reading, & Shepard, 1992) along with an informed assent and parental permission consent forms prior to participation. As part of the testing procedures, all 33 students performed three 12-min swimming tests at his respective high school or age-group swimming pool as well as one maximal graded exercise test at a southwestern university. One week prior to participating in the three 12-min swimming tests, each student completed a practice 12-min swim to become familiar with the testing protocol.

Testing

Order of test completion was counterbalanced to avoid any testing effect. The swimming tests were conducted on 3 different days separated by 48 to 72 hr, with all testing completed within a 14-day period. Participants were asked to refrain from eating a large meal prior to their tests and to refrain from vigorous exercise on the day of their tests. At their first assigned meeting, students were asked their age; how many seasons they had participated in high school swimming, high school water polo, or both; their best event; and how many yards per week they trained in the pool.

Cooper 12-min swim test. The participant arrived at his respective high school or age group swimming pool prepared to swim. A 5-min warm-up took place after which the following instructions were given:

> You will have 12 minutes to swim as far as possible. You may rest when necessary, and you must use open turns instead of flip turns. You may begin on my go.

At the conclusion of 12 min, the total distance covered was measured to the nearest yard by means of a tape measure that was placed at the edge of the pool adjacent to the swimming lanes. After completing the 12-min swim, the swimmer's radial pulse was taken for 15 sec, and the time it took him to find and begin counting his pulse was recorded. Radial pulse was taken by each participant at the conclusion of the 12-min swim because the majority of the swimmers completed the time allotment in the middle of the pool. When the swimmer heard the whistle indicating the conclusion of the 12 min, he stood where he was and began taking his pulse by looking at a pace clock on the edge of the pool. These procedures were practiced during the initial swim trial 1 week prior to the start of the study. Identical procedures were followed for each of the three swimming tests.

Maximal graded exercise test. The student arrived at the exercise physiology laboratory prepared to perform a maximal graded exercise test. Height and weight with shoes removed were measured and recorded to the nearest centimeter and kilogram, respectively. He then was familiarized with the testing procedures, the Quinton Model 65 treadmill (Quinton, Seattle, WA), the Truemax 2400 metabolic cart (Consentius Technologies), the Hans–Rudolph mouthpiece (2700B, Hans Rudolph, Inc., Kansas City, MO), and fit with a Polar Heart Rate Monitor (Country Technologies, Gays Mills, WI). A 5-min warm-up on the treadmill took place at a speed and grade that felt comfortable. During the warm-up, the participant wore the mouthpiece and headgear to become familiar with the equipment.

Maximal oxygen consumption (VO_{2max}) was determined by indirect calorimetry with open circuit spirometry. Prior to testing, the Truemax 2400 metabolic cart was calibrated with room air and known samples of oxygen and carbon dioxide. Boys were familiarized with the maximal graded exercise test protocol and told about the importance of exercising to exhaustion. The test protocol consisted of one 3-min stage at 3 mph and 0% grade and one 3-min stage at a speed up to 6 mph and 0% grade followed by 1-min stages increasing the grade 2% every minute until the participant could no longer run. The final speed was determined by the participant's comfort level and ability. Expired air was collected continuously and analyzed every 30 sec for O_2 and CO_2 content. At the conclusion of the test, the student was monitored until his heart rate returned to near preexercise values.

Statistical Analysis

Descriptive statistics, including means and standard deviations, were calculated for all variables. Test–retest reliability and 95% CIs were calculated as recommended by Morrow and Jackson (1993) for the swimming tests, using an intraclass correla-

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tion coefficient (*R*) obtained from a one-way analysis of variance (ANOVA). Reliability for 1 day of testing was estimated using the formula suggested by Baumgartner (1989). A one-way repeated measures ANOVA was employed to determine whether there were significant differences between swimming test scores. The validity of the Cooper 12-min swim test was calculated with a Pearson product–moment correlation (*r*) and 95% CIs to examine the relation between the 12-min swim and VO_{2max}. In addition, the coefficient of determination (r^2) was calculated to determine the amount of shared or explained variation between the 12-min swim and VO_{2max}.

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RESULTS

Means and standard deviations of physical characteristics of the participants are presented in Table 1. Seventy-six percent ($n = 25$) of the boys considered swimming their best aquatic event, whereas 24% ($n = 8$) considered water polo their best aquatic event. Aquatic experience ranged from 1 to 8 years. Their training level ranged from 16,000 to 50,000 yards per week, with 76% of the boys swimming an average of 16,000 yards per week. Table 2 provides the performance data.

A one-way repeated measures ANOVA indicated a significant difference between swimming performance across the 3 testing days, $F(2, 64) = 6.54$, $p = .0026$. Post hoc tests using Tukey HSD indicated a significant difference between Swim 1 and Swim 3, with no other significant differences being detected. Therefore, subsequent analyses were conducted on Swim 2 and Swim 3.

Reliability

Test–retest reliability (and 95% CIs) for Swims 2 and 3 indicated moderate reliability ($R = .66$, 95% CI = .42 to .81). As expected, when reliability was estimated for a single trial, it decreased ($R = .49$, 95% CI = .22 to .71).

TABLE 1
Means and Standard Deviations of Descriptive Data ($N = 33$)

Characteristics	*M*	*SD*
Age (year)	15.72	1.01
Height (cm)	178.62	5.15
Weight (kg)	68.12	9.08
Body mass index	21.31	2.39

TABLE 2
Means and Standard Deviations of Performance Data ($N = 33$)

Variable	*M*	*SD*
Distance		
Swim 1 Distance (yard)	833.09	109.48
Swim 2 Distance (yard)	863.21	73.54
Swim 3 Distance (yard)	888.61	66.27
Mean of Swims 2 and 3 (yard)	875.91	61.19
Swim heart rate[a] (bpm)	135.30	24.78
VO_{2max} (ml/kg/min)	62.15	7.62
Maximum heart rate[b] (bpm)	194.42	9.08

Note. bpm = beats per minute.
[a]Refers to the average of the two heart rates that were measured immediately following the 12-min swimming test. [b]Refers to the maximum heart rate achieved while running on the treadmill.

Validity

The treadmill test indicated that, as a group, the boys reached approximately 95% of their age-predicted maximum heart rate, whereas 89% of the boys achieved a respiratory exchange ratio greater than 1.05. The concurrent validity coefficient between the average of Swims 2 and 3 to VO_{2max} indicated low to moderate validity ($r = .47$, 95% CI = .15–.70, $r^2 = .22$).

Figure 1 provides a scattergram presenting the relation between 12-min swim distance and VO_{2peak}.

DISCUSSION

Coaches and practitioners continually search for field tests that are inexpensive, quick, and easy to administer but at the same time provide meaningful information about athletes' abilities. In this study, the validity and reliability of the Cooper 12-min swim test as a measure of cardiorespiratory endurance were examined in high school male swimmers.

Reliability

Test–retest reliability for the swim test was examined across three trials spaced 2 to 3 days apart. Significant differences were found between Trials 1 and 3, suggesting the need for at least one practice trial. However, of even more importance is the finding that reliability for the average of Swim Trials 2 and 3 was $R = .66$, whereas it decreased to $R = .49$ when estimated for a single trial.

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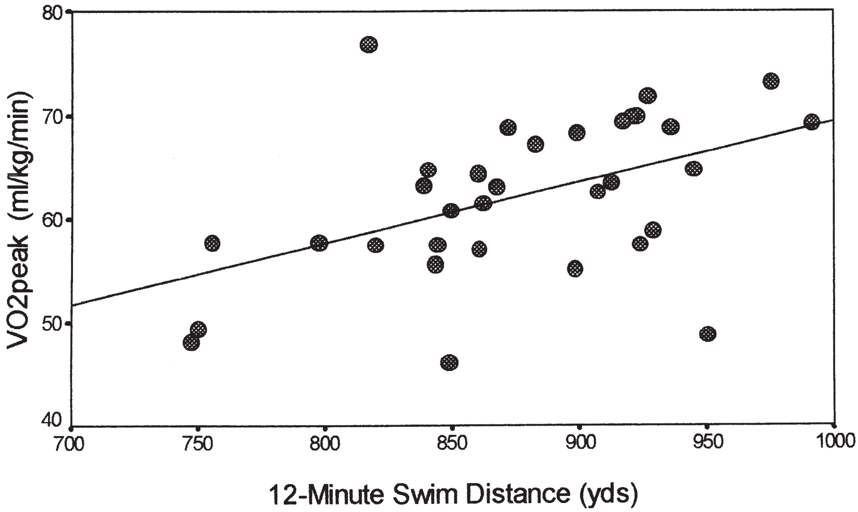

FIGURE 1 Scatter diagram and linear regression line describing the relation between 12-min swim distance (yards) and treadmill VO_{2peak} (ml/kg/min; $Y = 10.69 + .059x$, $r = .47$, SEE [standard error of estimate] = 6.82).

Reliability is affected by several factors, one of which is the variability of the group. In general, detecting reliable differences is easier (i.e., reliability is higher) in a heterogeneous group than a homogeneous group. The participants in this study were all high school swimmers, and the performance data in Table 2 suggest that this group was rather homogeneous. Thus, the moderate findings for reliability were not altogether unexpected.

Another factor affecting reliability is the motivation or effort level of the participants, with maximal efforts yielding higher reliability. A practice swim trial was completed prior to data collection in addition to Trial 1 being eliminated from analysis. The swimmers also self-reported that each felt he had “done his best.” However, it is possible that pacing problems confounded the ability of the swimmers to give a maximal effort in this single-stage field test. Although the participants were experienced swimmers and, therefore, accustomed to swimming intervals during their training, the 12-min test was considerably longer than the interval training in which they engaged. In an attempt to determine the relative intensity of each field trial, pulse rate was taken immediately on completion of each trial. Although the participants received instruction and practice in palpating their radial pulse, the accuracy of this procedure is questionable. Thus, the recorded heart rates may not accurately reflect the true intensity of the trials. Use of a downloadable waterproof heart rate monitor, not possible in this study, would improve

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the ability to examine these issues and provide more definitive information about the swimmers' efforts.

The results of this study demonstrate lower reliability than those reported previously on other field tests of cardiovascular fitness on adolescents of similar ages (Buono et al., 1991; Liu et al., 1992; Safrit & Wood, 1987). These studies reported reliability coefficients ranging from R = .80 to R = .95. Reasons for these differences are not readily apparent but may be a function of sample variability and motivation level.

Conley et al. (1992) examined test–retest reliability of the 12-min swim with college-age women and reported much higher reliability, R = .98, for two trials. One possible reason for the higher reliability in the Conley et al. study is the larger variance in their sample. These women swam, on average, about 278 yards less than the swimmers in this study, yet the standard deviation was 21 yards larger than that reported in this study.

Validity

Concurrent validity is determined by examining the strength of the relation between the field and criterion tests. In this case, the field test was the 12-min swim test, whereas the criterion test was VO_{2max} measured during a maximal graded treadmill test and the resultant validity coefficient was r = .47. To examine validity properly, a maximal effort is required for both tests. Empirical evidence collected during the treadmill test indicates that participants gave a maximal effort. However, self-report heart rates provide the only evidence for the level of effort put forth during the swim test. Although the boys swam, on average, at 70% of their maximum heart rate measured on the treadmill, several factors may account for this seemingly low intensity. First, heart rate during prone exercise is approximately 12 bpm lower than that during upright exercise (DiCarlo, Sparling, Millard-Stafford, & Rupp, 1991). Second, heart rate was palpated at the end of the swim. This likely underestimated the true heart rate during the swim. Third, lack of extensive experience in taking one's pulse may have caused the swimmers to miss some beats while counting the rapid rates associated with the exercise. Thus, the true exercise heart rates were probably considerably higher than those reported.

Two of the most important factors affecting the validity of this test are swimming skill and experience in pacing. Due to the drag created by water, skill in swimming is a crucial determinant of success in a timed test. Individuals with a similar VO_{2max} but greater skill will cover a far greater distance in 12 min compared to an unskilled swimmer. Similarly, experience in pacing is critical to the results. Although there was no difference statistically between Trials 2 and 3, the boys swam, on average, 25 yards farther in Trial 3 than in Trial 2. This suggests that they were still improving their ability in pacing to optimize the distance cov-

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ered in 12 min. Thus, both pacing and swimming skill may be confounding variables when examining the validity of the 12-min swim test.

An additional factor affecting validity is the choice of criterion test. This study employed a multistage treadmill test for VO_{2max} assessment. This decision was based on previous research examining the effect of protocol on VO_{2max} assessment. Two studies (Holmer, Lundin, & Eriksson, 1974; Holmer, Stein, Saltin, Ekblom, & Astrand, 1974) employed elite trained swimmers and examined whether there were differences in VO_{2max} obtained while swimming in a flume or while running on a treadmill. In both studies, VO_{2max} scores were significantly lower when conducted in a swimming flume. In fact, Holmer, Stein, et al. (1974) found VO_{2max} scores to be 17% lower in the flume than on the treadmill. The authors cited the difficulty of the swimmers in achieving a comfortable swimming position while wearing a mouthpiece as possible reasons for this discrepancy. Thus, it was felt that a treadmill protocol would yield the most accurate assessment of VO_{2max}.

Results of this study are similar to both studies by Conley and colleagues (Conley et al., 1991; Conley et al., 1992), who also compared the 12-min swim test to a maximal graded treadmill test. Validity coefficients were $r = .38$ and $r = .34$ for college-age men and women, respectively. However, the validity coefficient of $r = .47$ in this study is lower than coefficients reported with other field tests of cardiovascular endurance in adolescents.

In summary, the findings of this study suggest that the 12-min swim test may not possess adequate validity or reliability as a measure of cardiovascular fitness in high school male swimmers. However, the test does have practical use as a measure of progress in training for competitive and recreational swimmers. To better determine the level of effort during a swim test and, therefore, possibly elucidate the confounding effects of motivation, it is recommended that future studies employ downloadable heart rate monitors to improve the accuracy of heart rate scores during swimming. It is suggested that this test be used only as a measure of swimming progress or improvement.

ACKNOWLEDGMENTS

Dawn Huse was a graduate student in Exercise Physiology at San Diego State University at the time of this study.

This work was completed in partial fulfillment of the requirements for a master of science degree.

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