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THE TEACHING AND MEASUREMENT
OF SWIMMING EFFICIENCY

David Carl Bow

A dissertation presented to the
Graduate Faculty of Middle Tennessee State University
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THE TEACHING AND MEASUREMENT
OF SWIMMING EFFICIENCY

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ABSTRACT

THE TEACHING AND MEASUREMENT OF SWIMMING EFFICIENCY

by David Carl Bow

The purpose of this study was to investigate the use of a number of methods of measurement and to compare two methods of teaching college-level swimming classes. Twenty-one students enrolled in two intermediate swimming classes at Middle Tennessee State University were used as subjects. A form rating scale and an experimental method of measuring swimming efficiency were developed for this study. The results of these tests were treated by the computation of coefficients of correlation between each of them and the items of a battery of objective published tests. This test battery included the Fox power test, the Hewitt fifty yard crawl for time, and the Burris speed-stroke test of the crawl. The findings indicated significant correlations between the form rating scale and each of the items of the test battery. Each of the items of the test battery were significantly correlated with each other. None of the correlations between the experimental method of measuring swimming efficiency and the items of the test battery were significant. The correlations between the experimental method and a combination of variables of the test battery were too small for the development of a prediction formula for swimming efficiency by means of stepwise multiple linear regression analysis.

The two methods of teaching compared in the study consisted of a traditional approach and a mechanical principles approach. Two-way analysis of variance with repeated measures failed to indicate any significant difference in the performance of groups taught by either method.

ACKNOWLEDGEMENTS

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Chapter 1

INTRODUCTION

College level physical education swimming classes have often dealt with a variety of objectives. These objectives have typically related to swimming skill, safety, and recreation. From the student's point of view, the enjoyment of aquatic activities as a recreational pursuit has led to increased interest in swimming activities. Emphasis on the importance of learning to swim as a possible preventive measure was brought to public attention in the United States by such tragedies as the 1974 drowning rate of 8,100.[1] Fundamental among the stated objectives of such swimming courses has often been one that the student be able to demonstrate a certain level of efficiency in propelling his body through the water. The development of this swimming efficiency objective was selected as the focal point of investigation for this study. The purpose of concentrating on the particular objective of swimming efficiency was that it enhanced the chances of achieving the other objectives of safety and recreation as well as skill.

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[1] Accident Facts (Chicago: The National Safety Council, 1975), p. 6.

Evidence was reported which suggested that an effective approach to achieving the water safety objective was the development of efficiency in swimming. The American National Red Cross reported that the nation-wide effort to teach everyone to swim reduced the drowning rate from 10.2 per hundred thousand population in 1914 to a recent rate of 3.6 per hundred thousand population.[2] Furthermore, Hewitt suggested that the development of such skills was a means of increasing the satisfaction and enjoyment that comes from swimming as a recreational pursuit.[3]

STATEMENT OF THE PROBLEM

Swimming instructors have often been faced with a number of problems in the conduct of college level swimming classes. In regard to the swimming efficiency objective, the instructor has typically been faced with decisions regarding both the presentation of material and the evaluation of the results. Specifically, the following questions have arisen: (1) Can the swimming efficiency of a group of students in a class situation be evaluated by a form rating scale? (2) Can the swimming efficiency of a

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[2] Swimming and Water Safety (Washington, D.C.: The American National Red Cross, 1968), p. 110.

[3] Jack E. Hewitt, "Swimming Achievement Scale Scores for College Men," Research Quarterly, XIX (December, 1948), 283.

given student be accurately predicted from that student's performance on a battery of practical field tests? (3) Would students make greater accomplishments in swimming skills if a portion of the class time were spent in the classroom covering the mechanical principles involved in the skills? Thus, the purposes of this study were to assess the relative effectiveness of two methods of teaching students to swim efficiently and also to assess the effectiveness of various methods of evaluating the degree of efficiency with which the students swam.

IMPORTANCE OF THE STUDY

The task of instruction has often been compounded by overcrowded classes, inadequate facilities, inadequate time allotments, and heterogeneous groups in terms of swimming ability. Therefore, college swimming instructors have searched for the most economical and efficient methods of teaching and presenting subject matter to their students. After studying the effects of different approaches to teaching swimming, Mohr and Barrett recommended that further research be conducted on the effectiveness of instruction in mechanical principles.[4]

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[4] Dorothy R. Mohr and Mildred E. Barrett, "Effect of Knowledge of Mechanical Principles in Learning to Perform Intermediate Swimming Skills," Research Quarterly, XXXIII (December, 1962), 574-580.

Considered to be of equal importance to the presenting of the material was the evaluation of the results. According to Rosentswieg, form ratings have continued to be the primary method of evaluation for swimming classes.[5] The problem with such rating scales and achievement charts, as was pointed out by Parkhurst, was the fact that they often depended on the instructor's subjective judgment, and the way in which they were used to compute students' grades varied greatly.[6] Karpovich also pointed out that the correction of errors in swimming performance was much of an art and depended on the subjective qualities of the instructor. He further stated:

> A proper arm action, a degree of flexion in the joints, an amount of body rotation, cannot be accurately measured while a man is swimming; however, a deviation from the correct way can be noticed by an experienced coach. This will probably continue forever, bringing quite satisfactory results, nevertheless any method which can be used for an objective analysis of performance will be of great help.[7]

Thus, the literature suggested a need for further research in the area of the evaluation of swimming performance. The findings of such research were felt to

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[5] Joel Rosentswieg, "A Revision of the Power Swimming Test," Research Quarterly, XXXIX (October, 1968), 818.

[6] Mary Grant Parkhurst, "Achievement Tests in Swimming," Journal of Health, Physical Education and Recreation, V (May, 1934), 34.

[7] Peter V. Karpovich, "Analysis of the Propelling Force in the Crawl Stroke," Research Quarterly, VI (May, 1935), 49.

hold important implications for teaching college level swimming classes because of the common task among swimming instructors of the evaluation of students for the purpose of assigning grades. In addition, studies have shown the provision of feedback to be crucial to the learning process.[8] The evaluation of student performance has often played an important role in the process of providing such feedback. In this light, the improvement of the evaluation process appeared to hold great potential in the improvement of instruction.

The study contributed new information in the areas of instruction and evaluation in college level swimming classes. Unique aspects of the study were the development of a form rating scale and an experimental method for measuring swimming efficiency. In addition, the study shed light upon the issue concerning the relative value of two teaching techniques.

HYPOTHESES

For the purposes of this study the following statistical hypotheses were stated:

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[8] John N. Drowatzky, Motor Learning Principles and Practice (Minneapolis: Burgess Publishing Company, 1975), pp. 100-103.

H_1: There was no significant difference between the pre-test and the post-test data of the experimental group in swimming efficiency.

H_2: There was no significant difference between the pre-test and the post-test data of the control group in swimming efficiency.

H_3: There was no significant difference between the post-test data of the experimental group and the control group in swimming efficiency.

H_4: There was no significant relationship between the results of the experimental method of measuring swimming efficiency and the results of the Fox power test.

H_5: There was no significant relationship between the results of the experimental method of measuring swimming efficiency and the results of the Hewitt fifty yard crawl for time.

H_6: There was no significant relationship between the results of the experimental method of measuring swimming efficiency and the results of the Burris speed-stroke test of the crawl.

H_7: The relationship between the experimental method of measuring swimming efficiency and a combination of predictor variables of the battery of practical field tests was too small for the development of a prediction formula by means of stepwise multiple linear regression analysis for swimming efficiency.

H_8: There was no significant relationship between the results of the form rating scale and the results of the experimental method of measuring swimming efficiency.

H_9: There was no significant relationship between the results of the form rating scale and the results of the Fox power test.

H_{10}: There was no significant relationship between the results of the form rating scale and the results of the Hewitt fifty yard crawl for time.

H_{11}: There was no significant relationship between the results of the form rating scale and the Burris speed-stroke test of the crawl.

The .05 level was used to determine significance.

DEFINITIONS OF TERMS

The following terms were utilized in the study:

Efficiency. Work output divided by work input.

Swimming efficiency. The percentage of the student's maximum swimming working capacity, as indicated by his oxygen uptake level during a one minute, all-out tethered swim, that was required for the subject to complete a one minute tethered swim with the work load comparable to that required for the subject to propel himself through the water at a specific sub-maximal rate.

Experimental method of measuring swimming efficiency. A measurement of swimming efficiency based upon the subject's oxygen uptake level during a one minute sub-maximal tethered swim.

Swimming ergometer. A device designed to measure the propulsive force generated by a swimmer.

Tethered swimmer. A swimmer held in a relatively stationary position in the water.

Free swimming. Swimming while not restrained by any tethering device or other apparatus.

Resistance. The force which the swimmer must overcome in order to move through the water.

Propulsion. The force generated by the swimmer.

Traditional method of instruction. A method of instruction which employed the whole-part-whole method. Material was deomonstrated, explained verbally by the instructor, broken down into its component parts, practiced by the students in parts, and finally practiced as a whole under the instructor's guidance.

Experimental method of instruction. A method of instruction which employed all of the features of the traditional method plus classroom isntruction on the mechanical principles related to the skill being taught.

Control group. A class of students enrolled in intermediate swimming at Middle Tennessee State University during the Spring Semester of 1977 who were taught by the traditional method.

Experimental group. A class of students enrolled in intermediate swimming at Middle Tennessee State University during the Spring Semester of 1977 who were taught by the experimental method of instruction.

LIMITATIONS

The study was conducted under conditions of the following limitations:

1. The study was limited to data that were collected on the American crawl swimming stroke.

2. The study was limited by the differences between tethered swimming and free swimming.

3. The use of the snorkel-like mouthpiece for the collection of the expired air for the measurement of oxygen uptake did not require the swimmer to practice rhythmic breathing.

4. The measurement of oxygen uptake during swimming was subject to being affected by the horizontal body position and the temperature of the water.

Chapter 2

REVIEW OF LITERATURE

The following review of literature was divided into two major sections: (1) methods of teaching and (2) methods of testing swimming performance. The first major section dealt with instruction in mechanical principles in swimming courses. The second major section related to the apparatus used for measuring swimming efficiency and also with methods of evaluating student performance in swimming. The section relating to the apparatus was further sub-divided into studies related to resistance and propulsion and into studies related to advancing physiological measures. In reviewing such studies, the purpose was not to give results, but to describe the apparatus for the test and how and for what purpose it was used.

METHODS OF TEACHING

The position taken by the American National Red Cross swimming program was that swimming movements were exact and that any deviation from the accepted range of motion resulted in a hybrid stroke. "To be successful . . . the student must be concerned with accuracy, coordination, speed, and energy expended while performing the movements," stated the Red Cross Instructor's Manual.[1]

Holt and Holt reported the development of Silvia's hand-foot concept as a unique approach to teaching beginning swimming by YMCA personnel. Siliva's method incorporated the basic principles of anatomy, kinesiology, psychology, neurology, and mechanics. The basic differences between this approach and the Red Cross method were its utilization of flotation devices and its not requiring students to place their faces in the water during the early lessons. Mechanical principles related to the laws of flotation, laws of levers, vectorial analysis, and the laws of motion were incorporated in the method. Such principles of motor learning as transfer, whole versus part learning, apprehension in learning, and attention to the task were also incorporated in the method. The authors also reported the results of two studies conducted to compare the Silvia method with the Red Cross method which showed a statistically significant difference in favor of the Silvia method.[2]

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[1] Swimming and Water Safety Courses Instructor's Manual (Washington, D.C.: The American National Red Cross, 1968), p. 7.

[2] Laurence E. Holt and Alyce F. Holt, "Silvia's Hand-Foot Concept," Journal of Physical Education, LXVIII (October, 1970), 179, 189.

Holt, Thorpe, and Holt compared the effectiveness of the Red Cross and the Silvia methods of teaching. The Silvia hand-foot concept incorporated basic principles of anatomy, kinesiology, psychology, neurology, and mechanics. The term, hand-foot concept, was based on the fact that the sensory or post-central gyrus and the motor or pre-central gyrus areas of the brain have a large number of neurons assigned to the hands and feet. Therefore, proper hand and foot movements were the focus of attention in this method. The application of proper mechanical principles in hand and foot movements during swimming was considered to be important because of the strategic position of the hands and feet at the ends of the limbs, the focal point for the application of muscular effort. Four classes of beginning swimming students, at Southern Illinois University, were used as subjects. Two classes were taught the Silvia method and two classes were taught the Red Cross method. The results indicated that group performances differed significantly in favor of the Silvia method on tests of distance and survival time. Subjects in the experimental group required significantly fewer days to pass the Red Cross combined skills tests; however, the percentages of subjects in the two groups who passed the Red Cross combined skill tests were comparable.[3]

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[3] Alyce Holt, Jo Anne Thorpe, and Laurence Holt, "Two Methods of Teaching Beginning Swimming," Research Quarterly, XLI (October, 1970), 371-377.

In summarizing a number of methods of teaching swimming, Thomsen stated that the effective instructor must utilize a variety of teaching methods. He further proposed that the student should learn skills and concepts other than just how to perform the swimming skill. "Did the student actually learn the skill presented or were the actions merely mimicked and memorized?", asked the author. He went on to say that "If we are to provide an atmosphere where people can explore and learn, we the instructors must also explore and learn methods. . . ." All teaching methods fell into two categories according to Thomsen. The categories included methods that evoked the discovery capacity of the students and those that did not. A strong argument was made in favor of the "whole-part-whole" method as opposed to the "part-whole-part" method. This argument was defended on the grounds that students often learned better when they were first shown just where the various part fit into the whole before they attempted to master these individual parts.[4]

Mohr and Barrett conducted research similar to the present study which investigated the effect of knowledge of mechanical principles in learning to perform intermediate swimming skills. The subjects for the study were thirty-one college women students enrolled in two intermediate swimming

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[4] Mike Thomsen, "Teaching Swimming," Journal of Physical Education, LXX (May, 1973), 112-113.

classes at the University of Maryland. The experimental group of fifteen students was taught mechanical principles related to the front crawl, back crawl, sidestroke, and elementary back stroke. The control group of sixteen students was taught in an identical manner except the instruction on mechanical principles was omitted. After eight weeks the results indicated that the experimental group had made significantly greater improvements than had the control group in the front crawl sprint, sidestroke power, and on form ratings of the front crawl, back crawl, and sidestroke. Further research was recommended on the effectiveness of instruction in mechanical principles.[5]

METHODS OF TESTING

The following studies appeared in the literature and were related to the apparatus and tests used in this study.

Apparatus

Various types of apparatus have been developed for the study of resistance and propulsion and for the measurement of physiological variables in swimming.

Resistance and propulsion. In a review of research on swimming, Faulkner reported that the measurement of propulsion and resistance involved towing swimmers to

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[5] Dorothy R. Morh and Mildred E. Barrett, "Effect of Knowledge of Mechanical Principles in Learning to Perform Intermediate Swimming Skills," Research Quarterly, XXXIII (December, 1962), 574-580.

determine the drag, pulling or pushing against a measurement device while swimming in a stationary position, pulling against a measurement instrument while swimming at various speeds, and theoretical calculations based upon the principles of fluid mechanics.[6]

Karpovich studied water resistance in swimming. In addition to his own study, Karpovich also reported the history of studies on water resistance in swimming. R. Du Bois-Reymond towed several persons behind a rowboat and measured the resistance by a dynamometer. G. Liljestrand and N. Stenström towed swimmers with a towing device from the shore with the rope running over a pulley which was fastened to a spring scale to measure the resistance. F. Houssay indirectly measured resistance by measuring the force that a swimmer could develop. Amar described a formula for water resistance to be:

Resistance equals $K \times S \times V^2$

K equaled 73 or 55.
S equaled the area in square meters of the greatest cross-section of the body.
V equaled the velocity of the swimmer.

Karpovich began his study for the purpose of collecting more accurate data relative to resistance of man in swimming. The swimmers were towed by a device which Karpovich called a

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[6] John A. Faulkner, "Physiology of Swimming," Research Quarterly, XXXVII (March, 1966), 41-54.

"resistograph." The device towed the swimmer by a rope which was wound around a drum by an electric motor. The rope passed through a system of pulleys, one of which was attached to a spring scale. The spring scale was attached to a kymograph which recorded the tension developed as a result of the water resistance which developed as the swimmer was towed through the water. With the device, Karpovich studied the resistance caused by such things as speed, different stroke positions, skin friction, eddy resistance, wave making, lifting the head to breath, hydroplaning, acceleration, and wearing a bathing suit.[7]

Cake used an apparatus similar to that described by Karpovich to compare the relative effectiveness of two types of frog kicks. The swimmer swam against a rope which was fastened to a spring scale. A second rope extending from the swimmer to the opposite side of the pool prevented the swimmer from sliding back after each kicking action. Data were collected on subjects who could perform both the wedge type and the whip type kicks equally well. Data collected included: (1) pounds of force that the subjects exerted against the dynamometer, (2) the number of kicks, and (3) the time consumed to swim the length of a seventy-five foot pool. With the information gained from the use of this

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[7] Peter V. Karpovich, "Water Resistance in Swimming," Research Quarterly, IV (October, 1933), 201-204.

apparatus, Cake concluded that the whip kick was superior to the wedge type frog kick.[8]

Cureton studied the propulsive forces developed by the kick and listed the following reasons for the desirability of obtaining such data:

> (1) To compare the propulsive force of the flutter kick with other types of kicks.
>
> (2) To show the significance of weight of the feet in body position computations.
>
> (3) To compare swimmers with each other.
>
> (4) To use in computations of effective work done by the flutter kick, including the efficiency of the kick.[9]

To measure the propulsive forces developed by the kick, Cureton used an instrument called a "Kickmeter." This instrument was designed so that a board-shaped lever arm extended from a spring scale down to the surface of the water. As the swimmer exerted force with his kick, he pushed against the kickmeter lever arm with his hands which were extended above his head or with his head which was pressed against the board.[10]

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[8] Frances Cake, "The Relative Effectiveness of Two Types of Frog Kick Used in Swimming the Breast Stroke," Research Quarterly, XIII (May, 1942), 201-204.

[9] Thomas K. Cureton, Jr., "Mechanics and Kinesiology of Swimming," Research Quarterly, I (December, 1930), 107-108.

[10] Cureton, pp. 107-108.

Alley investigated the problems of water resistance and propulsion in the crawl stroke by means of an apparatus which had both the capacity to tow or to control the rate of a swimmer as he swam away from the device. The apparatus was powered by a one-horsepower electric motor which was equipped for reverse action. A rope from the swimmer was wound around a steel shaft which was turned by a V-belt and five-step pulley system connected to the motor. Speed was regulated by the pulley size. The entire apparatus was suspended so that the force exerted by the swimmer as he was being towed through the water could be measured. The propulsive force that could be exerted by the swimmer was calculated from the kymograph readings taken while the swimmer swam against the rope which was being let out at the same speed at which he had been towed. Since the swimmer had to produce enough force to propel his body at the speed of the rope before he could exert any force on the apparatus, the total propulsive force exerted by the swimmer was calculated by adding the force of resistance, which was measured by towing the swimmer, to the force which the swimmer exerted on the apparatus as he swam away from it.[11]

Counsilman improved upon the type of apparatus used in Alley's study. Alley suggested that a more stationary

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[11] Louis E. Alley, "An Analysis of Water Resistance and Propulsion in Swimming the Crawl Stroke," Research Quarterly, XXIII (October, 1952), 253-270.

platform be used since the cables which supported his apparatus permitted it to swing and interfered with the reading of the spring scale. Therefore, Counsilman constructed a similar device but mounted it on two steel beams instead of suspending it by cables. Four 5,000 ohm bobin type strain gauges were attached to each beam to measure the amount of force imparted to the platform by the swimmer as he swam away or as he was towed by the device. With this improved apparatus, Counsilman made extensive studies of water resistance and comparisons of various types of stroking effectiveness.[12]

Magel investigated the propelling force developed during tethered swimming in the crawl stroke, back stroke, butterfly, and breast stroke. The rope which the swimmer worked against ran through a system of pulleys and supported a counterweight. A force transducer was placed in the rope just above the weight. The transducer produced an electrical output which passed through an exciter demodulator and was recorded on a Sanborn recorder. The average propelling force for three minute swims was calculated from these recordings. The apparatus was used to compare the propelling force developed in four competitive strokes by twenty-six highly trained college swimmers. The

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[12] James E. Counsilman, "Forces in Swimming Two Types of Crawl Stroke," <u>Research Quarterly</u>, XXVI (April, 1955), 127-139.

conclusion was made that the propelling force developed during tethered swimming at zero velocity provided a good estimate of the force that could be developed during free swimming. Another finding showed greater average propelling force could be developed during swims of short duration than in swims of longer duration. The greatest propelling force developed by the swimmers in this study was during the breast stroke.[13]

Miyashita calculated the mechanical power developed by a single cycle of the breast stroke by means of underwater films and especially developed formulae for power and resistance. The data were collected on four swimmers of distinctly different ability and conditioning. The sixteen millimeter film was calibrated with timing marks at each one-hundredth of a second. The film was then analyzed by a film motion analyzer which enlarged the image fifteen times and projected it on an X-Y coordinate screen. Calculations were based upon the horizontal displacement of the swimmer's bathing suit. A single stroke cycle was divided into the kicking phase, gliding phase, pulling phase, and recovery phase. Thus, the calculation of the mechanical power

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[13] John R. Magel, "Propelling Force Measured During Tethered Swimming in the Four Competitive Swimming Styles," Research Quarterly, XLI (March, 1970), 68-74.

developed by the various phases of the stroke cycle was possible.[14]

Physiological measures. Various peices of equipment and methods have been developed for the measurement of such physiological variables as oxygen uptake in swimming.

Costill studied the use of a swimming ergometer, similar to the one used in this study, for the purpose of measuring maximum oxygen uptake during swimming. The purpose of his study was to develop an apparatus which would reliably regulate the workload and energy requirement while the swimmer was kept in a stationary position as he swam. The apparatus which was developed consisted of a rope which was fastened to the swimmer's belt and passed through a system of two pulleys so that as the swimmer swam he lifted a weight fastened to the end of the rope. Thus, the device worked much like a treadmill. If the swimmer swam too rapidly, he would lift the weight to the top just as a treadmill runner who ran too rapidly would run off the front of the track. On the other hand, if the swimmer swam too slowly the weight would drag him backward just as the treadmill runner who ran too slowly would be thrown off the back of the track. The workload was adjusted by adjusting the weight on the end of the rope. The mean weight for

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[14] Mitsumasa Miyashita, "Method of Calculating Mechanical Power in Swimming the Breast Stroke," Research Quarterly, XLV (May, 1974), 128-137.

thirteen college varsity swimmers for the crawl kick was 5.88 pounds with a range of 4.00 to 6.50 pounds for a period of three minutes. One National Collegiate Athletic Association champion maintained a weight of 8.50 pounds for three minutes and the estimation was made that few swimmers could maintain a weight of more than ten pounds for three minutes. Holding the swimmer in a stationary position facilitated the collection of the expired air in Douglas bags for the determination of the maximum oxygen consumption. A reliability coefficient based upon test-retest trials computed by the Pearson product moment correlation method was reported for maximum oxygen consumption to be .91. Furthermore, a t test on the means of the two trials showed no significance. Thus, the conclusion was made that the use of the swimming ergometer was a highly reliable method for the measurement of energy requirements imposed by swimming.[15]

Costill utilized the swimming ergometer described above to compare the effects of water temperature on aerobic work capacity. Four varsity college swimmers were tested for maximum oxygen uptake, heart rates, and core body temperatures in water temperatures of sixty-four, seventy-seven, and ninety degrees Fahrenheit. The open circuit

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[15] David L. Costill, "Use of a Swimming Ergometer in Physiological Research," Research Quarterly, XXXVII (December, 1966), 564-565.

method was used to determine the maximal oxygen uptake levels during the third minute of exercise. The results indicated no significant difference in either heart rates, rectal temperatures, or maximal oxygen uptake values for the three water temperatures. However, there was greater hyperventilation in water sixty-four degrees than at seventy-seven degrees Fahrenheit.[16]

Magel and others utilized a tethering device to facilitate the measurement of maximum oxygen uptake during swimming. The open circuit method was used to determine the oxygen uptake level. A test-retest procedure was used to ascertain the reliability of the maximum oxygen uptake level during the tethered swim. A reliability coefficient of .92 was reported for the method.[17]

Van Huss and Cureton studied the relationship of fifty-two selected metabolic and cardiovascular tests with swimming performance in forty-one college swimmers. The metabolic measures included gross oxygen intake and gross oxygen debt. These measures were taken during a one minute static swim, thirty seconds after the subject's performance

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[16] David L. Costill, "Effects of Water Temperature on Aerobic Working Capacity," Research Quarterly, XXXIX (March, 1968), 67-73.

[17] John R. Magel, Guido F. Foglia, William D. McArdle, Bernard Gutin, Gary S. Pechar, and Frank I. Katch, "Specificity of Swim Training on Maximum Oxygen Uptake," Journal of Applied Physiology, XXXVIII (January, 1974), 151-155.

of the Cureton one hundred yard drop-off test. In that test each successive twenty-five yard pool length was swam at maximum speed. Measurements were also collected during the recovery period. During the static swim the subject was restrained by a rope fastened to his belt. A helment equipped with a two-way valve was used in order to collect the expired air in Douglas bags. The data on metabolic and cardiovascular tests were shown to have a curvilinear relationship with the swimming tests involving time.[18]

Magel and Faulkner studied the maximum oxygen uptakes of college swimmers by various methods. These methods included the measurement of oxygen uptake by an open circuit system during treadmill running, free swimming, and tethered swimming. The test-retest correlation for maximum oxygen uptake during tethered swimming was .93. No significant difference was observed between the mean maximum oxygen uptake measured during treadmill running and tethered swimming. The correlation coefficient between the mean maximum oxygen uptake measured during treadmill running and tethered swimming was .85. However, pulmonary ventilation and respiratory exchange ratio were significantly lower and oxygen extraction was significantly higher during tethered swimming than in treadmill running. The correlation

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[18] W. D. Van Huss and T. K. Cureton, "Relationship of Selected Tests with Energy Metabolism and Swimming Performance," Research Quarterly, XXVI (May, 1955), 205-221.

coefficient of .90 was reported between maximum oxygen uptake measured during tethered swimming and free swimming. However, the mean aerobic capacity was significantly greater during free swimming than in tethered swimming.[19]

The treadmill test for Magel and Faulkner's study consisted of five minute runs at seven miles per hour with a ten minute rest between each run. The elevation was increased by two and one-half percent increments until the maximum voluntary physical work capacity was attained. Gas collections were made during the last minute of each swim and during each minute as the maximum working capacity approached. The tethered swimming test consisted of three minute swims with a three to five minute rest period between swims.[20]

In Magel and Faulkner's study the swimmer was held in a relatively stationary position by a pulley and weight system. The starting workload was 4.55 killograms. This weight was increased by 1.14 killograms until the weight could no longer be supported for three minutes. The free swimming test consisted of a warmup followed by six maximum fifty yard sprints with ten second rest intervals in which

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[19] John R. Magel and John A. Faulkner, "Maximum Oxygen Uptakes of College Swimmers," Journal of Applied Physiology, XXII (May, 1967), 929-938.

[20] Magel and Faulkner, pp. 929-938.

expired gas was collected in a neoprene bag which was carried alongside the pool by the examiner and connected to the swimmer by a hose and breathing valve.[21]

Martinez devised an apparatus which made it possible to establish a stationary swimming situation that required an expenditure of energy about equal to that which was required during an actual one hundred yard race. The swimmers first participated in one hundred yard races after which the expired air was collected to determine the recovery rates. To create a stationary swim comparable to the actual swim the subject was placed in a twelve by eight by four foot tank and tethered to hold him in place. The rope was attached to a spring scale through a system of pulleys. The arm stroke speed was regulated by the tape recorded sounds of a bell-type metronome. The subject breathed through a snorkel tube and mouthpiece which was equipped with a no-return valve in the exhaust side. Thus, the subject's oxygen uptake could be measured both during exercise as well as during the recovery. Through trial and error a workload was established for the subject which elicited about the same recovery heart rates, rectal temperatures and respiratory minute volumes as were elicited as a result of the actual one hundred yard races. The establishment of such a procedure was desirable since the

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[21] Magel and Faulkner, pp. 929-938.

expired air of a swimmer could not be collected during actual swimming without interference with the swimmer's progress through the water. After the development of the procedure, the researcher utilized it to compare the physiologic effects of swimming in water of five different temperatures on three well trained college swimmers. The findings indicated that less energy was expended during one hundred yard races in water temperature of seventy-nine degrees than in temperatures of sixty-nine, seventy-four, eighty-four, or eighty-nine degrees Fahrenheit.[22]

di Prampero, Pendergast, Wilson, and Rennie studied the energetics of swimming. Mechanical efficiency was calculated by the comparison of the oxygen uptake levels during tethered swims. The tethering device was mounted on a platform which enabled it to be moved alongside the swimmer at a constant rate. The weight on the tethering device was attached to the swimmer by means of a rope. The rope passed through a system of pulleys which caused the force of the weight to act in a horizontal direction. The tests were conducted in a round pool so that the swimmer could work at a constant rate without having to perform turns. During one swim a weight, which was equal to the swimmer's resistance for that speed, was attached in such a

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[22] Ray H. Martinez, "Physiologic Effects of Swimming 100-Yard Races in Water of Five Temperatures," Proceedings of Annual Meeting of the College Physical Education Association, LXIV (December, 1960), 108-112.

manner that it aided the swimmer to the point that his oxygen uptake was the same during swimming as it was during rest. During the second swim, the weight was attached in such a manner that it had to be supported by the swimmer's force before he could move to keep up with the moving platform. The difference in the two oxygen uptake levels was used to calculate the mechanical efficiency of the swimmer. Energy expenditure in excess of that which was required for the swimmer to overcome the resistance was considered to have been wasted.[23]

Astrand and Saltin compared the maximum oxygen uptake of seven subjects while performing the following activities: (1) leg work on the bicycle ergometer, (2) arm plus leg work on the bicycle ergometer, (3) running on the treadmill, (4) skiing, (5) leg work while cycling in a supine position, (6) arm work on the bicycle ergometer, and (7) swimming. The expired air was collected for analyzation during the swimming test by a two-way valve in a mouthpiece which was connected by a hose to a Douglas bag which was carried alongside the pool by an assistant while the swimmer performed. The results indicated that the maximum oxygen uptake during swimming was lower than the values obtained during running, cycling sitting, cycling and cranking, and

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[23] P. E. di Prampero, D. R. Pendergast, D. W. Wilson, and D. W. Rennie, "Energetics of Swimming in Man," _Journal of Applied Physiology_, XXXVII (July, 1974), 1-5.

skiing, and was higher than the values obtained during cycling supine or hand cranking.[24]

Astrand and Englesson reported the development of a swimming flume. The apparatus was designed to make it possible to study swimming in a manner similar to that of treadmill running or cycling on the bicycle egometer. Such measures as oxygen uptake taken on subjects during free swimming would have been complicated by the turns which would have interfered with normal rhythm and maintenance of a constant velocity. The apparatus consisted of a basin the overall outside dimensions of which were 7.3 meters in length, 3.1 meters in width, and 3.3 meters in height. The water was circulated in a 2.5 meter wide and 1.2 meter deep vertical loop by two electrical pumps. The swimming channel was 4.0 meters long. The water speed could be regulated from zero to 2.0 meters per second. The total water content of the apparatus was 38,000 liters. The equipment was designed for research physiology, kinesiology, training, instruction, and therapy.[25]

Holmer used the swimming flume or swimming treadmill to study oxygen uptake in three female and six male adult

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[24] Per-Olof Astrand and Bengt Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, XVI (July-November, 1961), 977-981.

[25] Per-Olof Astrand and Sixten Englesson, "Special Communications--A Swimming Flume," Journal of Applied Physiology, XXXIII (October, 1972), 514.

subjects of varying ability in swimming. Holmer found that at a given velocity the better trained swimmers were able to swim at a much lower oxygen uptake than the subjects who were not trained swimmers. At a given oxygen uptake level, the trained swimmers were also able to swim at a much faster rate than the untrained swimmers. Maximal oxygen uptake, maximal pulmonary ventilation, and maximal heart rate were significantly lower when measured during swimming than when measured during treadmill running or cycling on the bicycle ergometer.[26]

Karpovich and Le Maistre studied a method of predicting the swim time for various distances in the breast stroke based upon oxygen consumption. To determine the oxygen requirement for various speeds, the subject was asked to swim the specified distance at a predetermined rate while holding his breath. At the completion of the swim, the subject began to breathe into a Douglas bag while still in the water. While this collection was being made, the subject was removed from the water. He recovered while sitting in a chair for a period of thirty to forty-five minutes. The oxygen debt was then calculated by comparing this reading with the subject's resting oxygen uptake level

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[26] Ingvar Holmer, "Oxygen Uptake During Swimming in Man," Journal of Applied Physiology, XXXIII (October, 1972), 502-509.

for an equal period of time. Several preliminary tests were conducted to acquaint the subject with the discomfort of the test. In spite of the fact that duplicate samples of air were taken for analysis, only about half of the tests were acceptable because of mishaps. In addition to this phase of the study, the oxygen uptake of the swimmer was measured during a tethered swim of thirty strokes per minute. The swimmer was held by a rope which was tied at the edge of the pool and the expired air was collected in Douglas bags. The notation was made that the swimmers had almost reached their maximum oxygen uptake level during the first minute of this test. From the data it was concluded that by testing maximum oxygen uptake, maximum oxygen debt, and the oxygen requirement for various speeds it would be possible to predict swimming times for distances up to 1,320 feet based upon test distances of no more than 180 feet.[27]

Fox, Bartels, and Bowers devised a procedure for determining the energy expenditure during swimming turns. The subjects were six male competitive high school swimmers. The energy expenditure was calculated by having the subjects swim the width of the pool (thirty-five feet), complete either an open or closed turn, and swim back while holding their breath. At the completion of the bout, the subjects

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[27] Peter V. Karpovich and Harold Le Maistre, "Prediction of Time in Swimming Breast Stroke Based on Oxygen Consumption," Research Quarterly, XI (March, 1940), 40-44.

climbed from the pool, laid down, inserted a mouthpiece, and breathed into a Douglas bag for fifteen minutes. The oxygen debt was calculated from the expired air collected during the recovery period and from a sample taken during rest. The open and closed turns were compared in terms of both speed and energy expenditure. No significant difference was found between the two turns in terms of energy expenditure but the closed turn proved to be significantly faster than the open turn.[28]

Faulkner and Dawson devised a method of comparing the relative efficiency among swimmers and changes in efficiency of individual swimmers based upon the pulse rate after fifty meter swims. The subjects were nineteen female competitive swimmers between twelve and nineteen years of age. The swimmers swam fifty meters from a push-off at twenty, fifty, seventy-five, and one hundred percent of their maximum speed. The results indicated that there was a reasonably linear relationship between swimming velocity and heart rate at all speeds studied for the front crawl, back crawl, and breast stroke. The relationship between velocity in the butterfly and heart rate was curvilinear. The estimate of efficiency was based upon the assumption that

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[28] Edward L. Fox, Robert L. Bartels, and Richard W. Bowers, "Comparison of Speed and Energy Expenditure for Two Swimming Turns," Research Quarterly, XXXIV (October, 1963), 322-326.

the pulse rate after exercise was an indication of physical fitness and the degree to which the individual had stressed his system through exercise. The more proficient the swimmer, the lower his heart rate should have been during a standardized workload. A low pulse rate at maximum speed was concluded to indicate a lack of motivation or that the swimmer was unable to swim fast enough to stress the systems of the body to their maximum.[29]

St. Gavreesky developed a coefficient for assessing the state of preparedness (state of conditioning) of swimmers. The procedure was based upon the comparison of the swimmer's time for a given distance with the heart rate. Immediately after fifty and one hundred meter swims the pulse was counted by palpating the carotid artery for ten seconds. The pulse was counted again for ten seconds after one minute had elapsed. The number of seconds required to swim the distance was divided by the sum of the two ten second pulse rate counts. The resulting coefficient was lowest for the fastest swimmer and gradually increased as performance declined. Usually, but not always, the first place swimmers had the highest pulse rate. In some cases the effort did not represent the maximum. The time alone or the pulse rate alone was thus not considered to give

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[29] John A. Faulkner and Rosmary Mann Dawson, "Pulse Rate After 50-Meter Swims," Research Quarterly, XXXVII (May, 1966), 282-284.

enough information to adequately assess the state of conditioning of two swimmers of nearly the same performance. The coefficient was thus computed to combine data on the performance and pulse rate in assessing the state of preparedness or conditioning.[30]

Swimming Tests

Swimming performance has been evaluated by various methods. The most common methods have included: (1) subjective ratings, (2) achievement charts for a tally of skills learned, and (3) speed swimming measured as distance covered in a given time or time required for a given distance.[31]

Gold and Waglow surveyed ninety-six colleges in twenty-five states to determine the objectives of the swimming requirement. The results of the survey indicated the specific skills and the frequency with which they were listed as being used in the swimming classification test. The findings were as follow:

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[30] W. St. Gavreesky, "Assessing the State of Preparedness for Swimmers," Journal of Sports Medicine and Physical Fitness, III (March, 1963), 6-10.

[31] Gladys M. Scott and Esther French, Measurement and Evaluation in Physical Education (Dubuque: Wm. C. Brown Company, 1959), 216.

	Frequency
I. Entrance Into Water	
Dive into water	11
Jump into water	4
Slip down into water	1
Did not specify	40
II. Swimming Requirement	
50 feet	4
Swim 20 yards	6
Swim 20 yards (breast stroke)	3
Swim 20 yards (backstroke)	2
Swim 20 yards (side stroke)	3
Swim 20 yards (elementary back)	2
Swim 25 yards	7
Swim 25 yards (crawl)	2
Swim 25 yards (breast stroke)	3
Swim 25 yards (backstroke)	7
Swim 25 yards (side stroke)	3
Swim 40 yards	6
Swim 50 yards (any stroke)	9
Swim 60 yards	1
Swim 100 yards	6
Swim 100 yards (two standard strokes)	4
Swim 440 yards (side stroke, elementary backstroke and breast stroke)	2
Swim 5 minutes without touching bottom or sides	4
III. Skill Other Than Swimming	
Bob 15 times in deep water	1
Disrobe	1
Float	3
One elementary rescue	1
Pass a written test on elementary swimming	1
Recover 10 lbs. weight in 9 ft. of water	1
Stay in water 10 minutes	1
Surface dive	1
Tread water	8

Thus, a variety of aquatic skills have typically composed a check list of standards for the swimming requirement at a number of colleges.[32]

Parkhurst made a study of the methods used in testing and evaluating in swimming. The following skills and methods of measurement were listed:

SKILLS	METHOD OF MEASUREMENT
1. Form of strokes	Instructor's judgment
2. Form of dives	Instructor's judgment
3. Speed	Time
4. Endurance	Distance
5. Safety skills	Length of time one can support one's self in water
Breathing	A certain number of times in rhythm
Treading	Time
Floating	Time
6. Stunts	Instructor's judgment
7. Life saving technique	Instructor's judgment.

Tests which depended upon the instructor's judgment were classified into two categories. First, one class of tests was based upon the total number of points which the instructor awarded for varying degrees of perfection of the objectives. The individual's score was the total points awarded for the various skills. The second class of tests was based upon the number of skills an individual could perform to the satisfaction of the instructor's standards.[33]

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[32] M. Gold and I. F. Waglow, "Swimming Classification Test," *Research Quarterly*, XXVI (December, 1955), 485-486.

[33] Mary Grant Parkhurst, "Achievement Tests in Swimming," *Journal of Health, Physical Education and Recreation*, V (May, 1934), 34-36.

In the 1930's, the use of achievement scales and check lists to evaluate swimming ability was described by Glassow and Broer. They stated that swimming tests differed from measures in other skills in that they were for the most part considered ends in themselves. For example, the back float was usually considered only a test of the ability to float on the back and was not a measure of other skills. Thus, they concluded that none of the above achievement scales and check lists for swimming ability needed statistical tests of reliability or validity. The problem of the instructor, then, was described as one of simply deciding upon what achievements should be set as objectives for the beginning, intermediate, and advanced levels. A simple chart with desirable skills could then be used as a check list to evaluate the student's performance. By listing the students' names in a column at one side and the skills across the top, the check list could be adapted to a class testing situation.[34]

In the late 1940's, McCloy stated that few tests of swimming ability had been studied for reliability or validity and that no scale scores were available. He further stated that such tests depended for their validity

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[34] Ruth B. Glassow and Marion R. Broer, Measuring Achievement in Physical Education (Philadelphia: W. B. Saunders Company, 1939), pp. 198-205.

entirely upon the opinion of their author and might better have been classified as stunts or teaching devices than as actual tests.[35]

McCloy further commented on the problem of scale scores for swimming being complicated by the fact that "to be able to swim at all is far from zero ability." Without such a zero point, scales based upon the ratio level of measurement were not possible. Furthermore, if one attempted to establish scales such as T scores, the sample chosen would greatly affect the results.[36]

Cureton developed an endurance test for swimming based upon the "drop-off" time for each successive lap. Based upon studies of swimmers of Olympic caliber, National Collegiate Athletic Association champions, college varsity team members, and swimmers of poorer caliber, Cureton concluded that the ability to sustain the pace was the outstanding feature of winning performances. Assuming that the swimmer swam at an optimum pace in the first lap, each second that his lap time dropped off in succeeding laps would represent the deviation from the swimmer's potential performance. To measure the swimmer's endurance ability to prevent this loss of time, Cureton suggested the "drop-off"

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[35] Charles Harold McCloy, Tests and Measurement in Health and Physical Education (2d ed.; New York: F. S. Crofts and Co., 1964), pp. 182-184.

[36] McCloy, p. 183.

test. First, the swimmer was timed for one length of the pool at maximum speed. After a fifteen minute rest, the swimmer was asked to swim one hundred yards at maximum speed. The time for each length of the pool was compared with the previous lap time. The drop-off times for each succeeding lap were then added to give an index of endurance.[37]

Wilson studied the relation of coordination tests to swimming ability. He found that such drill tests as counting the maximum number of arm or leg movements that the subject could perform in ten seconds either on the land or while suspended by straps in water were not a reliable means of determining coordination ability in actual swimming performance. Velocity tests in which either the legs or the arms were immobilized did give high correlations with swimming performance and were useful in determining the relative contribution of the arms and legs to the total propulsive force developed.[38]

Two tests of swimming ability were proposed by Connor for elementary school children, ages five to twelve years. These included: (1) The fifty yard swim consisted

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[37] Thomas Kirk Cureton, Jr., "A Test for Endurance in Speed Swimming," Research Quarterly, VI (May, 1935), 106-112.

[38] Colin Theodore Wilson, "Coordination Tests in Swimming," Research Qaurterly, V (December, 1934), 81-88.

of a push-off in the water and a swim of fifty yards in the prone position without stopping. (2) The fifty yard combined swim consisted of pushing off in the water, swimming twenty-five yards in the prone position without stopping, and turning over and swimming twenty-five yards on the back. Scoring was as follows:

SEX	AGE	TEST	SCORING
Girls	5-9 years	50 yd. prone swim	Time
		50 yd. combined swim	Count strokes
	10-12 years	50 yd. prone swim	Time or count strokes
Boys	5-9 years	50 yd. prone swim	Time
	10-12 years	50 yd. combined swim	Count strokes[39]

Thus, many of the tests that have been used for evaluation in college swimming classes have also been proposed for elementary school age children.

Hewitt developed achievement scales which were based upon a battery of swimming tests for use by the armed forces, college men, and high school boys and girls. These tests included the following:

High school boys and girls:

(1) time for the twenty-five yard flutter kick while holding a water polo ball,

(2) time for the fifty yard crawl,

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[39] H. Harison Clark, Application of Measurement to Health and Physical Education (4th ed.; Englewood Cliffs: Prentice-Hall, Inc., 1967), pp. 326-327, citing from Donald J. Connor, "A Comparison of Objective and Subjective Testing Methods in Selected Swimming Skills for Elementary School Children," Microcard Master's Thesis, Washington State University, 1962.

(3) number of strokes required to cover twenty-five yards with the elementary back, side and breast strokes.

College men:

(1) time for twenty and twenty-five yard underwater swims,

(2) distance covered during a fifteen minute swim for endurance,

(3) time for the twenty-five and fifty yard swims each with the crawl, breast, and back crawl strokes,

(4) number of strokes to cover fifty yards each with the elementary back, side, and breast strokes.

Men in the armed forces:

(1) time for the twenty and twenty-five yard underwater swims,

(2) distance covered during a fifteen minute swim for endurance,

(3) number of strokes to cover fifty yards each with the elementary back, side, and breast strokes.[40]

Montoye suggested that Hewitt's test battery may be used to classify students, as self-testing devices, to measure improvement, or to determine a grade. The sample used to construct Hewitt's scales were 1,093 high school students, of whom 647 were girls. The college sample was 4,000 male students at the University of California.[41] The

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[40] Clark, pp. 325-326.

[41] Henry J. Montoye (ed.), Sports Tests and Evaluation in Dance, Vol. III, An Introduction to Measurement in Physical Education (Indianapolis: Phi Epsilon Kappa Fraternity, 1970), pp. 49-51.

scales were constructed in the form of standard scores with a mean of fifty and extending five standard deviations above and below the mean.[42] However, a perfect score was virtually impossible for the underwater swim test on such a scale; therefore, the scale for this item was constructed by placing the best score at one hundred and working down at predetermined intervals.[43]

A need for an objective test of swimming power was indicated by the fact that Fox found little correlation between swimming speed and form ratings. A more objective test of power was therefore established which was based upon the assumption that the more power that the swimmer produced, the further he would travel per stroke. The directions for the administration of the Fox power test were given as follow: A rope, eighteen to twenty feet longer than the width of the pool, was stretched across the pool one to two feet from the end. The rope was anchored on one side, held by the tester on the other side, and had a weight tied in the center. The side of the pool was marked off in five foot intervals starting at the rope and continuing for fifty-five feet. To take the test, the swimmer assumed a

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[42] Jack E. Hewitt, "Swimming Achievement Scale Scores for College Men," Research Quarterly, XIX (December, 1948), 282-289.

[43] Jack E. Hewitt, "Achievement Scale Scores for Wartime Swimming," Research Quarterly, XIV (December, 1943), 391-396.

floating position appropriate to the stroke being tested with the feet supported by the rope. On the signal "go" the rope was dropped and the swimmer started from a motionless float. A glide was used on strokes normally permitting a glide. The score was the number of feet that the swimmer moved in five complete stroke cycles. The distance was measured to the swimmer's ankles.[44]

Rosentswieg revised the Fox power test. He considered the Fox power test unsatisfactory for three reasons. First, the starting procedure was considered complicated and resulted in numerous errors. Second, students tended to "cheat" by taking additional kicks or by making sculling movements between strokes. Third, the test was a very good indicator of both the superior and the inferior swimmers but did not discriminate well among the large middle group.[45] Rosentswieg's revisions included changing the starting procedures, adding a form rating, making measurements at the shoulders rather than at the ankles, and using six stroke cycles instead of five. The instructions for administration of the test were as follow: The pool deck was marked off in one foot intervals beginning

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[44] Margaret G. Fox, "Swimming Power Test," Research Quarterly, XXVIII (September, 1957), 233-237.

[45] Joel Rosentswieg, "A Revision of the Power Swimming Test," Research Quarterly, XXXIX (October, 1968), 818-819.

with the starting line which was eight feet from the shallow end of the pool. A student stood beside the student being tested and supported the legs of the swimmer with his forearms. The student sculled or floated in the appropriate position with the shoulders parallel to the starting line. The student swam away from the helper when he was ready, using an arm stroke first. Two trials were allowed and the better score was counted. A subjective rating of form based on a five point scale was made at the same time the power measurement was being made.[46] The two measurements of power and form were combined into standard scores for the computation of a grade for each student.[47]

The Burris speed-stroke test of the crawl attempted to measure stroke proficiency from the two combined variables of time and number of strokes required to cover a constant distance; T scores for the two variables were added in order to combine the data from the two measures. Since the T scores were added, the mean equaled one hundred. The scale was set up so that the less time and smaller number of strokes required by the subject to cover the twenty-five yards, the better the score. Norms were developed for 89

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[46] Harold M. Barrow and Rosemary McGee, A Practical Approach to Measurement in Physical Education (2d ed.; Philadelphia: Lea and Febiger, 1971), pp. 324-325.

[47] Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education (2d ed.; Minneapolis: Burgess Publishing Co., 1974), pp. 280-281.

men and 143 women at Temple University but the suggestion was made that local norms be developed for use of this test.[48]

The American National Red Cross method of evaluating swimming performance consisted of a "worksheet" check list of skills to be performed by the student to achieve the various levels. The list of skills graded on a pass-fail basis for the intermediate level were as follow:

1. Leg Kicks
    - Scissors--20 yards
    - Crawl--20 yards
    - Breaststroke--20 yards
2. Arm Strokes
    - Side--10 yards
    - Crawl--10 yards
    - Breaststroke--20 yards
3. Elementary Backstroke--50 yards
4. Selected Stroke--100 yards
5. Turns--Front and Back
6. Survival Floating--5 minutes
7. Sculling--10 yards
8. Treadwater--1 minute
9. Float--1 minute
10. Underwater Swim--15 feet
11. Standing Front Dive
12. Rescue Skills
13. 5-Minute Swim.[49]

The above skills were more exactly described in the *Instructor's Manual* as follow:

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[48] Barrow and McGee, pp. 325-328.

[49] *Worksheet for Swimming Courses* (Washington, D.C.: The American National Red Cross), p. 2.

Individual Swimming, Diving, and Safety Skills

1. Using a swimboard or buoyant support for the arms, the student demonstrates the following leg strokes for a minimum distance of 20 yards: scissors kick, crawl kick, and breaststroke kick.
2. Using a leg support or trailing the legs with minimum motion, the student demonstrates the following arm strokes for a minimum distance of 10 yards: crawl, elementary backstroke, breaststroke, and sidestroke.
3. The student swims 50 yards continuously, using a coordinated elementary backstroke.
4. The student swims 100 yards continuously, using a fully coordinated sidestroke, breaststroke, or crawl stroke.
5. The student effectively demonstrates a simple turn on front and back.
6. The student demonstrates his ability to perform the survival floating skill for 5 minutes.
7. By sculling with the hands, the student moves backward through the water while on his back, for a minimum of 10 yards.
8. The student treads water, using auxiliary arm movements, continuously for 1 minute.
9. The student floats motionless or rests in floating position for 1 minute.
10. The student submerges feet-first to a depth of 4 or 5 feet, levels off, and swims a minimum of 15 feet underwater.
11. The student does a coordinated standing front dive into deep water in reasonably good form.
12. The student demonstrates his ability to perform the extension and equipment rescues. He also demonstrates the technique of giving mouth-to-mouth resuscitation.

13. As a final check of the student's ability, he must swim continuously for a minimum of 5 minutes. In this test, he may swim any or all of the strokes that he has mastered, on the front, the side, or the back.[50]

SUMMARY OF THE LITERATURE

Several studies have been conducted regarding the relative effectiveness of various methods of teaching physical activities. Some of those studies involving swimming have shown significantly better results for groups of students who were given additional instruction in mechanical principles related to the activity.

Many types of apparatus were devised to measure resistance and propulsion. Such apparatus involved towing swimmers and measuring the tension developed as a measure of the resistance. Propulsion has been studied by measuring the tension developed by tethered swimmers. Motion pictures have also been utilized to develop formulas for propulsion developed by swimmers based upon horizontal displacement per unit of time.

Physiological measures on swimming subjects have been made during tethered swims, swims in water-driven tanks, and during free swimming with a mouthpiece connected to a gas collection bag carried alongside the pool by a researcher. Energy cost has also been calculated from the

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[50] Swimming and Water Safety Courses Instructor's Manual, pp. 63-64.

measurement of recovery metabolism of subjects who performed while holding their breath. These physiological measures have typically dealt with the measurement of maximal oxygen uptake during swimming, the energy cost of specified workloads, or the effects of water temperature on swimming.

A number of practical tests have been developed and reported in the literature for use in a class situation. Some of the more significant of these include the Fox power test, the Rosentswieg revision of the power swimming test, the Burris speed-stroke test of the crawl, the Hewitt achievement scales, and the American National Red Cross achievement charts.

Chapter 3

PROCEDURES

The basic procedures followed in the conduct of the study included: (1) the selection of subjects, (2) methods of instruction, (3) collection of data, and (4) analysis of the data.

SELECTION OF SUBJECTS

The subjects for this study consisted of twenty-one students enrolled in two classes of intermediate swimming at Middle Tennessee State University during the Spring Semester of 1977. The total group on which the correlational aspect of the study was based consisted of fourteen male and seven female subjects. These subjects ranged in age from seventeen to twenty-five years with a mean of 19.1 and a standard deviation of 2.2 years. The range in height of the subjects was from 62.5 to 74.0 inches with a mean of 68.0 inches and a standard deviation of 4.0 inches. The subjects ranged in weight from 115 to 211 pounds with a mean weight of 141.4 pounds and a standard deviation of 28.5 pounds. Complete information for each subject on the above variables is presented in Appendix H. In order to participate in the intermediate swimming course, the student had to meet the eligibility standards established by the American National Red Cross. These standards included such skills as breath control, survival floating, treading water, diving, use of life jacket, safety skills, and a twenty-five yard swim on both the elementary backstroke and crawl stroke. The complete list of criteria for the above standards are presented in Appendix C.

METHODS OF INSTRUCTION

The two classes were randomly assigned to an experimental group and a control group for swimming instruction. The experimental group initially consisted of ten subjects, one of whom dropped out, and the control group consisted of eleven subjects, five of whom dropped out. Thus, pre-test and post-test data for the comparison of the two methods were collected on fifteen subjects. The class assigned to the control group met from 9:00 to 9:50 a.m. on Monday and Wednesday while the class assigned to the experimental group met from 10:00 to 10:50 a.m. on Monday and Wednesday. The two groups were taught by the author who conducted the classes utilizing two different methods of instruction. The treatment period consisted of the two fifty minute class periods per week for the seven weeks from January 31, 1977, to March 16, 1977, for a total of fourteen class periods.

Control Group

The control group was taught swimming by a traditional method which employed a whole-part-whole approach. The instructor introduced the whole stroke to the students by demonstration and explanation. The parts of the stroke such as the kick, the arm movements, the breathing, and the body position were then taught and practiced individually. Finally, the whole stroke was practiced by the students with the instructor offering suggestions for the correction of errors.

Class absences for the control group were made up during the free swim period conducted at the pool each day. This group had an average of 3.17 absences per student.

Experimental Group

The experimental group was taught in the same manner as the control group with the exception that ten or more minutes of eleven class periods were spent in the classroom studying the mechanical principles of swimming efficiency (see Appendix A). This classroom instruction consisted of brief lectures, printed instructions, overhead transparencies, and two eight millimeter loop filmstrips. The printed instructions outlined the mechanical principles that are presented in Appendix A. The overhead transparencies were prepared by the author to illustrate the mechanical principles covered. Some of the transparencies were hand drawn while others were reproduced by the thermofax process from Xerox copies of textbook illustrations.[1] The filmstrips were commercially prepared.[2]

The fact that a portion of the class time was spent in the classroom during eleven of the fourteen class sessions of the treatment period inadvertantly caused the experimental group to have ten or more minutes less time in the pool area than did the control group. This meant that the experimental group had approximately 110 minutes less actual swimming practice and instruction in the pool area than did the control group. No attempt was made to prevent this situation since an instructor who was to spend time in the classroom would do so at the expense of time spent in the pool. Other than the mechanical principles portion, the experimental group was taught from the same lesson plan, as was the control group, each day.

Class absences for the experimental group were made up during specially scheduled sessions conducted by the

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[1] James E. Counsilman, The Science of Swimming (Englewood Cliffs: Prentice Hall, Inc., 1968), pp. 2-65. See, also, John W. Bunn, Scientific Principles of Coaching (Englewood Cliffs: Prentice Hall, Inc., 1972), p. 207.

[2] George Haynes, Freestyle (Super eight millimeter Swimming Series number 675643 prepared by the California Academy of Sciences for McGraw-Hill Text Films, 1969); George Haynes, Freestyle Breathing (Super eight millimeter Swimming Series number 675647 prepared by the California Academy of Sciences for McGraw-Hill Text Films, 1969).

author. This group had an average of 3.11 absences per student.

COLLECTION OF THE DATA

The data collected, the instruments used to collect the data, and the methods of collecting the data were as follow.

Data Collected

Data were collected on each of the subjects on the following measures: (1) experimental method of measuring swimming efficiency, (2) the Fox power test, (3) the Hewitt fifty yard crawl for time, (4) the Burris speed-stroke test of the crawl, and (5) a form rating scale.

Instruments Used to Collect the Data

The following apparatus, tests, and rating scale were utilized to collect the data.

Experimental apparatus. The experimental apparatus for measuring the swimming efficiency of a swimmer while performing at a sub-maximal rate was designed to determine how economically an individual could perform a specified task. From the definition of efficiency as being the work output divided by the work input, efficient swimming at a sub-maximal rate would involve working at a relatively low percent of one's maximum working capacity. Specifically, the efficiency with which the student was able to swim at a workload comparable to a rate of 2.5 feet per second for a period of one minute was tested (see Figure 1). The rate and duration of the test were derived through the process of trial and error in the pilot study which was conducted in the fall of 1976. The rate and duration values were also modified as a result of student performances during the training period in which the subjects in the study were familiarized with the apparatus and test procedures. The percentage of the subject's maximum swimming working capacity as indicated by his oxygen uptake level during a one minute all-out tethered swim that was required to perform the task served as an efficiency index. The lower the percentage of the maximum that was required to perform the sub-maximal task was assumed to be an indication of the degree to which the individual had eliminated unnecessary work. The assumption was that this percentage index indicated the efficiency with which the individual had performed the skill.

Swimming ergometer. Since the collection of the expired air for the determination of oxygen uptake of a subject during free swimming without interfering with the performance of the skill would be difficult, if not impossible, a swimming ergometer was utilized (see Figure 2). This instrument consisted of a rope which was fastened to

Figure 1. Swimming Efficiency Test

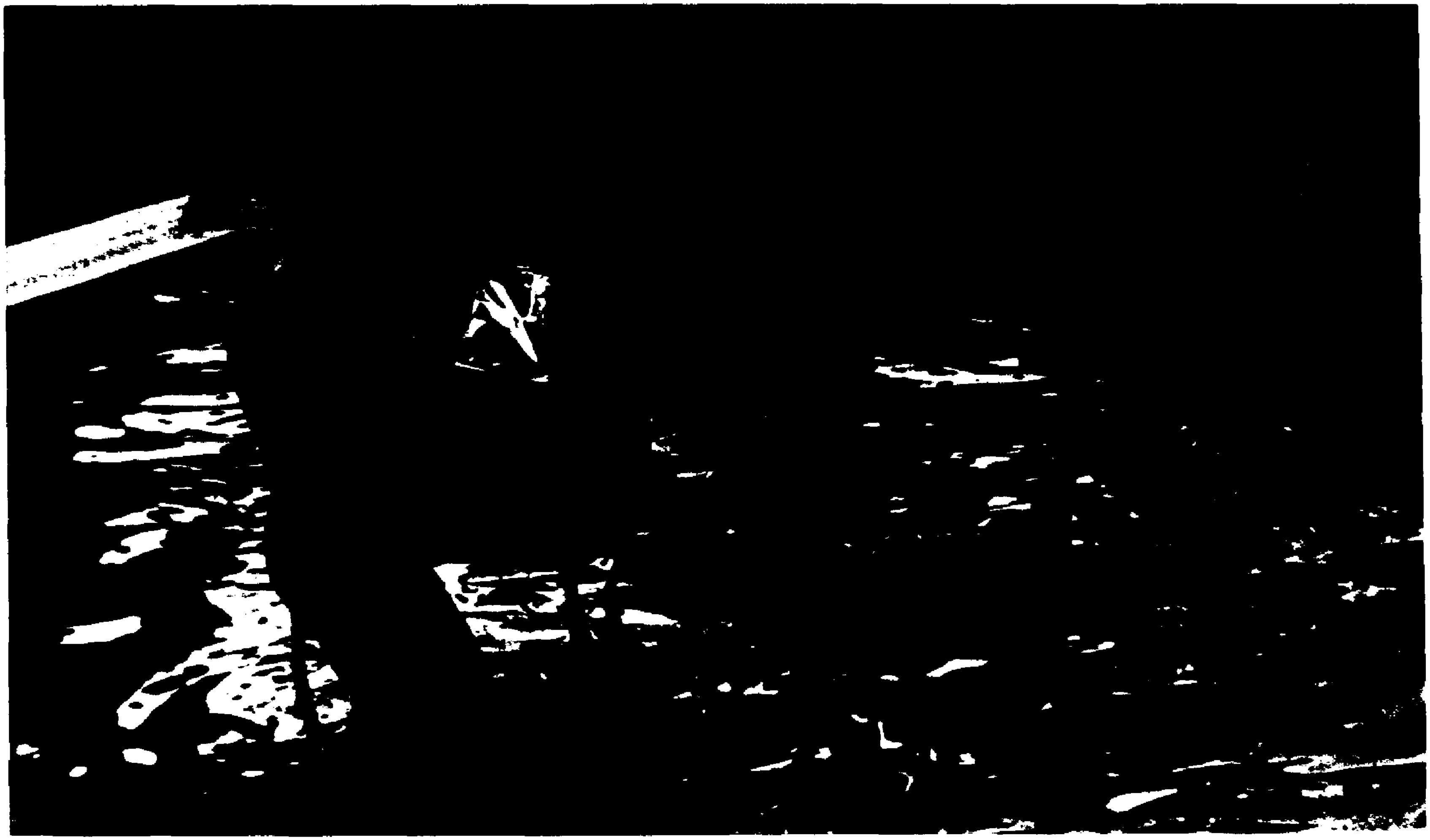

Figure 2. Apparatus/Collection System, Mouthpiece, and Swimming Ergometer

the swimmer's belt at one end and passed through a system of two pulleys and fastened to a counterweight at the other end. If the swimmer swam too rapidly, he lifted the weight just as the treadmill runner who ran too rapidly would run off the front of the track. On the other hand, if the swimmer swam too slowly, he was dragged backward just as the treadmill runner who ran too slowly would be thrown off the back of the track. By swimming with just enough force to keep the counterweight in a relatively stationary, suspended position, the swimmer was also held in a relatively stationary position. The subject adjusted his swimming speed during the test to keep the counterweight balanced by maintaining his head position directly over a line on the bottom of the pool. Verbal feedback was also given when needed. The counterweight on the swimming ergometer and the duration of the swim were adjusted so that the sub-maximal workload was equal to that which would have been required for the swimmer to have propelled his body through the water at a rate of 2.5 feet per second for a distance of fifty yards. To establish the proper weight which was equal to the workload that would have been required for the swimmer to have propelled himself through the water 2.5 feet per second, each individual swimmer was towed through the water at that rate and the resistance was measured by means of a spring scale attached to a pulley over which the rope traveled. A counterweight heavy enough to place the same amount of tension on the rope that was present during the towing was then placed on the rope of the swimming ergometer (see Appendix S). Thus, a one minute swim at such a workload was equal to a fifty yard swim at a rate of 2.5 feet per second.

Since the workload was established by towing each individual subject, several disadvantages normally associated with stationary swimming were overcome. The bow wave, hydroplaning, frontal resistance, resistance caused by such body features as hair or body cavities were accounted for in establishing the workload since all of these features were also present during the towing. Furthermore, individual differences in such things as cross-sectional area, bouyancy, specific gravity, percent of body fat, and body contours were also accounted for. The mouthpiece which could have caused additional resistance during free swimming caused no such resistance during the test since it was not present during the towing and since the swimmer was not moving through the water during the stationary swim.

Mouthpiece. A mouthpiece was designed by the author for use in this study. This device facilitated the collection of the expired air for the determination of oxygen uptake. The device was made from light 1.5 inch metal pipe. The metal construction gave the air-filled device almost neutral bouyancy and helped to prevent its natural tendency to float to the surface and interfere with the swimmer's performance. The largest measurement of the device was 4.5 inches and was thus small enough to be held in place by the swimmer by gripping the snorkel-like mouthpiece between his teeth. This situation made possible the simulation of free swimming since no other headgear was needed to hold the mouthpiece in place. Both the intake and the exhaust of the mouthpiece were equipped with one-way rubber air valves. The intake was open to the air several inches above the surface and the exhaust was connected to the sampling chamber. The subjects wore a standard swimming nose clip so that all of the exhaled air could be channeled through the sampling chamber. (See Figure 2.)

Oxygen analysis. The stationary position facilitated the collection of expired air for the determination of oxygen uptake (see Figure 3). Each subject was tested for oxygen uptake during both a one minute sub-maximal workload followed by a one minute all-out tethered swim. The open circuit method was utilized to measure oxygen uptake during both stationary swims. Essentially, this arrangement meant that the swimmer received his supply of air through a mouthpiece with the intake opened to the surrounding atmosphere. The exhaust from the mouthpiece was connected by a hose to a sampling chamber. Samples of the expired air were drawn from this chamber for oxygen analysis. Another hose connected the sampling chamber to a flow meter for the measurement of the

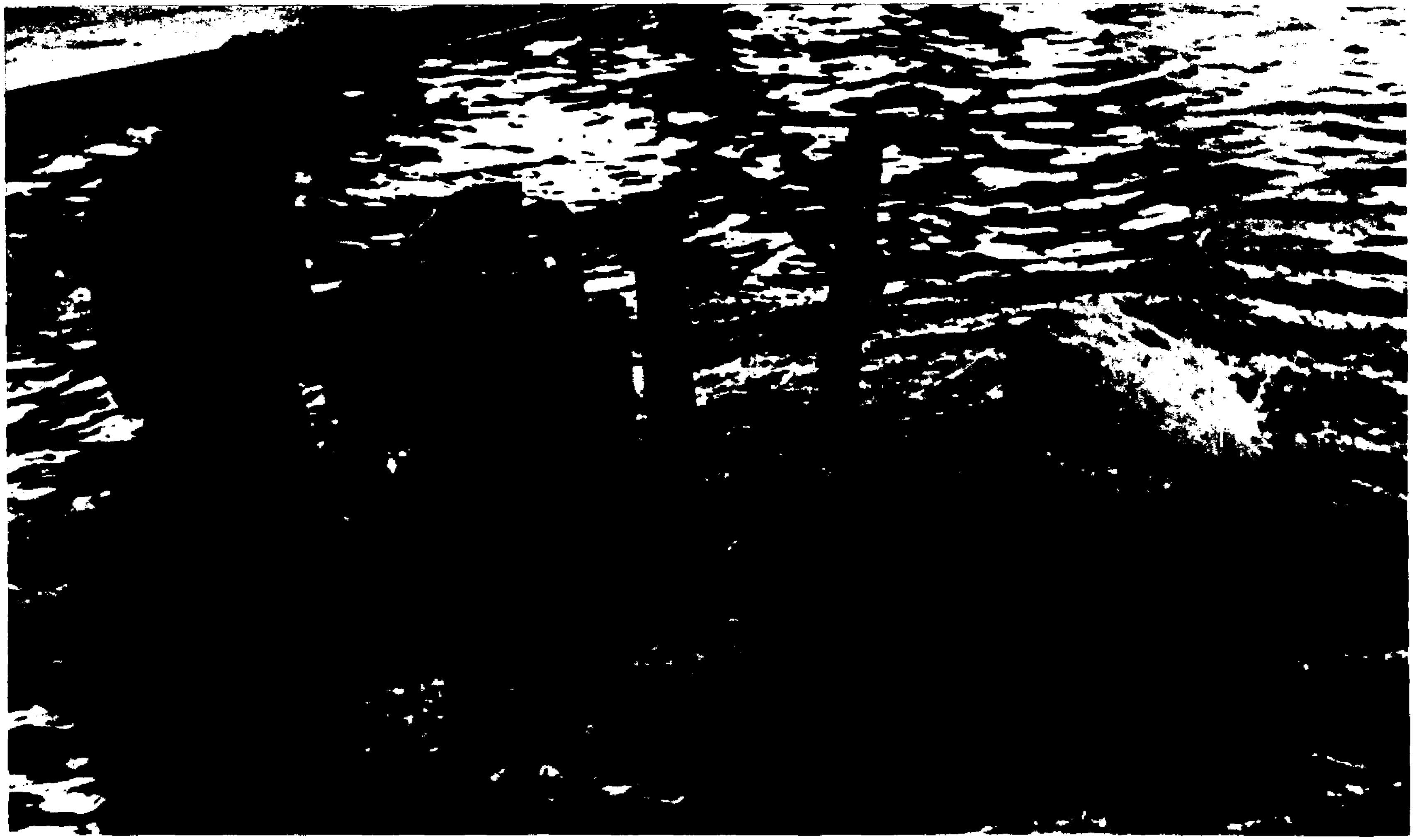

Figure 3. Oxygen Collection

volumes of expired air. These measurements made possible the computation of the subject's oxygen uptake during the tethered swims. The values were then converted from liters per minute to milliliters per killogram of body weight per minute. This conversion was performed in order to compensate for differences in size of the subjects. The determination was then made as to what percentage of the subject's maximum swimming working capacity that was required to perform the standardized sub-maximal workload. Each subject was scheduled for an individual pre-test and post-test using this procedure.

Battery of published tests. A battery of published tests was administered to the subjects for the purpose of computing coefficients of correlation between their results and the results of the experimental method of measuring swimming efficiency and the form rating scale. The battery of published tests was also planned to provide predictor variables for swimming efficiency.

The Fox power test was administered in the following manner. A rope which was longer than the width of the pool was stretched across the pool two feet from the end. The rope was anchored on one side, held by the tester on the other side, and a small weight fastened to the center. The deck on the side of the pool was marked off in one foot intervals starting at the rope and continuing for fifty-five feet. The swimmer assumed a prone floating position with the feet supported by the rope. On the signal "go" the rope was dropped and the swimmer started from a motionless float. The score was the number of feet that the swimmer moved in five complete stroke cycles. The distance was measured to the swimmer's ankles. By counting each hand movement, the distance was marked when the eleventh hand entry was made.[3]

The Hewitt fifty yard crawl for time was administered in the following manner. The student swam the crawl stroke for fifty yards at maximum speed. The students were given the option of using any type of entry and turn that they wished. All of the subjects in this study chose to use a freestyle racing entry and an open turn. The score was the time to the nearest tenth of a second required to complete the distance.[4]

The Burris speed-stroke test of the crawl was administered in the following manner. Starting in the water without pushing off the wall, the swimmer was instructed to swim twenty-five yards both as rapidly as possible and in as small a number of strokes as possible. The results of the time measurement, which was made to the nearest tenth of a second, and the results of the total number of strokes

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[3] Margaret G. Fox, "Swimming Power Test," Research Quarterly, XXVIII (September, 1957), 233-237.

[4] Jack E. Hewitt, "Swimming Achievement Scale Scores for Colelge Men," Research Quarterly, XIX (December, 1948), 282-289.

required to complete the distance were converted to T scores. The T scores, which were based upon a mean of fifty and a standard deviation of ten, were added; thus, the mean equaled one hundred and the standard deviation equaled twenty. The published norms for the test were based on separate scales for males and females which were inverted so that the less the time and the smaller the number of strokes required to complete the distance, the higher the score. The test instructions suggested the computation of local norms.[5] The local norms developed from the Middle Tennessee State University students in this study were computed by adding the T scores and were not inverted since the published directions did not explain how the scales were inverted. Thus, the lower scores were the better ones on the local norms.

Form rating scale. A form rating scale which was designed for the purpose of evaluating the swimming efficiency of a number of students in a class situation was developed for this study. The complete rating scale is presented in Appendix B. Five basic components of the crawl swimming stroke were identified. These components included the arm action, breathing, kicking action, body position,

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[5] Harold M. Barrow and Rosmary McGee, A Practical Approach to Measurement in Physical Education (2d ed.; Philadelphia: Lea and Febiger, 1971), pp. 324-325.

and coordination. Each of the components was rated on a four point scale similar to a grade point average. The ratings were then multiplied by five and added. The inflation of the scale placed it on a one hundred point basis for clarity and made differences more obvious.

Methods of Collecting the Data

The subjects were familiarized with the apparatus and test procedures during classes which met during the two weeks preceding the actual testing. In this familiarization period the subjects duplicated the actual test with the exception that no oxygen analysis measurements were made. The pre-tests were conducted between 7:00 p.m. and 10:00 p.m. one evening and between 10:00 a.m. and 12:00 noon on the following day. The post-tests were conducted seven weeks later between 7:00 p.m. and 10:00 p.m. one evening and between 10:00 a.m. and 12:00 noon the following day.

The Fox power test, the Hewitt fifty yard crawl for time, the Burris speed-stroke test of the crawl, and the form rating scale were administered during the regular class periods. One item of the battery was administered in each of the first four class periods of the treatment period. The administration of just one item per class period prevented the fatigue factor from interfering with performance on other items and also minimized the amount of time devoted to testing during any given class period.

ANALYSIS OF THE DATA

The data were analyzed using analysis of variance with repeated measures, correlation matrixes, and stepwise multiple linear regression. Hypotheses one through three which dealt with a comparison of two teaching methods were tested by two-way analysis of variance with repeated measures performed on the pre-test and post-test swimming efficiency results of the control group and the experimental group. This treatment indicated whether or not either group had made significant improvements and if either group had performed significantly better than the other.

Hypotheses four through six and eight through eleven were tested by the computation of a correlation matrix on the results of the pre-test data of the experimental method of measuring swimming efficiency, the battery of published tests, and the form rating scale. The pre-test data were used because they were collected during the same time span as the other items such as the form rating scale which could have been subject to greater bias at a later date after the rater had become more familiar with the subjects. The correlation matrix furnished coefficients of correlation between each of the variables tested in the study. These coefficients indicated the strength of relationship that existed between the results of the experimental method of measuring swimming efficiency and the results of the other tests.

Hypothesis seven was tested by stepwise multiple linear regression analysis. This technique indicated the strength of the relationship that existed between the results of the experimental method of measuring swimming efficiency and various combinations of the other variables. This analysis was also designed to enable the development of a formula for the prediction of a given subject's swimming efficiency from his performance on a number of predictor variables of the test bettery.

The .05 level was utilized to determine significance for the analysis of variance and the coefficients of correlation.

Chapter 4

RESULTS AND DISCUSSION

The results of the study have been presented in four major sections which include: (1) form rating scale, (2) battery of published tests, (3) swimming efficiency, and (4) teaching methods. Each section contains both the results of the statistical treatment as well as a discussion of each analysis.

The raw data for the rating scale, the battery of published tests, and the experimental method of measuring swimming efficiency are presented in Appendixes D through S. A complete correlation matrix which was computed among all of the tests is presented in Appendix T. For the correlational aspects of the study, an r of .43 was necessary for significance at the .05 level.

Form Rating Scale

Coefficients of correlation were computed between the results of the form rating scale and the results of each of the other tests.

Results. The results of the form rating scale were significantly correlated with the results of all of the other items of the test battery with the exception of the experimental method of measuring swimming efficiency and the number of strokes component of the Burris speed-stroke test of the crawl. Specifically, the form rating scale results were significantly correlated with the results of the Fox power test ($r = .50$) and the Burris speed-stroke test of the crawl. The results of the form rating scale were also significantly correlated with the time required to swim twenty-five yards component of the Burris speed-stroke test of the crawl ($r = -.70$). Furthermore, the form rating scale results were significantly correlated with the combined Burris test results both when the published standards for that test were utilized ($r = .58$) as well as when local norms were devised for the subjects in this study ($r = -.61$). The coefficients of correlation between the form rating scale and each of these variables are included in Table 1.

Discussion of rating scale. The following implications were drawn from the above findings. The battery of tests with which the form rating scale results were significantly correlated consisted of three basic components. These components were speed, distance that could be covered with a specified number of strokes, and the number of strokes required to cover a specified distance. The greater the distance that the subject was able to cover with each stroke as well as his swimming speed were assets.

Table 1

Correlations Between Form Rating Scale and Various Tests

	Form Rating*
Experimental Method of Measuring Swimming Efficiency	-0.00
Number of Strokes for 25 Yards	-0.40
Time for 25 Yards	-0.70
Hewitt 50 Yards for Time	-0.70
Fox Power (Feet in 5 Stroke Cycles)	0.50
Burris Test Based on Local Norms	-0.61
Burris Test Based on Published Norms	0.58

*An r of .43 was required for significance at the .05 level.

Thus, in the author's subjective opinion, both of these components were related to swimming efficiency. This opinion was substantiated by Counsilman who stated that the swimmer's progress depended upon two basic components. These factors included, first, the reduction of resistance and, second, the increasing of the propulsive forces.[1] To accomplish these objectives mentioned by Counsilman the swimmer would need the strength to produce the propulsive forces required to drive his body through the water as well

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[1] James E. Counsilman, The Science of Swimming (Englewood Cliffs: Prentice-Hall, Inc., 1968), pp. 1-14.

as the skill required to decrease unnecessary resistance. Thus, skill and strength appeared to be the essential components of swimming efficiency. These components were the objectives of measurement by the Fox power test, the Hewitt fifty-yard crawl for time, and the Burris speed-stroke test of the crawl. In other words, the powerful and swift swimmers scored well on these tests.

Since the form rating scale results correlated significantly with the results of each of the items of the battery of published tests given, such an instrument could be used effectively for the evaluation of a group of students in a class situation. However, due to the subjectivity often associated with rating scales, the instructor could utilize any of the above objective tests and expect to obtain similar results. The use of more objective tests have been advocated by some who found no such relationship to exist between the results of rating scales and objective techniques. For example, Fox stated that a reason for the development of the power test was her finding of no significant relationship between form rating results and tests of swimming speed.[2]

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[2] Margaret G. Fox, "Swimming Power Test," <u>Research Quarterly</u>, XXVIII (September, 1957), 233-237.

Battery of Published Tests

A correlation matrix was computed for the results of each of the items of the test battery. This correlation matrix is presented in Table 2.

Results. The results of the number of strokes and time for twenty-five yard components of the Burris speed-stroke test of the crawl were significantly related ($r = .60$). The faster swimmers demonstrated more swimming power than the slower swimmers by traveling farther on each stroke and thus required fewer strokes to swim twenty-five yards. The published norms differed from the local norms in that an inverted scale was devised so that the better scores were higher than the poorer ones. In addition, the published norms were based upon separate scales for males and females. In spite of these differences, a significant negative coefficient of correlation ($r = -.91$) existed between the two combinations of results. Furthermore, the results of the individual components of the Burris test were each demonstrated to be significantly related to the combined results which were based upon local norms and also upon the published norms for the test. All aspects of the Burris test were significantly related to each other.

The results of the Hewitt fifty yard crawl for time test were significantly correlated with the results of the number of strokes component of the Burris test ($r = .81$),

Table 2

Correlation Matrix for the Battery of Published Tests

	25 Yards Strokes	25 Yards Time	50 Yards Time	Fox Power Feet	Burris Norms Local	Burris Norms Published
25 Yards Strokes	1.00					
25 Yards Time	.60	1.00				
50 Yards Time	.81	.92	1.00			
Fox Power Feet	-.75	-.61	-.75	1.00		
Burris Norms Local	.89	.90	.97	-.76	1.00	
Burris Norms Published	-.86	-.77	-.85	.65	-.91	1.00

An r of .43 was required for significance at the .05 level.

the time for twenty-five yards component of the Burris test (r = .92), and the combined Burris test results based upon published norms (r = -.85).

The results of the Fox power test were significantly correlated with the results of the number of strokes component of the Burris test (r = -.75), the time for twenty-five yards component of the Burris test (r = -.61), the combined results of the Burris test based on local norms (r = -.76), and the combined results of the Burris test based on published norms (r = .65). The results of the Fox power test were also significantly correlated with the results of the Hewitt fifty yard crawl for time (r = -.75).

Discussion of the test battery. The finding that all aspects of the Burris speed-stroke test of the crawl were significantly related implies that relatively similar results could be obtained from the administration of just one item of the test. Thus, an instructor could save class time by administering just one item of the test.

The finding that all of the items of the test battery, the Burris test, the Hewitt test, and the Fox power test, were significantly correlated demonstrated a relationship between swimming speed and swimming power.

Comparison of results. In general, it was found that the results of the above three tests for the Middle Tennessee State University students in this study were very similar to the norms published for these tests. A comparison of the available means and standard deviations for the published norms and the local norms for the Middle Tennessee State University students in this study is presented in Table 3. Attention should be called to the fact that the norms for this study were developed from a mixed group of males and females while some of the published norms were based upon a single sex group.

Table 3

Comparison of Published Norms and Middle Tennessee State University Norms

	Means		SD	
	Published	MTSU	Published	MTSU
Burris Test				
No. Strokes for 25 Yds.	28 m 30.5 w	27.67 mw		8.58 mw
Time for 25 Yds. (Sec.)	20 m 26.5 w	22.28 mw		6.28 mw
Combined Results (Based on Local Norms)*		99.96 mw		17.93 mw
Combined Results (Based on Published Norms)*	100.0 m 100.0 w	104.43 mw	20 m 20 w	27.20 mw
Hewitt 50 Yds. Test (Sec.)	44.8 w	44.8 m		19.85 mw
Fox Power Test (Ft.)	27.74	29.52	5.68 w	5.82 mw

m = men w = women mw = men and women combined

*The published norms for this test were based on an inverted scale so that the better scores were higher. The MTSU norms were not based on an inverted scale so the better scores were lower than the poorer scores.

Performance of students in this study compared favorably with the norms published for the Burris speed-stroke test of the crawl. The published norms were based upon 89 men and 143 women swimmers at Temple University. On the number of strokes component of the Burris test the male and female Middle Tennessee State University students scored just slightly better than the published means. The subjects in this study required an average of 27.67 strokes to cover twenty-five yards while the published means for this component were 28.0 for men and 30.5 for the women. On the time for twenty-five yards component of the Burris test the subjects in this study scored 22.28 seconds while the published means were 20.0 seconds for the men and 26.5 for the women. The published combined results were scaled so that the mean equaled one hundred for both men and women. Based upon the published standards for each component, the combined results for the male and female subjects in this study equaled 104.43. Thus, the subjects in this study scored slightly better than the published means for the Burris speed-stroke test of the crawl. This finding came in spite of the fact that the local norms developed for the subjects in this study were somewhat negatively skewed by the extremely poor performance of one subject who required sixty strokes and 41.9 seconds to cover the twenty-five yards.

The mean for the males and females in this study was slightly higher on the Hewitt fifty yard crawl for time than the published mean for that test. The published mean was based on 4,000 college males at the University of California. The fact that both males and females were subjects for this study could have accounted for the two second difference between the published mean (44.8) and the mean for subjects in this study (46.8). Yet, the poorest score among the subjects (1:57.1) was scored by a male.

The mean for the subjects in this study (29.52) was slightly better on the Fox power test than was the published mean for the test (27.74). However, the fact that both men and women were included in the norms for this study and the published norms were based upon the performances of fifty females at the State University of Iowa could have accounted for the difference. The standard deviation of 5.68 for the published test was similar to the standard deviation of 5.82 for the local norms developed for this study.

Thus, the performances of the subjects in this study generally appeared to be similar to those on which the published norms for the test battery were based.

Swimming Efficiency Results

The pre-test data were treated by the computation of coefficients of correlation between the variables and with multiple linear regression analysis.

Correlations. The results of the pre-test data for the experimental method of measuring swimming efficiency did not correlate significantly with the results of the Burris speed-stroke test, the Hewitt fifty yard test, the Fox power test, nor the form rating scale. The correlations which indicated the relationship between each of the above variables are presented in Table 4.

Table 4

Correlations Between the Experimental Method
of Measuring Swimming Efficiency
and Various Tests

	Experimental Method*
No. Strokes for 25 Yds.	0.02
Time for 25 Yes.	0.17
Hewitt 50 Yds. for Time	0.16
Fox Power (Feet in 5 Stroke Cycles)	-0.23
Form Rating Scale	-0.00
Burris Test Based on Local Norms	0.10
Burris Test Based on Published Norms	-0.05

*An r or .43 was required for significance at the .05 level.

Discussion of swimming efficiency correlations. There were a number of possible reasons for the non-significant correlations that were found. Central among these reasons was the level of swimming ability of many of the subjects in the study. Although the means for the subjects in this study were similar to the reported means in the literature for the Burris test, the Hewitt fifty yard test, and the Fox power test, there was extreme variability among the subjects in this study. For example, it was found at one extreme that one subject could swim the crawl stroke continuously for a distance over one mile while at the other extreme fifty yards represented the maximum distance that could be swam. Since the method was originally planned for subjects of at least the intermediate level of ability, modifications had to be made in order to accommodate these relatively weak swimmers. The basic purpose was to measure the swimmer's oxygen uptake during a sub-maximal swim and then to compare the results with the subject's maximal oxygen uptake level. A low percentage or low ratio between these measures was planned to indicate a high level of swimming efficiency. However, when it was found that over fifty percent of the subjects could not swim the crawl stroke at a sub-maximal rate of 2.5 feet per second for a period of three minutes, the duration of the test was reduced to one minute. This shortening of the time led to an important source of error among the swimmers of low ability. Namely, a possibility existed that these subjects had slightly hyperventilated immediately before beginning the test; thus, they did not consume as large a volume of air during the test. As was found in Magel and Faulkner's study, the possibility also existed that the less skilled subjects were impaired by muscle fatigue and/or respiratory distress before the maximal value was attained.[3] Furthermore, since the test lasted for only one minute, much of the work was likely accomplished anaerobically rather than aerobically. Evidence that the above situation occurred was the fact that several of the swimmers who scored poorly on the other tests had difficulty in completing the one minute swims in which the expired air was collected by means of a snorkel-like mouthpiece. For these subjects the readings from the oxygen analyzer indicated that the oxygen was being extracted from the air at a relatively low rate and also that a small volume of air was expired during the one minute test. These irregularities could have accounted for the relatively low oxygen uptake level. The raw data for the oxygen uptake components of the test are included in Appendixes O through R. Some of the typical and atypical cases are presented in Table 5. As can be seen from the example, in Table 5, of the relatively powerful swimmer who scored poorly on the efficiency test, the oxygen extraction dropped off sharply during the maximal swim. This reading seemed to indicate that the work was being accomplished anaerobically. Thus, hyperventilation and anaerobic work were two likely causes of the low correlations.

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[3] John R. Magel and John A. Faulkner, "Maximum Oxygen Uptakes of College Swimmers," Journal of Applied Physiology, XXII (May, 1967), 933.

Table 5

Comparison of Ventilation and Oxygen Extraction of Typical and Atypical Cases

	Fox Power	Sub-max. Min./Vent. Liters	Sub-max. O_2 Extraction	Max. Min./Vent. Liters	Max. O_2 Extraction	Efficiency* Percent
<u>Typical Cases</u>						
(1) Weak swimmer who scored poorly (C.P.)	27 ft.	55.9	2.88	65.3	3.33	74.2
(2) Powerful swimmer who scored well (M.S.)	42 ft.	30.06	1.48	71.0	3.83	16.7
<u>Atypical Cases</u>						
(1) Weak swimmer who scored well (S.M.)	14 ft.	24.6	1.23	47.4	1.23	51.9
(2) Powerful swimmer who scored poorly (L.B.)	33 ft.	41.5	4.13	63.7	2.89	93.1
Group Mean	29.52	34.3		58.0		64.3

*Lower scores were the better ones.

A second area of possible error involved in the method was the determination of each subject's maximum oxygen uptake level to serve as a standard comparison. The determination of the subject's maximum oxygen uptake level during actual swimming instead of during some other type of work such as treadmill running or while cycling on the bicycle ergometer was desirable because of such factors as heat dissipation by the surrounding water and the decreaded workload on the cardiovascular system due to the horizontal body position during swimming. Since high correlations (r = .85) had been reported in the literature between maximum oxygen uptake when measured during swimming and when measured during treadmill running,[4] the decision was made that the maximum working capacity should be determined during actual swimming. However, such a measurement proved impossible with subjects who could swim the crawl stroke continuously for no longer than one minute. Thus, the decision was made that the maximal value would be represented by the subject's oxygen uptake level during an all-out one minute tethered swim. By limiting the duration of this test to one minute, the workload was standardized for all subjects. Karpovich and Le Maistre reported that swimmers in his study practically reached their maximum oxygen uptake level by the end of the first minute of such a maximal swim.[5]

Furthermore, the mean maximal values obtained in this study were comparable to some of those reported in the literature when the differences in swimming ability were taken into consideration. The mean oxygen uptake level during the pre-test one minute maximal swim for the twenty-one subjects in this study was 1.71 liters per minute. This

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[4] Magel and Faulkner, p. 931.

[5] Peter V. Karpovich and Harold Le Maistre, "Prediction of Time in Swimming Breast Stroke Based on Oxygen Consumption," Research Quarterly, XI (March, 1940), 42.

value was comparable to some of the maximal oxygen uptake values reported in the literature when differences in the situation were taken into consideration. For example, di Prampero et al. reported a mean maximum oxygen uptake level for ten well trained male college students during tethered swimming of 1.94 liters per minute.[6] Costill reported a mean maximal oxygen uptake value during tethered swimming of 2.47 liters per minute for a group of thirteen male varsity college swimming team members, one of whom was a National Collegiate Athletic Association individual medley champion.[7] Holmer reported a mean maximal oxygen uptake value during performance in a swimming flume of 2.78 liters per minute for a group of twelve female competitive swimmers, two of whom belonged to the European elite, five were of the Swedish top class, and the remainder were promising competitors.[8] Although these reported values were higher than the one found for subjects in this study, the differences were not too large in light of the fact that these studies involved highly trained competitive swimmers.

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[6] P. E. di Prampero, D. R. Pendergrast, D. W. Wilson, and D. W. Rennie, "Energetics of Swimming in Man," Journal of Applied Physiology, XXXVII (July, 1974), 1-5.

[7] David L. Costill, "Use of a Swimming Ergometer in Physiological Research," Research Quarterly, XXXVII (December, 1966), 564-565.

[8] Ingvar Holmer, "Oxygen Uptake During Swimming in Man," Journal of Applied Physiology, XXXIII (October, 1972), 502-509.

The subjects in this study were as a group not highly trained nor from competitive backgrounds. In addition, these reported studies actually measured maximal oxygen uptake values while this study measured only the oxygen uptake level during one minute of maximal intensity swimming. Thus, the maximal values reported for subjects in this study were not out of line with maximal values reported in other studies. For this study the maximal value used for comparison was the subject's oxygen uptake level during a one minute maximal swim and was defined as "maximal swimming working capacity." Thus, the maximal oxygen uptake level was not actually measured. The utilization of the subject's maximal swimming working capacity as a standard for comparison could have represented another source of error.

Multiple linear regression analysis. When the results of the experimental method of measuring swimming efficiency were treated with multiple linear regression analysis, only weak relationships were found to exist between this variable and a combination of the published tests and form rating (predictor variables). For example, the relationship between the experimental method and a combination of the components of the Burris test, the Fox power test, and the form rating scale was weak ($r^2 = .19$).

The development of a formula with which to predict the swimming efficiency for subjects based upon their performance on the battery of published field tests and the form rating scale was desirable. However, since the experimental method of measuring swimming efficiently did not yield significant correlations with the predictor variables either singularly or in combinations, such a prediction formula could not be developed from the data collected on the subjects in this study.

Of all the prediction formulae attempted, the variable that was predicted best from the battery of tests was the oxygen uptake level expressed in milliliters per killogram of body weight per minute during a one minute maximal swim. The relationship ($r^2 = .62$) between this variable and the distance covered in five stroke cycles in the Fox power test was used for prediction. The addition of the twenty-five yard time component of the Burris test to the regression equation did not increase the prediction appreciably. (See Table 6.) The formula for the prediction of oxygen uptake during a one minute maximal swim was developed as follows:

$$\dot{V}O_2 = (\text{Fox power})(0.897725) + (-1.800918).$$

Discussion of multiple linear regression analysis. Although the above finding contribured relatively little to the issue of swimming efficiency as originally conceived in this study, it did shed light upon some of the aspects of swimming. The one minute maximal swim required an intense and somewhat explosive effort. Apparently, a similar

Table 6

Stepwise Multiple Regression Analysis

Dependent variable = $\dot{V}O_2$ during maximal tethered swim

Predictor variables = Fox power test (feet)
Time for 25 yds. (seconds)

Step 1	F-CRIT	DOF	R-SQ	SEE
	0.05	19	0.6218	4.1798
VAR:LABEL	COEFFICIENT	STD-ERR	F-RATIO	BETA-WT
feet	0.897725	0.1606	31.24	0.7886
CONS	-1.800918			
Step 2	F-CRIT	DOF	R-SQ	SEE
	0.05	18	0.6275	4.2618
VAR:LABEL	COEFFICIENT	STD-ERR	F-RATIO	BETA-WT
time 25 yds.	0.100087	0.1906	0.28	0.0948
feet	0.962978	0.2056	21.94	0.8459
CONS	-5.957004			

explosive effort was also required for success on the Fox power test and the twenty-five yard swim for time. Thus, it appeared that swimmers who scored the highest on these two tests were also the ones who were capable of performing the greatest swimming workload during an explosive one minute bout of tethered swimming. Conversely, it further appeared that a swimmer with a relatively high explosive swimming working capacity (as measured by oxygen uptake level during a one minute maximal swim) would also be likely to possess a high level of swimming speed and swimming power. This finding again seemed to indicate that the ability to cover a relatively large distance on each stroke and also to be able to swim swiftly were two important components of swimming efficiency.

Teaching Methods

The relative effectiveness of a traditional method of instruction and an experimental method of instruction were investigated in this study.

Analysis of variance. The results of the pre-test and post-test measurements of swimming efficiency were treated with two-way analysis of variance with repeated measures. This analysis was extended to include the components of the method of measurements as well as the final results of the test. Thus, five analyses were computed. The variables for these procedures included the pre-test and post-test results on (1) oxygen uptake expressed in liters per minute during a one minute sub-maximal tethered swim with a workload comparable to 2.5 feet per second, (2) oxygen uptake expressed in milliliters per killogram of body weight during a one minute sub-maximal tethered swim with a workload comparable to 2.5 feet per second, (3) oxygen uptake expressed in liters per minute during a one minute maximal intensity tethered swim, (4) oxygen uptake expressed in milliliters per killograms of body weight during a one minute maximal intensity tethered swim, and (5) the percentage of the subject's oxygen uptake during a one minute maximal intensity tethered swim expressed in milliliters per killogram of body weight that was required for each subject to complete a one minute sub-maximal tethered swim with the workload comparable to

2.5 feet per second. The fifth of the above variables represented swimming efficiency and the first four variables were components of the measurement. The results of the analyses indicated no significant differences between the control group and the experimental group either on the pre-test or on the post-test on the swimming efficiency measurement or any of its components. The pre-test and post-test mean values for the swimming efficiency measurements are presented in Table 7. The results of the analysis of variance are presented in Tables 8 through 12.

Table 7

Pre- and Post-test Swimming Efficiency Values

	Pre-test $\bar{X}$	Post-test $\bar{X}$
Control Group		
Sub-maximal (liter/min.)	1.16	1.19
Sub-maximal (ml./kg./min.)	16.29	16.23
Maximal (liters/min.)	1.67	2.01
Maximal (ml./kg./min.)	22.05	27.39
Efficiency (percent)	64.15	57.52
Experimental Group		
Sub-maximal (liter/min.)	1.04	.91
Sub-maximal (ml./kg./min.)	16.38	14.00
Maximal (liters/min.)	1.76	1.79
Maximal (ml./kg./min.)	27.23	27.18
Efficiency (percent)	61.84	53.17

Table 8

Two-way Analysis of Variance with Repeated Measures for Sub-maximal Oxygen Uptake Expressed in Liters Per Minute

	df	Sums of Squares	Mean Squares	F Ratios
Between SS	14	5.474	0.319	
Groups	1	0.2920	0.2920	0.7326
Error (B)	13	5.1820	0.3986	
Within SS	15	2.1250	0.141	
Pre-post	1	0.0367	0.0367	0.2342
Interaction	1	0.0483	0.0483	0.3081
Error (W)	13	2.0399	0.1569	
Total	29	7.5991	0.2620	

Table 9

Two-way Analysis of Variance with Repeated Measures for Sub-maximal Oxygen Uptake Expressed in Milliliters Per Killogram of Body Weight

	df	Sums of Squares	Mean Squares	F Ratios
Between SS	14	1045.8336	74.7024	
Groups	1	8.1920	8.1920	0.1026
Error (B)	13	1037.6416	79.8185	
Within SS	15	428.3510	28.5567	
Pre-post	1	15.7107	15.7107	0.5070
Interaction	1	9.8093	9.8093	0.3166
Error (W)	13	402.8309	30.9869	
Total	29	1474.1847	50.8339	

Table 10

Two-way Analysis of Variance with Repeated Measures for Oxygen Uptake During Maximal Swim in Liters

	df	Sums of Squares	Mean Squares	F Ratios
Between SS	14	11.1382	0.7955	
Groups	1	0.0286	0.0286	0.0335
Error (B)	13	11.1096	0.8545	
Within SS	15	1.1958	0.0797	
Pre-post	1	0.1687	0.1687	2.6010
Interaction	1	0.1836	0.1836	2.8311
Error (W)	13	0.8434	0.0648	
Total	29	12.3340	0.4253	

Table 11

Two-way Analysis of Variance with Repeated Measures for Oxygen Uptake During Maximal Swim in Milliliters Per Killogram of Body Weight

	df	Sums of Squares	Mean Squares	F Ratios
Between SS	14	934.7597	66.7685	
Groups	1	44.47	44.47	0.6494
Error (B)	13	890.2883	68.4837	
Within SS	15	255.6198	17.0413	
Pre-post	1	33.1381	33.1381	2.5324
Interaction	1	52.3691	52.3691	4.0020
Error (W)	13	170.1125	13.0855	
Total	29	1190.3796	41.0475	

Table 12

Two-way Analysis of Variance with Repeated Measures for Swimming Efficiency

	df	Sums of Squares	Mean Squares	F Ratios
Between SS	14	8786.1630	627.5830	
Groups	1	79.8935	79.7935	0.1193
Error (B)	13	8706.2695	669.7130	
Within SS	15	5068.6816	337.9121	
Pre-post	1	462.6396	462.6396	1.3078
Interaction	1	7.4091	7.4091	0.0209
Error (W)	13	4598.6328	353.7409	
Total	29	13854.8447	477.7532	

The control group mean oxygen uptake level during the sub-maximal tethered swim changed from 1.16 liters per minute or 16.28 milliliters per killogram of body weight on the pre-test to 1.19 liters per minute or 16.23 milliliters per killogram of body weight on the post-test. Neither of these variable changes was significant. The control group mean oxygen uptake level during the maximal tethered swim changed from 1.67 liters per minute or 22.05 milliliters per killogram of body weight on the pre-test to 2.01 liters per minute or 27.39 milliliters per killogram of body weight on the post-test. Neither of these variable changes was significant.

The experimental group mean oxygen uptake level during the sub-maximal tethered swim changed from 1.04

liters per minute or 16.38 milliliters per killogram of body weight on the pre-test to .90 liters per minute or 14.00 milliliters per killogram of body weight on the post-test. This decrease was not significant. The experimental group mean oxygen uptake level during the maximal tethered swim changed from 1.76 liters per minute or 27.23 milliliters per killogram of body weight on the pre-test to 1.79 or 27.17 milliliters per killogram of body weight on the post-test. This change was not significant. The differences between the control group and the experimental group on the above four variables were not significant.

The control group mean performance on the swimming efficiency variable changed from 64.15 percent on the pre-test to 57.52 percent on the post-test. This decrease indicated improvement in efficiency but the change was not significant. The differences on the swimming efficiency variable between the control group and the experimental group on either the pre-test or post-test were not significant.

Discussion of teaching method results. A possible explanation as to why no significant differences were found by the analysis was the fact that the study attempted to investigate a realistic situation in which the time devoted to classroom instruction in mechanical principles came at the expense of time spent in regular swimming instruction and practice in the pool area. Such an arrangement was desirable since the instructor might find himself in a position of having to decide whether or not to devote a portion of the regular class time to classroom instruction. Thus, the control group in this situation was inadvertantly given approximately 110 minutes more time in such activities as demonstration and practice in the pool. This extra time in the pool area could have equalized the effect of the mechanical principles instruction.

Chapter 5

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS FOR TEACHING

The following discussion contains a brief summary of the study, the conclusions drawn from the study, a number of recommendations, and some implications for teaching.

SUMMARY

Twenty-one Middle Tennessee State University students enrolled in two intermediate swimming classes served as subjects for the study. The study consisted of three basic components of investigation. One aspect of the study investigated the possibility of validly assessing the swimming efficiency of a number of students in a class situation by means of a form rating scale. The results of the form rating scale that was developed for this study were found to yield statistically significant coefficients of correlation with the Burris speed-stroke test of the crawl, the Fox power test, and the Hewitt fifty yard crawl for time test.

A second aspect of the study investigated the possibility of actually measuring the swimming efficiency of a swimmer performing at a sub-maximal rate. To study this possibility, an experimental method of measuring swimming efficiency was developed. The method was designed on the theory that the more efficient swimmer would utilize a relatively smaller volume of oxygen during a sub-maximal swim of uniform intensity and duration than his less efficient counterpart. The results of this experimental method did not yield significant correlations with either the Burris speed-stroke test of the crawl, the Fox power test, the Hewitt fifty yard crawl for time, or the above mentioned form rating scale. The relationship between the experimental method of measuring swimming efficiency and a combination of variables from the test battery was too small for the development of a prediction formula by means of stepwise multiple linear regression analysis for swimming efficiency.

The third aspect of the study compared the relative effectiveness of two teaching methods. The control group was taught the crawl stroke by a traditional method consisting of demonstration and explanation by the instructor and class practice under the supervision of the instructor. The experimental group received basically the same type of instruction as did the control group with the exception that part of each class period was devoted to instruction in the mechanical principles of swimming. Two-way analysis of variance with repeated measures revealed that no significant differences existed between the groups on either the pre-test or post-test or between the pre-test and the post-test for either group.

CONCLUSIONS

Based upon the findings reported in the analysis of the data, the following conclusions were made concerning the statistical hypotheses that were tested.

H_1: The null hypothesis that there was no significant difference between the pre-test and the post-test means of the experimental group on swimming efficiency was accepted.

H_2: The null hypothesis that there was no significant difference between the pre-test and the post-test means of the control group in swimming efficiency was accepted.

H_3: The null hypothesis that there was no significant difference between the post-test means of the experimental group and the control group in swimming efficiency was accepted.

H_4: The null hypothesis that there was no significant relationship between the results of the experimental method of measuring swimming efficiency and the results of the Fox power test was accepted.

H_5: The null hypothesis that there was no significant relationship between the results of the experimental method of measuring swimming efficiency and the results of the Hewitt fifty yard crawl for time was accepted.

H_6: The null hypothesis that there was no significant relationship between the results of experimental method of measuring swimming efficiency and the results of the Burris speed-stroke test of the crawl was accepted.

H_7: The null hypothesis that the relationship between the experimental method of measuring swimming efficiency and a combination of predictor variables of the battery of practical field tests was too small for the development of a prediction formula by means of stepwise multiple linear regression analysis for swimming efficiency was accepted.

H_8: The null hypothesis that there was no significant relationship between the results of the form rating scale and the results of the experimental method of measuring swimming efficiency was accepted.

H_9: The null hypothesis that there was no significant relationship between the results of the form rating scale and the results of the Fox power test was rejected.

H_{10}: The null hypothesis that there was no significant relationship between the results of the form rating scale and the results of the Hewitt fifty yard crawl for time was rejected.

H_{11}: The null hypothesis that there was no significant relationship between the results of the form rating scale and the results of the Burris speed-stroke test of the crawl was rejected.

RECOMMENDATIONS

The following recommendations were made as a result of the findings of this study.

Further research should be conducted on the experimental method of measuring swimming efficiency using subjects of a higher and more uniform level of ability than that of those in this study so that modifications in the testing procedures would not have to be made. The actual maximum oxygen uptake of each subject should be made to serve as a standard of comparison for the experimental method of measuring swimming efficiency.

IMPLICATIONS FOR TEACHING

Based upon the findings of this study, there appeared to be two major implications for teaching. First, since no difference in performance was observed between the control group and the experimental group, either method of teaching used in this study might be utilized equally well. The swimming instructor might base his decision as to the use of a mechanical principles approach upon other factors such as student experience, teacher experience, and the teaching environment. For example, many students have learned the skill of floating with no mention of Archimedes' principle. Yet, such an explanation could be beneficial to other students. Furthermore, the use of overhead transparencies and filmstrips used in this study are not available in some teaching situations. Thus, the individual situation should be considered in the selection of methods.

Second, this author found that the swimming efficiency of a group of students in a class situation could be evaluated by a form rating scale with a significant degree of validity. This finding does not imply, however, that such results could be generalized to all other situations. Instructors who use rating scales might profit from a comparison of their method of evaluation with other objective tests.

APPENDIXES

APPENDIX A

MECHANICAL PRINCIPLES

MECHANICAL PRINCIPLES

- I. General principles:
  Efficiency depends upon two factors:
  - A. Resistance--drag caused by pushing water out of the swimmer's way or by pulling it along with him.
    - 1. Frontal
    - 2. Skin
    - 3. Tail suction (eddy)
    - 4. Waves
      - a. Up and down movements
      - b. Rolling
      - c. Bow wave
    - 5. Eddies
      - a. Middle lane
      - b. Water level
      - c. Scum gutter
    - 6. Streamlining (horizontal body position)
      - a. Less frontal resistance
      - b. Less drag
    - 7. Cavitation
      - a. Breathing
      - b. Hands
    - 8. Internal resistance
    - 9. Physical features
    - 10. Bouyancy
      - a. Center of gravity: hips
      - b. Center of bouyancy: chest
  - B. Propulsion (Newton's three laws)
    - 1. Action and reaction
      - a. Angle of application of force
      - b. Horizontal body alignment
        - (1) Bobbing
        - (2) Climbing up
      - c. Lateral body alignment
        - (1) Head
        - (2) Arms
    - 2. Inertia
      - a. Constant pace
      - b. Starting and stopping
      - c. Continuous force
    - 3. Acceleration
    - 4. Theoretical square law
      - a. Resistance varies with the square of the velocity, thus doubling the speed of the arms creates four times as much propulsion.

b. Energy expenditure cubes with the speed of muscular contraction, thus doubling the speed of the arms uses eight times as much energy.

II. American Crawl
  A. Body position
    1. Head
      a. Less resistance with water level at hairline.
      b. Height of head depends upon bow wave.
      c. Wrinkles in back of neck: too rigid.
      d. If head is too high trunk sinks and drags.
      e. Rotating head causes less resistance than lifting it does.
    2. Trunk
      a. Upper spine is slightly flexed to give a mechanical advantage to arm depressor muscles.
      b. The trunk serves as a base for arm and leg movement.
    3. Hips--If legs become tired the hips may wiggle to compensate and keep legs moving.
    4. Legs
      a. If too high: feet break surface.
      b. If too low: drag and eddy resistance.
  B. Kick
    1. Propulsive or stabilizing
      a. Propulsive
      b. Stabilizer
        (1) Two beat crossover
        (2) Six beat
        (3) Lateral body alignment
        (4) Bouyancy for lower body
    2. Kick from hips
    3. Depth = 18 to 26 inches
      a. If too shallow and fast: hips will wiggle.
      b. If too deep: eddy and drag resistance cause fatigue.
    4. Ankle
      a. Parallegram of force
      b. Flexibility
  C. Arm Action
    1. Recovery
      a. Wide recovery
      b. Elbows high

- c. Energy
  - (1) Ballistic
  - (2) Centrifugal force
- d. Flexibility
- 2. Pull
  - a. Entry (Glide for distance men)
  - b. Do not "reach" with shoulder
    - (1) Lateral body alignment
    - (2) Mechanical disadvantage for muscles
  - c. Speed
    - (1) Begin catch early for longer application of force
    - (2) Water must be pushed back faster than swimmer is travleing
    - (3) Hand stays near spot of entry
  - d. Pull
    - (1) Elbow up
    - (2) Elbow bend = 90° to 100°
    - (3) Power line (S pull)
    - (4) Bernoulli effect
  - e. Push (most power at 90°)
  - f. Release--momentum carries into recovery
- D. Body roll
  - 1. Detrimental--creates waves
  - 2. Helpful
    - a. Facilitates recovery with short radius of rotation
    - b. Places the pulling arm under center of gravity
    - c. Lets feet thrust sideward to maintain lateral alignment
    - d. Facilitates breathing
- E. Breathing
  - 1. Bow wave creates cavity.
  - 2. Exhale continuously while under water.
  - 3. Explosive breathing
  - 4. No pause should occur after breathing.
  - 5. There should be no breath taken on stroke after a start or turn.

BIBLIOGRAPHY FOR APPENDIX A

Armbruster, David A. and others. Swimming and Diving. St. Louis: C. V. Mosby Company, 1963.

Bunn, John W. Scientific Principles of Coaching. Englewood Cliffs: Prentice-Hall, 1972.

Caughran, James A. Advanced Swimming. Dubuque: Wm. C. Brown Company, Publishers, 1972.

Clark, Steve. Competitive Swimming As I See It. N. Hollywood: Swimming World, 1967.

Collis, Martin, and Bill Kirchoff. Swimming. Boston: Allyn and Bacon, Inc., 1974.

Counsilman, James E. The Science of Swimming. Englewood Cliffs: Prentice-Hall, Inc., 1968.

Cureton, Thomas K. How to Teach Swimming and Diving. York, Pa.: The Maple Press Company, 1934.

Harris, Marjone. Basic Swimming Analyzed. Boston: Allyn and Bacon, Inc., 1969.

Hooks, Gene. Application of Weight Training to Athletics. Englewood Cliffs: Prentice-Hall, 1962.

Still, Athole. Competitive Swimming. New York: St. Martin's Press, 1971.

Swimming and Water Safety. Washington, D.C.: American National Red Cross, 1968.

APPENDIX B

FORM RATING SCALE

Form Rating Scale

Stroke ________

	Name												
Arms	Rating												
	Score												
Breathing	Rating												
	Score												
Kick	Rating												
	Score												
Body Position	Rating												
	Score												
Coordination	Rating												
	Score												
Total													

Directions: Rank each student on each skill on a four point scale and multiply results by five to compute score. Add scores to find total.

APPENDIX C

RED CROSS ELIGIBILITY STANDARDS FOR INTERMEDIATE SWIMMING

RED CROSS ELIGIBILITY STANDARDS FOR INTERMEDIATE SWIMMING

To be eligible for intermediate swimming the student had to be able to perform the skills listed for the advanced beginner course. These skills were listed as follow in the Swimming and Water Safety Courses Instructor's Manual of the American National Red Cross.

To successfully complete the Advanced Beginner course, the student must pass the following individual and combined skills. They are numbered to correspond with the numbered skills on the Advanced Beginner Skill Sheet.

Individual Skills

1. Breath control: Student demonstrates rhythmic breathing ability by regularly inhaling and exhaling for a minimum of 2 minutes. He also bobs up and down in water over his own depth, with good breath control, for a minimum of 20 times.
2. Survival floating: Student demonstrates his ability to perform the survival floating skill in a relaxed, coordinated manner for a minimum of 2 minutes.
3. Changing positions and treading water: Student changes from a prone position to vertical and treads water for 30 seconds. He then goes to the supine position. From supine position, the student goes to the vertical and in this position treads water for 30 seconds and then returns to the prone position.
4. Elementary backstroke: Student swims 25 yards using the elementary backstroke.
5. Crawl stroke: Student swims 25 yards using the crawl stroke.
6. Diving and underwater swimming: Student dives from deck and swims 15 feet underwater.

7. Use of life jacket: Student jumps from deck into the deep water while wearing jacket. He demonstrates his ability to be comfortable while in prone, vertical, and supine positions. Each position should be held for at least 1 minute. NOTE. Any Coast Guard approved jacket-type preserver may be used.

8. Safety and rescue techniques: Student demonstrates assists using arm extension, pole, and article of clothing. He demonstrates, using a partner, the proper head position for maintaining an open airway for mouth-to-mouth resuscitation. No attempt should be made to actually make mouth-to-mouth contact.

Combined Skills

9. Student dives into deep water and swims a minimum of 15 feet under water, then comes to the surface and treads water for 30 seconds, then swims 20 yards using a crawl stroke.

10. Student jumps into deep water, then comes to the surface and performs the survival floating skill for 2 minutes, then swims 20 yards using the elementary backstroke.

Source: Swimming and Water Safety Courses Instructor's Manual (Washington, D.C.: The American National Red Cross, 1968), pp. 52-54.

APPENDIX D

RESULTS OF THE FORM RATING SCALE

RESULTS OF THE FORM RATING SCALE

Name	Score
Control Group	
J. B.	60.00
K. B.	50.00
G. G.	60.50
D. L.	67.50
S. M.	46.00
R. M.	72.50
D. O.	74.00
C. P.	56.00
T. S.	72.50
G. W.	73.50
R. Y.	61.50
Experimental Group	
L. B.	71.50
E. D.	65.50
G. D.	69.50
G. H.	52.50
C. J.	74.00
K. M.	89.00
R. S.	59.00
D. S.	84.00
M. S.	61.00
C. T.	74.50

APPENDIX E

RESULTS OF THE BURRIS SPEED-STROKE TEST OF THE CRAWL

RESULTS OF THE BURRIS SPEED-STROKE TEST OF THE CRAWL

Name	Raw Scores		Norms	
	No. of Strokes	Time for 25 Yards	Local Norms*	Published Norms**
Control Group				
J. B.	24	19.5	91.32	134
K. B.	32	24.7	108.93	80
G. G.	21	24.7	96.10	102
D. L.	20	23.0	92.23	108
S. M.	60	41.9	169.03	0
R. M.	23	21.0	92.55	107
D. O.	27	15.3	87.64	117
C. P.	22	34.0	112.10	107
T. S.	28	20.5	97.21	100
G. W.	22	21.3	9.86	109
R. Y.	29	21.5	100.34	98
Experimental Group				
L. B.	23	25.4	99.56	119
E. D.	25	16.9	88.34	114
G. D.	24	18.7	90.04	110
G. H.	35	26.7	115.16	91
C. J.	35	22.7	109.24	100
K. M.	30	14.9	90.98	111
R. S.	28	20.7	97.53	121
D. S.	27	18.0	92.42	137
M. S.	22	20.5	90.58	109
C. T.	24	15.9	85.58	119

*Local Norms--The better scores were lower.

**Published Norms--The better scores were higher.

APPENDIX F

RESULTS OF THE HEWITT FIFTY YARD CRAWL FOR TIME TEST

RESULTS OF THE HEWITT FIFTY YARD CRAWL FOR TIME TEST

Name	Time
Control Group	
J. B.	44.1
K. B.	54.4
G. G.	36.7
D. L.	39.6
S. M.	1:57.1
R. M.	43.7
D. O.	32.7
C. P.	1:06.8
T. S.	37.7
G. W.	38.6
R. Y.	45.7
Experimental Group	
L. B.	54.3
E. D.	34.1
G. D.	36.3
G. H.	1:14.6
C. J.	53.2
K. M.	29.5
R. S.	39.0
E. S.	32.5
M. S.	39.3
C. T.	32.8

APPENDIX G

RESULTS OF THE FOX POWER TEST

RESULTS OF THE FOX POWER TEST

Name	Feet*
Control Group	
J. B.	31
K. B.	28
G. G.	35
D. L.	30
S. M.	14
R. M.	30
D. O.	32
C. P.	27
T. S.	31
G. W.	36
R. Y.	23
Experimental Group	
L. B.	33
E. D.	32
G. D.	28
G. H.	21
C. J.	26
K. M.	35
R. S.	27
E. S.	31
M. S.	42
C. T.	28

*This figure represented the number of feet that the subject could swim the crawl in five complete arm strokes.

APPENDIX H

AGE, HEIGHT, AND WEIGHT OF THE SUBJECTS

AGE, HEIGHT, AND WEIGHT OF THE SUBJECTS

Name	Age	Height (in.)	Weight (lb.)
Control Group			
J. B.	19	68.00	132.00
K. B.	21	71.00	165.00
G. G.	24	68.00	183.00
D. L.	19	67.50	138.00
S. M.	20	67.50	133.50
R. M.	17	69.00	140.00
D. O.	19	72.00	148.00
C. P.	19	63.00	170.00
T. S.	18	72.00	211.00
G. W.	19	74.00	190.00
R. Y.	17	64.00	118.00
Experimental Group			
L. B.	19	64.50	117.50
E. D.	25	67.50	131.00
G. D.	18	72.50	176.50
G. H.	19	62.25	116.50
C. J.	20	60.00	120.00
K. M.	21	71.50	173.00
R. S.	18	66.75	128.75
E. S.	22	64.50	116.00
M. S.	21	69.75	146.00
C. T.	23	74.50	184.00

APPENDIX I

PRE-TEST OXYGEN UPTAKE DURING A SUB-MAXIMAL ONE MINUTE SWIM

PRE-TEST OXYGEN UPTAKE DURING A SUB-MAXIMAL ONE MINUTE SWIM

Name	Liters/Minute	Ml./Kg./Min.
Control Group		
J. B.	.50	8.35
K. B.	2.44	32.64
G. G.	1.72	20.82
D. L.	.92	14.75
S. M.	.26	4.36
R. M.	1.78	27.94
D. O.	.93	13.90
C. P.	1.40	18.22
T. S.	.59	6.16
G. W.	2.01	23.28
R. Y.	.48	9.02
Experimental Group		
L. B.	1.49	28.02
E. D.	.54	9.03
G. D.	1.30	16.22
G. H.	.93	17.51
C. J.	1.03	18.94
K. M.	1.57	19.97
R. S.	.70	11.93
E. S.	.92	17.41
M. S.	.40	5.98
C. T.	1.20	14.33

APPENDIX J

PRE-TEST OXYGEN UPTAKE DURING A MAXIMAL ONE MINUTE SWIM

PRE-TEST OXYGEN UPTAKE DURING A MAXIMAL ONE MINUTE SWIM

Name	Liters/Minute	Ml./Kg./Min.
Control Group		
J. B.	1.23	20.59
K. B.	1.94	25.92
G. G.	2.57	31.00
D. L.	1.83	29.16
S. M.	.51	8.41
R. M.	1.22	19.28
D. O.	1.62	24.26
C. P.	1.89	24.57
T. S.	3.21	33.53
G. W.	2.33	27.04
R. Y.	.56	10.41
Experimental Group		
L. B.	1.60	30.09
E. D.	1.49	25.16
G. D.	2.07	25.87
G. H.	1.09	20.63
C. J.	1.44	26.41
K. M.	2.10	26.76
R. S.	1.14	19.51
E. S.	1.41	26.79
M. S.	2.37	35.80
C. T.	2.30	27.58

APPENDIX K

PRE-TEST DATA FOR THE PERCENT OF OXYGEN UPTAKE LEVEL REQUIRED TO COMPLETE A ONE MINUTE SUB-MAXIMAL SWIM

PRE-TEST DATA FOR THE PERCENT OF OXYGEN UPTAKE LEVEL REQUIRED TO COMPLETE A ONE MINUTE SUB-MAXIMAL SWIM

Name	Percent
Control Group	
J. B.	40.55
K. B.	125.92
G. G.	67.16
D. L.	50.58
S. M.	51.85
R. M.	44.91
D. O.	57.29
C. P.	74.15
T. S.	18.37
G. W.	86.09
R. Y.	86.64
Experimental Group	
L. B.	93.12
E. D.	35.89
G. D.	62.69
G. H.	84.87
C. J.	71.71
K. M.	74.62
R. S.	61.14
E. S.	64.98
M. S.	16.70
C. T.	51.95

APPENDIX L

POST-TEST OXYGEN UPTAKE DURING A SUB-MAXIMAL ONE MINUTE SWIM

POST-TEST OXYGEN UPTAKE DURING A SUB-MAXIMAL ONE MINUTE SWIM

Name	Liters/Minute	Ml./Kg./Min.
Control Group		
J. B.	.69	11.64
D. B.	1.08	14.48
S. M.	.38	6.20
R. N.	1.90	29.96
C. P.	1.55	20.09
T. S.	1.40	15.02
Experimental Group		
L. B.	.79	14.75
E. D.	1.11	18.70
G. D.	.90	11.29
L. H.	.55	10.36
C. J.	.76	13.87
K. M.	1.47	18.79
D. S.	.68	12.95
M. S.	.78	11.80
C. T.	1.12	13.47

APPENDIX M

POST-TEST OXYGEN UPTAKE DURING A MAXIMAL ONE MINUTE SWIM

POST-TEST OXYGEN UPTAKE DURING A MAXIMAL ONE MINUTE SWIM

Name	Liters/Minute	Ml./Kg./Min.
Control Group		
J. B.	1.35	22.63
D. B.	2.66	35.53
S. M.	.92	15.23
R. N.	2.16	34.02
C. P.	2.05	26.55
T. S.	2.91	30.37
Experimental Group		
L. B.	1.34	25.09
E. D.	1.44	24.26
G. D.	2.32	29.02
L. H.	.87	16.45
C. J.	1.35	24.85
K. M.	2.78	35.42
D. S.	1.47	28.00
M. S.	2.37	36.12
C. T.	2.11	25.30

APPENDIX N

POST-TEST DATA FOR THE PERCENT OF OXYGEN UPTAKE LEVEL REQUIRED TO COMPLETE A ONE MINUTE SUB-MAXIMAL SWIM

POST-TEST DATA FOR THE PERCENT OF OXYGEN UPTAKE LEVEL REQUIRED TO COMPLETE A ONE MINUTE SUB-MAXIMAL SWIM

Name	Percent
Control Group	
J. B.	51.41
D. B.	40.75
S. M.	40.78
R. N.	87.03
C. P.	75.66
T. S.	49.47
Experimental Group	
L. B.	58.74
E. D.	77.08
G. D.	38.90
L. H.	62.97
C. J.	55.81
K. M.	53.06
D. S.	46.25
M. S.	32.66
C. T.	53.07

APPENDIX O

RAW DATA FOR PRE-TEST SUB-MAXIMAL OXYGEN UPTAKE

RAW DATA FOR PRE-TEST SUB-MAXIMAL OXYGEN UPTAKE

Name	Barometric Pressure	Temperature (Centigrade)	Minute Volume (liters)	% Oxygen Extracted
Control Group				
J. B.	747.4	28.1	16.1	3.62
D. B.	755.0	26.6	57.9	4.83
G. G.	755.0	25.9	49.5	3.98
C. L.	747.4	28.9	22.2	4.88
S. M.	755.0	26.5	24.6	1.23
R. N.	769.0	26.8	63.8	3.13
D. O.	747.4	28.9	35.5	3.08
C. P.	755.0	26.8	55.9	2.88
T. S.	747.4	28.7	22.7	3.04
G. W.	747.4	28.3	47.5	4.93
R. Y.	747.4	28.4	18.8	3.00
Experimental Group				
L. B.	758.6	28.0	41.5	4.13
E. D.	758.6	28.0	21.6	2.85
G. D.	758.6	27.6	36.9	4.03
L. H.	747.4	28.3	37.5	2.88
C. J.	758.6	28.0	34.7	3.41
K. M.	747.4	28.7	29.0	4.70
R. S.	747.4	29.0	22.5	3.63
D. S.	758.6	28.0	23.2	4.53
M. S.	758.6	27.5	30.6	1.48
C. T.	747.4	28.9	27.8	5.04

APPENDIX P

RAW DATA FOR PRE-TEST OXYGEN UPTAKE DURING A ONE MINUTE MAXIMAL SWIM

RAW DATA FOR PRE-TEST OXYGEN UPTAKE DURING A ONE MINUTE MAXIMAL SWIM

Name	Barometric Pressure	Temperature (Centigrade)	Minute Volume (liters)	% Oxygen Extracted
Control Group				
J. B.	747.4	28.3	46.0	3.13
D. B.	755.0	27.0	61.3	3.63
G. G.	755.0	26.3	83.0	3.53
C. L.	747.4	28.9	44.8	4.78
S. M.	755.0	26.7	47.4	1.23
R. N.	769.0	27.0	82.0	1.68
D. O.	747.4	28.9	41.2	4.63
C. P.	755.0	27.1	65.3	3.33
T. S.	747.4	29.0	88.9	4.23
G. W.	747.4	29.0	70.4	3.88
R. Y.	747.4	28.4	21.7	3.00
Experimental Group				
L. B.	758.6	28.0	63.7	2.89
E. D.	758.6	28.0	59.8	2.85
G. D.	758.6	28.0	56.2	4.23
L. H.	747.4	28.3	50.3	2.53
C. J.	758.6	28.1	57.3	2.88
K. M.	747.4	28.9	51.2	5.04
R. S.	747.4	28.8	32.3	4.13
D. S.	758.6	28.1	41.4	3.91
M. S.	758.6	27.9	71.0	3.83
C. T.	747.4	28.9	82.2	3.28

APPENDIX Q

RAW DATA FOR POST-TEST SUB-MAXIMAL OXYGEN UPTAKE

RAW DATA FOR POST-TEST SUB-MAXIMAL OXYGEN UPTAKE

Name	Barometric Pressure	Temperature (Centigrade)	Minute Volume (liters)	% Oxygen Extracted
Control Group				
J. B.	755.2	27.2	27.3	2.93
D. B.	740.8	29.6	41.5	3.10
S. M.	755.2	26.7	17.0	2.53
R. N.	755.2	27.0	61.8	3.53
C. P.	741.5	30.0	57.0	3.23
T. S.	738.5	30.6	41.2	4.18
Experimental Group				
L. B.	739.8	30.0	20.9	4.48
E. D.	741.5	29.2	42.0	3.13
G. D.	738.5	30.0	23.8	3.88
L. H.	755.2	25.9	18.2	3.43
C. J.	738.5	30.4	33.7	2.68
K. M.	755.2	25.9	36.3	4.63
D. S.	739.8	30.1	19.9	4.08
M. S.	739.8	29.9	18.5	5.03
C. T.	738.5	30.5	29.0	4.64

APPENDIX R

RAW DATA FOR POST-TEST OXYGEN UPTAKE DURING ONE MINUTE MAXIMAL SWIM

RAW DATA FOR POST-TEST OXYGEN UPTAKE DURING ONE MINUTE MAXIMAL SWIM

Name	Barometric Pressure	Temperature (Centigrade)	Minute Volume (liters)	% Oxygen Extracted
Control Group				
J. B.	755.2	27.1	51.3	3.03
D. B.	740.8	30.0	80.9	3.91
S. M.	755.2	26.2	26.0	4.05
R. N.	755.2	27.2	92.5	2.68
C. P.	741.5	30.0	77.0	3.16
T. S.	738.5	30.7	80.8	4.31
Experimental Group				
L. B.	739.8	30.1	44.4	3.59
E. D.	741.5	29.5	49.8	3.43
G. D.	738.5	30.2	72.1	3.85
L. H.	755.2	26.0	24.6	4.03
C. J.	738.5	30.5	71.1	2.28
K. M.	755.2	26.4	87.5	3.63
D. S.	739.8	30.2	54.4	3.23
M. S.	739.8	30.0	78.5	3.63
C. T.	738.5	30.5	79.3	3.23

APPENDIX S

COUNTERWEIGHTS USED TO ESTABLISH THE WORKLOAD ON THE SWIMMING ERGOMETER

COUNTERWEIGHTS USED TO ESTABLISH THE WORKLOAD ON THE SWIMMING ERGOMETER

Name	Pounds
Control Group	
J. B.	11
D. B.	23
G. G.	23
C. L.	10
S. M.	17
R. N.	17
D. O.	20
C. P.	16
T. S.	17
G. W.	20
R. Y.	8
Experimental Group	
L. B.	12
E. D.	14
G. D.	15
L. H.	13
C. J.	9
K. M.	15
R. S.	8
D. S.	14
M. S.	13
C. T.	17

APPENDIX T

CORRELATION MATRIX FOR THE COMPLETE BATTERY OF TESTS

CORRELATION MATRIX FOR THE COMPLETE BATTERY OF TESTS*

	Swimming Efficiency	25 Yards Strokes	25 Yards Time	50 Yards Time	Fox Power Feet	Form Rating	Burris Local	Burris Published
Swimming Efficiency	1.00							
25 Yards Strokes	0.02	1.00						
25 Yards Time	0.17	0.60	1.00					
50 Yards Time	0.16	0.81	0.92	1.00				
Fox Power Feet	-0.24	-0.75	-0.61	-0.75	1.00			
Form Rating	-0.00	-0.40	-0.70	-0.68	0.50	1.00		
Burris Local	0.11	0.89	0.90	0.97	-0.76	-0.61	1.00	
Burris Published	-0.05	-0.86	-0.77	-0.85	0.65	0.58	-0.91	1.00

*An r of .43 was required for significance at the .05 level.

BIBLIOGRAPHY

BIBLIOGRAPHY

BOOKS

Accident Facts. Chicago: The National Safety Council, 1975.

Barrow, Harold M., and Rosmary McGee. A Practical Approach to Measurement in Physical Education. 2d ed. Philadelphia: Lea and Febiger, 1971.

Bunn, John W. Scientific Principles of Coaching. Englewood Cliffs: Prentice-Hall, Inc., 1972.

Clark, H. Harison. Application of Measurement to Health and Physical Education. 4th ed. Englewood Cliffs: Prentice-Hall, Inc., 1967.

Counsilman, James E. The Science of Swimming. Englewood Cliffs: Prentice-Hall, Inc., 1968.

Drowatzky, John N. Motor Learning Principles and Practice. Minneapolis: Burgess Publishing Company, 1975.

Glassow, Ruth B., and Marion R. Broer. Measuring Achievement in Physical Education. Philadelphia: W. B. Saunders Company, 1939.

Johnson, Barry L., and Jack K. Nelson. Practical Measurement for Evaluation in Physical Education. 2d ed. Minneapolis: Burgess Publishing Co., 1974.

McCloy, Charles Harold. Tests and Measurement in Health and Physical Education. 2d ed. New York: F. S. Crofts and Co., 1964.

Montoye, Henry J. (ed.). Sports Tests and Evaluation in Dance. Vol. III. An Introduction to Measurement in Physical Education. Indianapolis: Phi Epsilon Kappa Fraternity, 1970.

Scott, Gladys M., and Esther French. Measurement and Evaluation in Physical Education. Dubuque: Wm. C. Brown Company, 1959.

Swimming and Water Safety. Washington, D.C.: The American National Red Cross, 1968.

Swimming and Water Safety Courses Instructor's Manual. Washington, D.C.: The American National Red Cross, 1968.

JOURNALS AND PERIODICALS

Alley, Louis E. "An Analysis of Water Resistance and Propulsion in Swimming the Crawl Stroke," Research Quarterly, XXIII (October, 1952), 253-270.

Astrand, Per-Olof, and Sixten Englesson. "Special Communications--A Swimming Flume," Journal of Applied Physiology, XXXIII (October, 1972), 514.

________, and Bengt Saltin. "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, XVI (July-November, 1961), 977-981.

Cake, Frances. "The Relative Effectiveness of Two Types of Frog Kick Used in Swimming the Breast Stroke," Research Quarterly, XIII (May, 1942), 201-204.

Costill, David L. "Effects of Water Temperature on Aerobic Working Capacity," Research Quarterly, XXXIX (March, 1968), 67-73.

________. "Use of a Swimming Ergometer in Physiological Research," Research Quarterly, XXXVII (December, 1966), 564-565.

Counsilman, James E. "Forces in Swimming Two Types of Crawl Stroke," Research Quarterly, XXVI (April, 1955), 127-139.

Cureton, Thomas Kirk, Jr. "A Test for Endurance in Speed Swimming," Research Quarterly, VI (May, 1935), 106-112.

________. "Mechanics and Kinesiology of Swimming," Research Quarterly, I (December, 1930), 107-108.

di Prampero, P. E., D. R. Pendergast, D. W. Wilson, and D. W. Rennie. "Energetics of Swimming in Man," Journal of Applied Physiology, XXXVII (July, 1974), 1-5.

Faulkner, John A. "Physiology of Swimming," Research Quarterly, XXXVII (March, 1966), 41-54.

________, and Rosmary Mann Dawson. "Pulse Rate After 50-Meter Swims," Research Quarterly, XXXVII (May, 1966), 282-284.

Fox, Edward L., Robert L. Bartels, and Richard W. Bowers. "Comparison of Speed and Energy Expenditure for Two Swimming Turns," Research Quarterly, XXXIV (October, 1963), 322-326.

Fox, Margaret. "Swimming Power Test," Research Quarterly, XXVIII (September, 1957), 233-237.

Gold, M., and I. F. Waglow. "Swimming Classification Test," Research Quarterly, XXVI (December, 1955), 485-486.

Hewitt, Jack E. "Achievement Scale Scores for Wartime Swimming," Research Quarterly, XIV (December, 1943), 391-396.

________. "Swimming Achievement Scale Scores for College Men," Research Quarterly, XIX (December, 1948), 282-289.

Holmer, Ingvar. "Oxygen Uptake During Swimming in Man," Journal of Applied Physiology, XXXIII (October, 1972), 502-509.

Holt, Alyce, Jo Anne Thorpe, and Laurence Holt. "Two Methods of Teaching Beginning Swimming," Research Quarterly, XLI (October, 1970), 371-377.

Holt, Laurence E., and Alyce F. Holt. "Silvia's Hand-Foot Concept," Journal of Physical Education, LXVIII (October, 1970), 179, 189.

Karpovich, Peter V. "Achievement Tests in Swimming," Research Quarterly, VI (May, 1935), 49.

________. "Analysis of the Propelling Force in the Crawl Stroke," Research Quarterly, VI (May, 1935), 49.

Karpovich, Peter V. "Water Resistance in Swimming," Research Quarterly, IV (October, 1933), 21-28.

________, and Harold Le Maistre. "Prediction of Time in Swimming Breast Stroke Based on Oxygen Consumption," Research Quarterly, XI (March, 1940), 40-44.

Magel, John R. "Propelling Force Measured During Tethered Swimming in Four Competitive Swimming Styles," Research Quarterly, XLI (March, 1970), 68-74.

________, and John A. Faulkner. "Maximum Oxygen Uptakes of College Swimmers," Journal of Applied Physiology, XXII (May, 1967), 929-938.

________, Guido F. Foglia, William D. McArdle, Bernard Gutin, Gary S. Pechar, and Frank I. Katch. "Specificity of Swim Training on Maximum Oxygen Uptake," Journal of Applied Physiology, XXXVIII (January, 1974), 151-155.

Martinez, Ray H. "Physiologic Effects of Swimming 100-Yard Races in Water of Five Temperatures," Proceedings of the Annual Meeting of the College Physical Education Association, LXIV (December, 1960), 108-112.

Miyashita, Mitsumasa. "Methods of Calculating Mechanical Power in Swimming the Breast Stroke," Research Quarterly, XLV (May, 1974), 128-137.

Mohr, Dorothy R., and Mildred E. Barrett. "Effect of Knowledge of Mechanical Principles in Learning to Perform Intermediate Swimming Skills," Research Quarterly, XXXIII (December, 1962), 574-580.

Parkhurst, Mary Grant. "Achievement Tests in Swimming," Journal of Health, Physical Education and Recreation, V (May, 1934), 34-36.

Rosentswieg, Joel. "A Revision of the Power Swimming Test," Research Quarterly, XXXIX (October, 1968), 818-819.

St. Gavreesky, W. "Assessing the State of Preparedness for Swimmers," Journal of Sports Medicine and Physical Fitness, III (March, 1963), 6-10.

Thomsen, Mike. "Teaching Swimming," Journal of Physical Education, LXX (May, 1973), 112-113.

Van Huss, W. D., and T. K. Cureton. "Relationship of Selected Tests with Energy Metabolism and Swimming Performance," Research Quarterly, XXVI (May, 1955), 205-221.

Wilson, Colin Theodore. "Coordination Tests in Swimming," Research Quarterly, V (December, 1934), 81-88.

OTHER SOURCES

Haynes, George. Freestyle. (Super eight millimeter Swimming Series number 675643 prepared by the California Academy of Sciences for McGraw-Hill Text Films, 1969).

________. Freestyle Breathing. (Super eight millimeter Swimming Series number 675647 prepared by the California Academy of Sciences for McGraw-Hill Text Films, 1969).

Worksheet for Swimming Courses. Washington, D.C.: The American National Red Cross.