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Relationships of Scores Achieved on a Crawl Stroke Rating Form and Selected Measures of Stroke Efficiency in Swimming

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RELATIONSHIPS OF SCORES ACHIEVED ON A CRAWL STROKE RATING FORM AND SELECTED MEASURES OF STROKE EFFICIENCY IN SWIMMING

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor Date

Head, Health, Physical Education and Recreation Department Date

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CHAPTER I

INTRODUCTION

Significance of the Study

The continuous surpassing of records is an indication that performances in competitive swimming are steadily improving. Success in competition depends upon a swimmer's ability to "maintain a high velocity over time."[1] Factors which determine the ability to maintain high velocity include muscle endurance, efficiency, and total capacity for energy expenditure.[2]

Through various types of training methods, the swim coach has been able to increase physiological changes in his athletes, including muscular endurance.[3] A valid measure for determining energy expenditure is through analysis of data obtained by testing for oxygen consumption. There is also a linear relationship between oxygen consumption and heart rate. By observing heart rates, the energy expended could be determined by similar procedures.[4] However, measures of determining stroke efficiency are either time consuming or confined to laboratory

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[1] John A. Faulkner, What Research Tells the Coach About Swimming, ed. John M. Cooper (Washington: American Association for Health, Physical Education, and Recreation, 1967), p. 38.

[2] Ibid.

[3] James E. Counsilman, The Science of Swimming (Englewood Cliffs: Prentice-Hall, Inc., 1968), p. 225.

[4] M. S. Malhorta, J. Sen Cupta, and R. M. Rai, "Pulse Count as a Measure of Energy Expenditure," Journal of Applied Physiology, 18:994, September, 1963.

equipment. The swim coach should have a measuring tool that could be used to determine efficiency of the swimmer available at poolside without being time consuming or limited to laboratory equipment. Therefore a comparative analysis of selected measures of determining stroke efficiency to a crawl stroke form rating scale was deemed necessary by the investigator.

Statement of the Problem

The purpose of this study was to develop a form rating scale for the crawl stroke to determine stroke efficiency.

Hypotheses

The following hypotheses were investigated:

1. There is no significant relationship between scores achieved on the crawl stroke rating scale and selected measures of stroke efficiency.

2. A multiple regression equation to significantly predict scores achieved on the crawl stroke rating scale cannot be developed.

Limitations and Delimitations

1. The eight male subjects for this study were chosen from members of the South Dakota State University men's intercollegiate varsity swimming team on the basis of past performance and predicted success in future competition.

2. Assessment of stroke efficiency was limited to velocity-pulse rate, velocity-stroke rate, and velocity-maximal oxygen uptake.

3. The oxygen consumed at the various work loads was determined by tethered swimming of the crawl stroke and may not be

representative of the oxygen consumption when free swimming of the crawl stroke is involved.

4. The degree of motivation involved in testing could not be objectively measured.

5. The outside activities of the subjects were not controlled and may have affected the subjects data.

Definition of Terms

Maximal Oxygen Uptake. The definition as stated by Cook was adopted for this study:

> Maximal oxygen uptake is the maximum amount of oxygen that can be supplied to the active tissues of the body per minute. This measurement may be recorded in liters per minute (l/min) or milliliters per kilogram of body weight per minute (ml/kg/min). This term is also known as aerobic capacity, maximum oxygen intake, or maximum oxygen consumption.[5]

Stroke. The movement of one arm through the motion of an entry, a pull, and a recovery in the crawl stroke. This term is also defined as each time a hand enters the water for a pull.[6]

Tethered Swimming. In this study tethered swimming refers to swimming in a fixed or stationary position while attached to a pulley-weight system.[7]

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[5]William G. Cook, "The Physiological Effects of a Season of Varsity Swimming Competition and Training on Selected Bodily Responses of Swimmers" (unpublished Master's thesis, South Dakota State University, 1971), p. 3.

[6]Harold M. Barrow and Rosemary McGee, A Practical Approach to Measurement in Physical Education (2nd ed., Philadelphia: Lee & Febiger, 1971), p. 328.

[7]John R. Magel and John A. Faulkner, "Maximum Oxygen Uptake of College Swimmers," Journal of Applied Physiology, 22:929, May, 1967.

Efficient Movement.

The combining of coordinated movement to produce the force required by the particular purpose and to apply it though [sic] the most advantageous point, and the most advantageous direction with the least expenditure of energy.[8]

Velocity. As used in this study, velocity is the rate or speed of motion, measured in seconds.[9]

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[8]Marion Broer, Efficiency of Human Movement, (3rd ed., Philadelphia: W. B. Saunders Company, 1973), p. 39.

[9]__________, Webster's Seventh New Collegiate Dictionary, (Springfield: G. & C. Merriam Company, 1971), p. 984.

CHAPTER II

REVIEW OF RELATED LITERATURE

The review of related literature was divided into three parts: (1) literature related to maximal oxygen uptake and effects of training on specific pulmonary parameters; (2) literature related to specific measures of stroke efficiency; and (3) literature related to the construction of rating scales.

Literature Related to Maximal Oxygen Uptake and Effects of Training on Specific Pulmonary Parameters

When the body is at rest, the muscles require only 200 to 300 cc. of oxygen per minute. During vigorous exercise this need may increase more than twenty times.[1] After prolonged work the respiratory and cardiovascular system can no longer adjust to the increased work load. At this point the maximum amount of oxygen that can be supplied to the active tissues of the body is reached.[2] This maximum amount of oxygen being supplied is called maximal oxygen uptake and, ". . . is usually expressed as an absolute value in liters per minute or a relative value in milliliters per kilogram per minute".[3]

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[1]Peter V. Karpovich and Wayne E. Sinning, Physiology of Muscular Activity (7th ed., Philadelphia: W. B. Saunders Company, 1971), p. 90.

[2]William G. Cook, "The Physiological Effects of a Season of Varsity Swimming Competition and Training on Selected Bodily Responses of Swimmers" (unpublished Master's thesis, South Dakota State University, Brookings, 1971), p. 7.

[3]Karpovich and Sinning, loc. cit.

Saltin and Astrand tested 95 male athletes of which 5 were swimmers belonging to Swedish National Teams. The swimmers were tested on a bicycle ergometer pedaling at a rate of 60 or 70 rpm. Workloads for each athlete were selected by Saltin and Astrand. Oxygen uptake was determined by collecting the expired air in a Douglas-bag and the volume was measured in a spirometer. Gas samples were analyzed by the Haldane technique. The mean maximal oxygen uptake was 5.0 liters per minute and 67 ml/kg/min.[4]

Magel and Anderson studied cardiac output in 10 well trained Norwegian male swimmers and 9 healthy untrained Norwegian males. The subjects were tested on a bicycle ergometer for maximal oxygen uptake. Each subject began at a workload of 300 kgm/min with an increase of 300 kgm each minute until each subject reached exhaustion. All subjects pedaled at a rate of 50 rpm, with work periods lasting approximately 8 minutes. Maximal oxygen uptake was measured by open-circuit spirometry using a Douglas-bag for collecting the expired gas. Maximal oxygen uptake was reached when samples plateaued or any two measurements agreed within 5 percent of each other. The mean maximal oxygen uptake in liters per minute was 4.33 and in ml/kg/min was 58.5.[5]

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[4]Bengt Saltin and P. O. Astrand, "Maximal Oxygen Uptake in Athletes," Journal of Applied Physiology, 23:353-358, September, 1967.

[5]John R. Magel and Lange Andersen, "Pulmonary Diffusing Capacity and Cardiac Output in Young Trained Norwegian Swimmers and Untrained Subjects," Medicine and Science in Sports, 1:131-139, September, 1969.

McArdle and Magel compared results obtained using a treadmill and a bicycle ergometer to determine maximal oxygen uptake. Twenty-three male students, 3 of whom were athletes from Queens College, were the subjects. The treadmill speed was set at 3.4 mph and the subject walked for the first 2 minutes at 0 percent grade. The grade was increased to 2 percent and increased 1 percent per minute until exhaustion was attained. The subjects pedaled on the bicycle ergometer at a rate of 60 rpm. The workload was increased 180 kgm/min every two minutes until the subjects could no longer continue. For both tests gas samples were collected for each minute after the heart rate reached 170 beats per minute. Gas samples were analyzed in a Fisher-Hamilton gas partitioner. On the bicycle ergometer the mean maximal oxygen uptake was 2.95 liters per minute and 38.5 ml/kg/min, while the mean maximal oxygen uptake on the treadmill was 3.27 liters per min. and 42.7 ml/kg/min.[6]

Astrand and Saltin studied seven subjects in workloads performed by the arms, legs, and arms and legs by employing bicycle ergometers, running on a treadmill, skiing, and swimming. Oxygen uptake and other functions were studied.[7]

Arm and leg work exercise testing involved the use of two ergometers which were modified so that the subject could pedal one

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[6] William D. McArdle and John R. Magel, "Physical Work Capacity, and Maximum Oxygen Uptake in Treadmill and Bicycle Exercise," Medicine and Science in Sports, 2:118-123, Fall, 1970.

[7] P. O. Astrand and Bengt Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, 16:977-981, November, 1961.

ergometer with the arms and the other ergometer with the legs. Air samples were taken at specified intervals. The same procedure was employed in testing separately the arms and the legs.

A motor driven treadmill was used in running. Running started at seven miles per hour on a grade selected from scores subjects obtained on a Harvard fitness test. Expired air was collected and fractionized in 20-60 second samples. The procedure was repeated on another day with a 2.5 percent grade increase. This procedure was continued until maximal running time was less than 2 minutes and 45 seconds.[8]

A Douglas-bag was carried by the subjects on a rucksack during skiing. The subject had a 10 minute warm-up period, then was to ski at a high speed which would exhaust him in 3-4 minutes. Expired air was collected for the last 45-60 seconds. Skiing was done on the horizontal. For swimming a low resistance respiratory valve was used for testing purposes. The inspiratory side was lengthened to reach above the water, the expiratory side was connected to a Douglas air bag which was carried alongside the pool. "Warm-up period, (running and calisthenics), speed, work time, and so forth were balanced as described for skiing, and 2 to 4 determinations were made on each subject."[9]

The experiments were conducted over a period of 3-5 months. Results indicated that heart rate and maximal oxygen uptakes in the ergometer tests did not differ significantly. Maximal oxygen uptake values in running were 87 percent of that obtained during cycling.

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[8] Ibid. [9] Astrand and Saltin, loc. cit.

Heart rates were similar in experiments where oxygen intakes were close to the maximum ever recorded for that subject.[10]

Magel and Faulkner tested and retested seventeen male college swimmers for maximal oxygen uptake during tethered swimming, free swimming and treadmill running. The study was designed to test the reliability and reproducibility of maximal oxygen uptake during tethered swimming, and to compare this value with those obtained during treadmill running and free swimming.[11]

In tethered swimming, the swimmers were attached to a pulley-weight system while maintaining a stationary position over an object fixed on the bottom of the pool. Testing began with a workload of 4.55 kg and a 3 minute swimming period. After a rest of 3 to 5 minutes, swimming began with an increased load of 1.14 kg. These three minute periods continued until the swimmers could no longer support the weight during the three minute swim and remain above the fixed object. Testing on the treadmill consisted of a 5 minute run at 7 miles per hour, beginning at 0 percent grade, with a 10 minute rest between runs. Each run had a 2.5 percent grade increase until the maximum voluntary capacity was reached. The free swimming test consisted of ten 50-yard sprints starting every 45 to 60 seconds. After a warm-up, the swimmers performed six 50-yard sprints with a 10-second rest between sprints. Gas samples for all 3 tests were analyzed by a

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[10] Ibid.

[11] John R. Magel and John A. Faulkner, "Maximum Oxygen Uptakes of College Swimmers," Journal of Applied Physiology, 22:929-933, May, 1967.

model number 29 Fisher-Hamilton gas partitioner for carbon dioxide, oxygen, and nitrogen. Results found no significant difference between maximal oxygen uptake obtained during tethered swimming and maximal oxygen uptake obtained during treadmill running.[12]

Costill investigated an apparatus which would reliably regulate energy requirements for exercise in water. Thirteen members of the Cortland College varsity swimming teams were chosen for the investigation. Two trials were administered to determine reliability of volumes of oxygen consumed and heart rates obtained during the third minute of a three-minute exercise bout. The swimmers were fitted with a belt attached to a pulley weight system. When the exercise period was initiated, the swimmer flutter-kicked hard enough to maintain an elevated weight at a height of from 10 to 15 inches. When more work was desired, a heavier weight was added, requiring the subject to exert more force with the legs. The mean weight selected for all subjects was 5.38 lb.[13]

The open circuit method using a Douglas-bag was used to collect the expired gas during the third minute of exercise. A Haldane-Henderson-Bailey gas analyzer was employed to determine carbon dioxide and oxygen content, and a Collins chain compensated spirometer measured the volume of expired gas. The mean maximal oxygen uptake for the tests

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[12] Ibid.

[13] David L. Costill, "Use of a Swimming Ergometer in Physiological Research," Research Quarterly, 37:564-567, December, 1966.

were 2.471 liters per minute for test one and 2.492 liters per minute for test two. Reliability was 0.915. Similar results could be obtained when the complete crawl stroke was used.[14]

Faulkner, in his study on the physiology of swimming, found that maximum oxygen uptake values obtained during swimming are approximately 15 percent lower than those obtained on a bicycle ergometer, or a treadmill, or in skiing.[15] Karpovich stated that the average water pressure exerted on each square inch of the chest is .182 lbs., causing a vital capacity of about 300 cc's, less than on the land.[16]

Summary

A review of the available literature has revealed that there is disagreement among researchers with respect to values obtained during tests of maximal oxygen uptakes of swimmers.[17,18,19,20,21] Tests of maximal oxygen uptake during swimming are limited because of the difficulty experienced in obtaining results in the water.[22] Values

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[14] Ibid.

[15] John A. Faulkner, "Physiology of Swimming," Research Quarterly, 37:49-50, March, 1966.

[16] P. V. Karpovich, "Respiration in Swimming and Diving," Research Quarterly, 10:8-9, October, 1939.

[17] Saltin and Astrand, loc. cit.

[18] Magel and Andersen, loc. cit.

[19] Astrand and Saltin, loc. cit.

[20] Magel and Faulkner, loc. cit.

[21] Costill, loc. cit.

[22] Karpovich and Sinning, op. cit., p. 130.

measured in the water tend to be lower than those obtained on land.[23,24,25]

Literature Related to Specific Tests of Stroke Efficiency

Chapman compared three methods of measuring efficiency in swimming:

1. Number of strokes constant, time and distance vary.
2. Time constant, number of strokes and distance vary.
3. Distance constant, time and number of strokes vary.[26]

Results of the study indicated the third method of measuring efficiency in swimming to be most satisfactory.[27]

Burris studied the speed-stroke test and its relationship to other tests of crawl stroking ability in sixty-nine college men and women. Her scores were converted to T-scores, then added to get a measureable criterion. Her results, computed on a test-retest basis, indicated the test to be valid (.836), reliable (.906), and objective (.933). T-score norms were constructed for the speed-stroke test for 20- and 25-yard distances for men and women, however local norms needed to be developed. Since the speed-stroke scores represented two combined T-scores, the average score was 100 instead of 50.[28]

Faulkner and Dawson studied pulse-rate velocity relationships

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[23]Magel and Faulkner, loc. cit. [24]Costill, loc. cit.

[25]Faulkner, loc. cit.

[26]Harold M. Barrow and Rosemary McGee, A Practical Approach To Measurement in Physical Education (2nd ed., Philadelphia: Lea & Febiger, 1971), pp. 325-328.

[27]Ibid. [28]Ibid.

of nineteen girls ranging from 12-19 years in age. Swims of fifty meters at slow, moderate, fast, and all out speeds from a push-off were recorded to the nearest tenth of a second, then converted into velocity in meters per second. When each swim was completed, the swimmers turned around and stood on the bottom while the experimenter measured the carotid pulse count. Pulse was taken fifteen seconds after the touch for fifteen seconds, then multiplied by four to obtain a rate in beats per minute. The four coordinates were plotted and a line of best fit was drawn.[29]

Maximal oxygen uptake-velocity was investigated by Karpovich. The formula for stroke efficiency which resulted from his investigation includes the following:

$$\% \text{ efficiency} = \frac{kv^2s \times .0004686}{\text{oxygen uptake (liters/min)}} \times 100$$

Where k = 3.17, v = velocity in m/sec.

s = distance in m., and 1 kg-m of work = .0004686[30]

Karpovich and Pestrecov reported that the range of efficiency of swimming was between 0.5 to 2.2 percent, while Karpovich and others reported a range of 1.71 to 3.99 percent. Pugh and others reported that the range in efficiency of channel swimmers was from 1.6 to 7.2 percent.[31]

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[29] John A. Faulkner and Rosemary Dawson, "Pulse Rates After 50-Meter Swims," Research Quarterly, 37:282-284, May, 1966.

[30] Peter V. Karpovich and Wayne E. Sinning, Physiology of Muscular Activity (7th ed., Philadelphia: W. B. Saunders Company, 1971), pp. 22-25.

[31] Ibid.

Literature Related to the Construction of Rating Scales

Haskins stated performance dealing with the quality of execution must be evaluated through subjective ratings. Through the use of a rating scale, subjective evaluation can be objectified.[32]

Rating scales may serve several purposes. Before a scale can be constructed, the evaluator must have a clear understanding of ways in which the results will be used. The trait or activity being measured must then be determined, and its components must be subdivided and defined as carefully and objectively as possible.[33]

The division of traits into sub-traits is the next step in the construction of rating scales. This operation adds to the validity of the scale. An example of the division of traits into sub-traits is that of the golf swing, which could be divided into address, takeaway, backswing, contact, and follow through. The rating device must be divided into points on the scale called categories. The usual number of categories is five, if two or more categories are required. These categories should be defined as concisely as possible and should describe the level of accomplishment at each point of the scale. When a number is assigned to each category the data obtained may be statistically treated.[34,35]

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[32]Mary Jane Haskins, Evaluation in Physical Education (Dubuque: Wm. C. Brown Company Publishers, 1971), pp. 180-181.

[33]Harold M. Barrow and Rosemary McGee, A Practical Approach to Measurement in Physical Education (2nd ed., Philadelphia: Lea & Febiger, 1971), pp. 558-559.

[34]Ibid. [35]Haskins, op. cit., pp. 188-189.

When the rating scale is prepared, several principles must be followed. It must be accurate and easily administered. The instructions on the rating sheet must be clear and concise. When more raters use the scale, it adds to the validity of the instrument. Evaluators must be as fair and impartial as possible in order to maintain the validity of the instrument.[36,37,38]

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[36]Helen M. Matthews, Measurement in Physical Education, (3rd ed., Philadelphia: W. B. Saunders Company, 1968), p. 306.

[37]Barrow and McGee, loc. cit.

[38]Haskins, op. cit., pp. 188-189.

CHAPTER III

METHODS AND PROCEDURES

Organization of the Study

The purpose of this study was to develop a form rating scale for the crawl stroke to determine stroke efficiency. The study was conducted during the 1974-1975 men's intercollegiate swimming season. Maximal oxygen uptake, heart rate, and stroke rate were measured during free and tethered swims. Each subject was tested three times for each selected measure of stroke efficiency. Test dates were scheduled so that a subject was not given the same test on consecutive test days. Sequence for the administration of the tests was determined by a coin toss procedure.

The entire test battery was administered in a period of fifteen days, beginning on February 10 and ending on February 25. Additional data was accumulated through the use of a rating scale. Four area swimming coaches observed each subject at the same time. Each time the subject was rated, the judge was located in the same observation point. Data from the selected measures of stroke efficiency were compared with the scores achieved on the rating scale.

Source of Data

Eight members of the men's intercollegiate swimming team at South Dakota State University were selected as subjects for this investigation. These individuals were selected on the basis of past performance and predicted success in future competition. The subjects ranged in age from 18-21, and the weight of the subjects ranged from 142-189 pounds. Five of the subjects were freestylers participating in sprint and distance events. The remaining three subjects were middle distance swimmers whose primary events were backstroke and breaststroke. The characteristics of the subjects have been presented in Table I.

Collection of the Data

Three different measures for determining stroke efficiency in swimming the crawl stroke were used. Velocity-pulse rate, velocity-stroke rate, and velocity-maximal oxygen uptake were selected as measures because all are ". . . reasonably linear functions of swimming velocity between 20 and 70 m/min."[1] A rating scale was developed and used to determine whether a relationship exists between performance and efficiency.

Measurement of Maximal Oxygen Uptake. As the workload increases, the amount of oxygen consumed also increases in a linear fashion. Cook states, "When the work rate reaches an exhaustive high for the subject, the oxygen consumption does not increase to any extent and the subject's maximal uptake has been reached".[2]

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[1]John A. Faulkner, What Research Tells the Coach About Swimming, ed. John M. Cooper (Washington: American Association for Health, Physical Education and Recreation, 1967), p. 21.

[2]William G. Cook, "The Physiological Effects of a Season of Varsity Swimming Competition and Training on Selected Bodily Responses of Swimmers," (unpublished Master's thesis, South Dakota State University, 1971), p. 32.

TABLE I

SUBJECT CHARACTERISTICS AT
THE TIME OF INITIAL TEST

Name	Age	Weight	Competitive Stroke
R.A.	19	162	Freestyle
S.A.	21	171	Freestyle
R.F.	19	147	Breaststroke
M.I.	19	189	Freestyle
T.K.	18	146	Freestyle
M.R.	21	177	Freestyle
M.R.	18	158	Backstroke
T.W.	20	142	Backstroke

The technique employed in the present study to measure maximal oxygen uptake was a modification of the tethered swimming test developed by Magel and Faulkner.[3] Olympic-type weights in a pulley-weight system were used to provide the resistance.

The subject began swimming for three minutes while maintaining a position over a fixed object (a racing line on the bottom of the pool 2.13 meters from the edge) while pulling against a resistance of 4.55 kg. After a four-minute rest the workload was increased by 1.14 kg and the swimmer began another 3-minute swim. The subject was signaled by a whistle whenever he did not maintain his position over the target area.

The test was terminated once any of three conditions were observed:

(1) The subject could no longer support the weight.

(2) Upon hearing the whistle, the subject could not return to a position over the target area.

(3) Oxygen percentages in the expired air no longer continued to rise.

The open circuit method was used for the collection of the expired gases. Nasal breathing was restricted by the use of a nose plug fitted with a strap. One outlet of a Collins high velocity, low resistance two-way breathing valve suspended above water level was connected by a tube 73.8 cm. in length to a Collins P-357 rubber mouthpiece which the subject held between his teeth and through which he breathed.

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[3]John R. Magel and John A. Faulkner, "Maximum Oxygen Uptake of College Swimmers," Journal of Applied Physiology, 22:929, May, 1967.

A second outlet was connected by a tube 4.34 meters in length to a CD4 Dry Gas Meter, which measured the volume of expired air. The remaining outlet of the two-way breathing valve was open to allow the subject to inhale atmospheric air while submerged in water. All connections were made with low resistance plastic tube which had an inside diameter of 3.8 cm. All of the equipment employed for the tethered swim test can be seen in Figure 1.

Connected to the inlet of the gas meter was a centigrade thermometer which recorded the temperature of the expired air. The expired air was then passed through a valve into the gas meter which measured the volume of expired air. This procedure was followed during the last minute of each three-minute bout and during each minute as the subject approached exhaustion. If the test was stopped prior to the completion of a full minute, data obtained in the previous minute was recorded.

Expired air temperature was recorded along with barometric pressure in order to correct the gas volume measurement to STPD (standard temperature and pressure, dry). Barometric pressure was obtained by contacting the Weather Engineering department on the South Dakota State University Campus which provided readings uncorrected for sea level. Barometric pressure was corrected along with temperature by the use of a conversion table. Figure 2 shows the recording of gas temperature.

From the dry gas meter the expired air passed through a mixing chamber. A small electric pump was used to draw a sample of the expired air into a 5 liter Collins P-337-5 rubber breathing bag for a period of one minute. A Godart Pulmo-Analyzer was used to measure the percentage

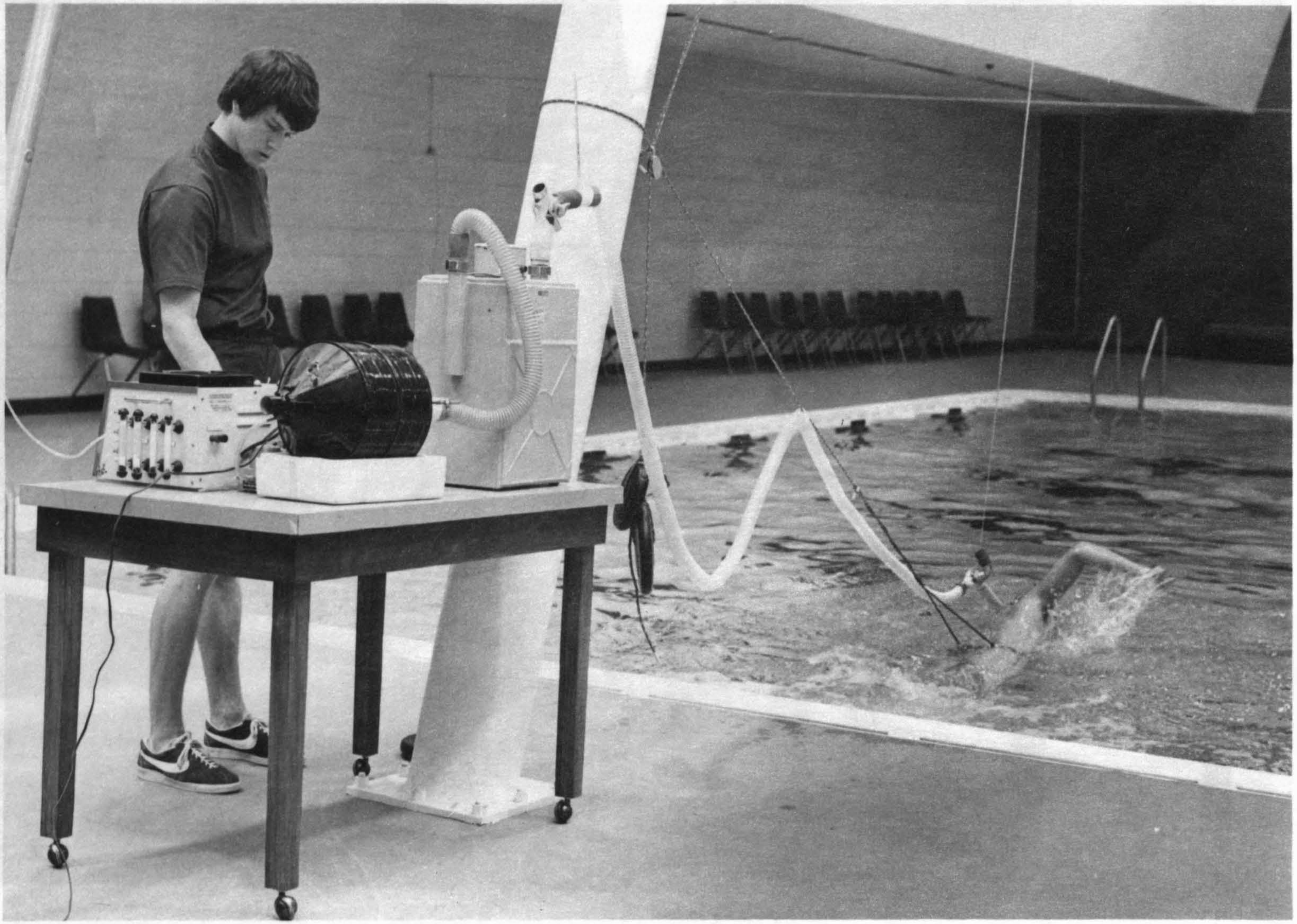

Figure 1. Apparatus for testing maximal oxygen uptake in tethered swim test.

Figure 2. Recording temperature of expired gases.

of carbon dioxide and oxygen in the expired air (see Figure 3). This was accomplished by connecting the breathing bag to the Pulmo-Analyzer. Deflection readings representing the percentage of carbon dioxide and oxygen were recorded at this time.

A male member of the South Dakota State University swimming team who did not participate in the actual experiment served as a subject for the pilot study, which was conducted to determine placement and modification of the equipment.

Measurement of Rating Scale Score. A rating scale was constructed based upon principles recommended by swimming coaches James Counsilman of Indiana University and George Haines of the Santa Clara Swim Club. These coaches were selected because they have been prominent in the advancement of the sport of swimming in the United States. The rating scale can be found in Appendix A.

The crawl stroke was divided into three major divisions; the arm stroke, breathing, and the kick. The arm stroke was subdivided into the pull, push and recovery phases. More emphasis was placed on the arms because, according to Counsilman, ". . . at fast speeds the kick contributes nothing to the propulsion created by the arms."[4] The degree of elbow flexion in the pull phase is emphasized since research indicates that the best position from fingertips to elbow is between 45° and 90°. Counsilman states that the force created with the arms in the above position generates a force of 48 pounds, compared with a force of

[4]James E. Counsilman, The Science of Swimming (Englewood Cliffs: Prentice-Hall, Inc., 1968), p. 7.

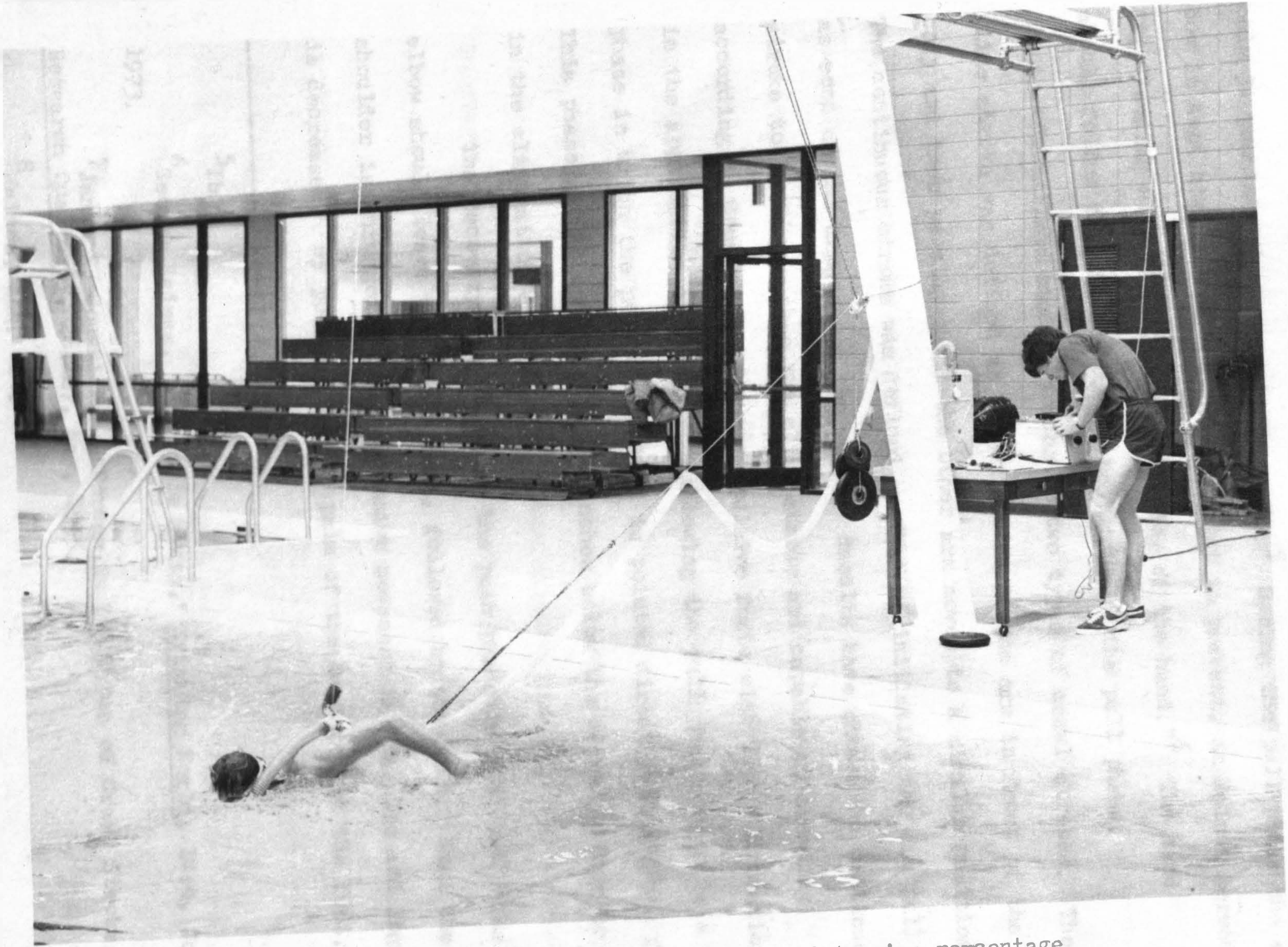

Figure 3. Recording deflection readings to determine percentage of carbon dioxide and oxygen in expired air.

only 31 pounds with a straight arm pull.[5] During the pull phase the elbow is kept higher than the hand or wrist to prevent, as Haines termed it, "leading with the elbow and slipping of the hand."[6] The hand should follow the midline of the body through the pull phase.

Counsilman studied forces in two types of crawl strokes. The glide stroke was defined as the extension of one arm in front of the body and then pausing until the other arm moves to a similar position. The continuous stroke was defined as that of initiating the arm pull as soon as the arm enters the water. Results have shown the continuous stroke to be faster than the glide stroke and capable of creating, according to Counsilman, "more propulsive force with less fluctuation in the application of force."[7] Following the pull phase there is a push phase in which the palm of the hand is pointed directly toward the feet. This phase should end four to six inches below the water surface to aid in the elimination of bobbing.[8]

The recovery starts before the push phase is finished. The elbow should leave the water first, followed by the hand. When the shoulder is shrugged forward excessive movement in the hips and legs is decreased. By positioning the palm of the hand toward the feet,

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[5]Ibid.

[6]George Haines, "Freestyle Hints," Swimming World, 14:4, July, 1973.

[7]James E. Counsilman, "Forces in Two Types of Crawl Stroke," Research Quarterly, 26:127, May, 1955.

[8]Haines, loc. cit.

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[7]James E. Counsilman, "Forces in Two Types of Crawl Stroke," Research Quarterly, 26:127, May, 1955.

[8]Haines, loc. cit.

the shoulder and elbow are further aided in the forward shrug allowing for a higher elbow recovery.[9,10] The entry of the hand should be thumb first well out in front of the shoulder, and between the midline of the body and the shoulder.[11] This normal reach entry prevents the swimmer from digging his hands in too deeply, which is the result of an early arm entry.[12]

Swimmers are encouraged to develop their own breathing style depending on the rhythm of the kick and head roll. The head should be in a comfortable position in a point between the hairline and the eyebrows.[13] Lifting the head to breathe causes a distortion in the body alignment. By turning, the swimmer's head is working with the arms and body.[14]

Counsilman states that the kick is used as a streamlining and stabilizing force, rather than a propulsive force. The swimmer should employ the kicking method which allows him to swim the fastest. Discontinuing the kick causes the hips and legs to drop too low in the

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[9] Counsilman, The Science of Swimming, op. cit., p. 36.

[10] Haines, loc. cit. [11] Ibid.

[12] Counsilman, The Science of Swimming, op. cit., pp. 40-41.

[13] Haines, loc. cit.

[14] Counsilman, The Science of Swimming, op. cit., p. 59.

water and results in an undesired drag.[15] Haines states, "The kick should not be too deep in the water but within the surface of the water."[16]

The original rating scale was devised with the aid of the swimming coach, the thesis adviser, and a staff member. A pilot study was conducted to aid in determining the final draft, using four swimming coaches as judges. Results of the pilot study revealed that the scale failed to adequately discriminate between performance levels. It was revised to include three categories instead of the original five. A second pilot investigation supported the use of three categories, since all functioned with greater frequency. Each pilot study for the rating scale was discussed with the four coaches for purposes of familiarizing them with terms on the scale and the scoring of the scale.

The rating scale was administered to each subject during four 50-meter swims. The coaches observed each swimmer and scores were recorded at this time. If any coach desired to see the swimmer in order to complete the scale, the swimmer was requested to swim an additional 50 meters. Each swimmer was rated three times by the four coaches. Location of observers remained constant throughout the evaluation process.

Measurement of Velocity. The watch was started on the signal, "go", and stopped when any part of the body of the swimmer touched

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[15] Counsilman, The Science of Swimming, op. cit., pp. 25-30.

[16] Haines, loc. cit.

the side of the pool after completing the prescribed distance. Times were recorded to the nearest tenth of a second.

Measurement of Stroke. The technique employed in the present study to measure the stroke-velocity of each subject was described by Burris.[17] Strokes were counted and recorded for each subject during a 25-yard swim. Each subject was instructed to swim the 25-yard distance as fast as possible using as few strokes as possible, starting on the signal go. No swimmer was allowed to push off of the side with his feet at the start of the swim. Each time either hand entered the water for a pull, one stroke was counted. Counting was begun when the first arm entering the water pulled and continued every arm pull until a hand touched the side. Immediately thereafter the number of strokes and the time was recorded for the subject.

Measurement of Pulse Rate. Faulkner and Dawson described the method used to obtain the pulse rate-velocity relation used in this investigation.[18] Each subject was instructed to swim four 50-meter swims at speeds of 25, 50, 75, and 100 percent of his maximum. After completing each swim, the subject stood on the bottom, turned around, and faced the far end of the pool. Fifteen seconds after the completion of each swim, a carotid pulse was measured for 15 seconds and multiplied by four to determine the pulse rate for one minute.

[17]Harold M. Barrow and Rosemary McGee, A Practical Approach to Measurement in Physical Education (2nd ed., Philadelphia: Lea & Febiger, 1971), pp. 325-328.

[18]John A. Faulkner and Rosemary Dawson, "Pulse Rates After 50-Meter Swims," Research Quarterly, 37:282-284, May, 1966.

When pulse rates obtained were above 140 beats/min., sufficient time was allowed for the pulse rate to return below this level. Pulse rate and time were recorded after each 50-meter swim was completed.

Procedure for Collecting Data

All testing was completed in the Natatorium located in the South Dakota State University Health, Physical Education, and Recreation Center. After a general overview to acquaint the subjects with the tests, an explanation and demonstration of techniques of the various tests was given. The subjects were told that the tests not only served as a conditioning device, but that the results would be used to more accurately formulate training programs. The actual purpose of this investigation was not explained to them.

Test dates and times were set for each subject before the tests were given. The procedure followed for each of the three testing periods was:

1. The subject reported to the Natatorium in his suit.
2. The subject was tested for stroke-velocity.
3. After a brief recovery period, the subject was tested for pulse rate-velocity. The rating scale was administered at this time.
4. On the next alternate day the subject's weight was recorded.
5. Maximal oxygen uptake was determined through the use of tethered swimming.

The scores achieved in each measure of efficiency for all test periods were ranked for each swimmer and compared with the results of the rating of the swimmers form as evaluated by the four coaches.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Organization of the Data for Analysis

The purpose of this investigation was to develop a form rating scale for the crawl stroke to determine stroke efficiency.

The data collected from the eight subjects were maximal oxygen uptake obtained during tethered swimming, velocity-pulse rate, velocity-stroke rate, and performance on the form rating scale. The subjects were tested on all variables three times during a fifteen-day period. Raw data for all variables are presented in Appendix B. Table II indicates the mean scores and standard deviations for all variables.

A coefficient of correlation analysis was the primary statistical treatment applied to the data on the tests.[1] The purpose of this treatment was to analyze the data to see whether a relationship existed between scores obtained in selected measures of stroke efficiency and scores achieved on a form rating scale for the crawl stroke.

Multiple regression was a second statistical treatment which was applied to each of the variables on the tests.[2] The application of this procedure was suggested by the Experiment Station Statistician, at South Dakota State University and was used to determine whether a

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[1] Jerome C. Weber and David R. Lamb, Statistics and Research in Physical Education (St. Louis: The C. V. Mosby Company, 1970), pp. 59-66.

[2] Ibid., pp. 153-169.

TABLE II

TABLE OF MEANS

Variable	Mean	S.D.
Rating Scale	48.27	2.25
Stroke	22.63	3.00
Pulse	142.83	6.67
Maximal Oxygen Uptake	41.01	6.36
Velocity	1.65	0.09
Efficiency	4.49	0.91

regression equation could be developed for prediction purposes. An electronic computer was used for data analysis to facilitate speed and accuracy. In both statistical treatments the 0.05 level of confidence was required before the null hypothesis was rejected.

Analysis of the Data

The results of the coefficient of correlation analysis are shown in matrix form in Table III. A coefficient of 0.396 was required for correlations to be significant at the 0.05 level. Significant correlations at the 0.05 level of confidence were found for the variables of rating scale score to pulse (-0.481), stroke to velocity (-0.559), efficiency to maximal oxygen uptake (-0.781), and efficiency to velocity (0.590).

The results of the multiple regression analysis indicated a significant relationship at the 0.05 level for all variables, which accounted for 77.4 percent of the variance in the score obtained on the rating scale. The multiple regression equation developed for this study to determine score on the rating scale from the selected variables is:

y = -0.161 (pulse) + 0.099 (stroke) -3.379 (efficiency) -0.364 (maximal oxygen uptake) + 19.086 (velocity) + 67.649.

Total variance = 116.865

MS variance = 4.26

Sum of squares reduced in final step = 17.257

Minimum needed to contribute significantly to the equation = 6.467

TABLE III

CORRELATION MATRIX TABLE
FOR ALL VARIABLES

	Rating Scale	Stroke	Pulse	Maximal Oxygen Uptake	Velocity	Efficiency
Rating Scale	1.000	-0.257	-0.481*	-0.389	0.313	0.043
Stroke		1.000	-0.344	0.154	-0.559*	-0.021
Pulse			1.000	0.349	-0.102	-0.348
Maximal Oxygen Uptake				1.000	-0.378	-0.781*
Velocity					1.000	0.590*
Efficiency						1.000

*Significant at 0.05 level
r = .396

Discussion of the Results

The correlation coefficient indicated a significant relationship between score and pulse, stroke and velocity, efficiency and maximal oxygen uptake, and efficiency and velocity. Through the use of multiple regression analysis, it was revealed that all variables indicated a significant relationship to the rating scale score.

Maximal Oxygen Uptake. The correlation coefficient indicated no significant relationship between maximal oxygen uptake values and rating scale scores. The mean maximal oxygen uptake in this investigation for all tests was 48.27 ml/kg/min. or 2.99 liters per minute. Costill investigated maximal oxygen uptake values of swimmers obtained by a tethered swim procedure and found mean values of 2.49 liters per minute.[3] Magel and Andersen found maximal oxygen uptake values in Norwegian swimmers to be 4.33 liters per minute while being tested on a bicycle ergometer.[4] Faulkner stated, however, that values obtained during swimming are approximately fifteen percent lower than those obtained on land.[5]

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[3]David L. Costill, "Use of a Swimming Ergometer in Physiological Research," Research Quarterly, 37:564-567, December, 1966.

[4]John R. Magel and Lange Andersen, "Pulmonary Diffusing Capacity and Cardiac Output in Young Trained Norwegian Swimmers and Untrained Subjects," Medicine and Science in Sports, 1:131-139, September, 1969.

[5]John A. Faulkner, "Physiology of Swimming," Research Quarterly, 37:49-50, March, 1966.

Magel and Faulkner used a tethered swim procedure to obtain maximal oxygen uptake values of swimmers. Results indicated a mean value of 4.27 liters per minute. The higher value obtained here could have been due to the fact that several subjects used in the study were Olympic or All-American swimmers.[6]

Velocity and Strokes. Coefficient of correlation analysis found no significant relationship between the number of strokes or the velocity to the rating scale. There was, however, a significant negative correlation between the number of strokes and the velocity. This correlation could be explained by noting that one subject participating in the present study had the fewest number of strokes and the greatest velocity, while another subject had the largest number of strokes and the least velocity. Burris developed norms for the speed-stroke relationship for swimmers having intermediate or above skill level. The average T-score was found to be 100.[7] In the present investigation the mean T-score was 130, indicating the skill level to be well above the average score of 100.

Pulse Rate. Through the use of coefficient of correlation analysis, a significant relationship was observed between pulse rate and the form rating scale. Faulkner and Dawson observed a linear relationship between pulse rate and velocity recorded in four

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[6]John R. Magel and John A Faulkner, "Maximum Oxygen Uptakes of College Swimmers," Journal of Applied Physiology, 22:929, May, 1967.

[7]Harold M. Barrow and Rosemary McGee, A Practical Approach to Measurement in Physical Education (2nd ed., Philadelphia: Lea & Febiger, 1971), pp. 325-328.

50-meter swims.[8] Linear relationships were also observed between pulse and velocity in this investigation. Figures 4-6 graphically illustrate the relationship between pulse and velocity in each test for each subject.

Efficiency. No significant relationship was found between calculated efficiency and the rating scale when coefficient of correlation analysis was used. However, there was a significant relationship between efficiency and maximal oxygen uptake as well as for efficiency and velocity. This finding was further supported by the fact that both velocity and maximal oxygen uptake were part of the formula used in determining efficiency. The range in efficiency in this investigation was found to be from 3.18 to 6.47 percent.

Karpovich and Pestrecov reported the range in the efficiency of swimming to be from 0.5 to 2.2 percent, while Karpovich and others reported a range of 1.71 to 3.99 percent. In an investigation involving channel swimmers, Pugh and others reported a range of efficiency in swimming from 1.6 to 7.2 percent.[9] The present researcher was unable to obtain the procedures of data collection, and methods of computation for the efficiency rating in any of these studies.

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[8] John A. Faulkner and Rosemary Dawson, "Pulse Rates After 50-meter Swims," Research Quarterly, 37:282-284, May, 1966.

[9] John A. Faulkner, What Research Tells the Coach About Swimming, ed. John M. Cooper (Washington: American Association for Health, Physical Education, and Recreation, 1967), pp. 22-23.

Figure 4. Pulse-Velocity Relationships for Each Individual in Test 1.

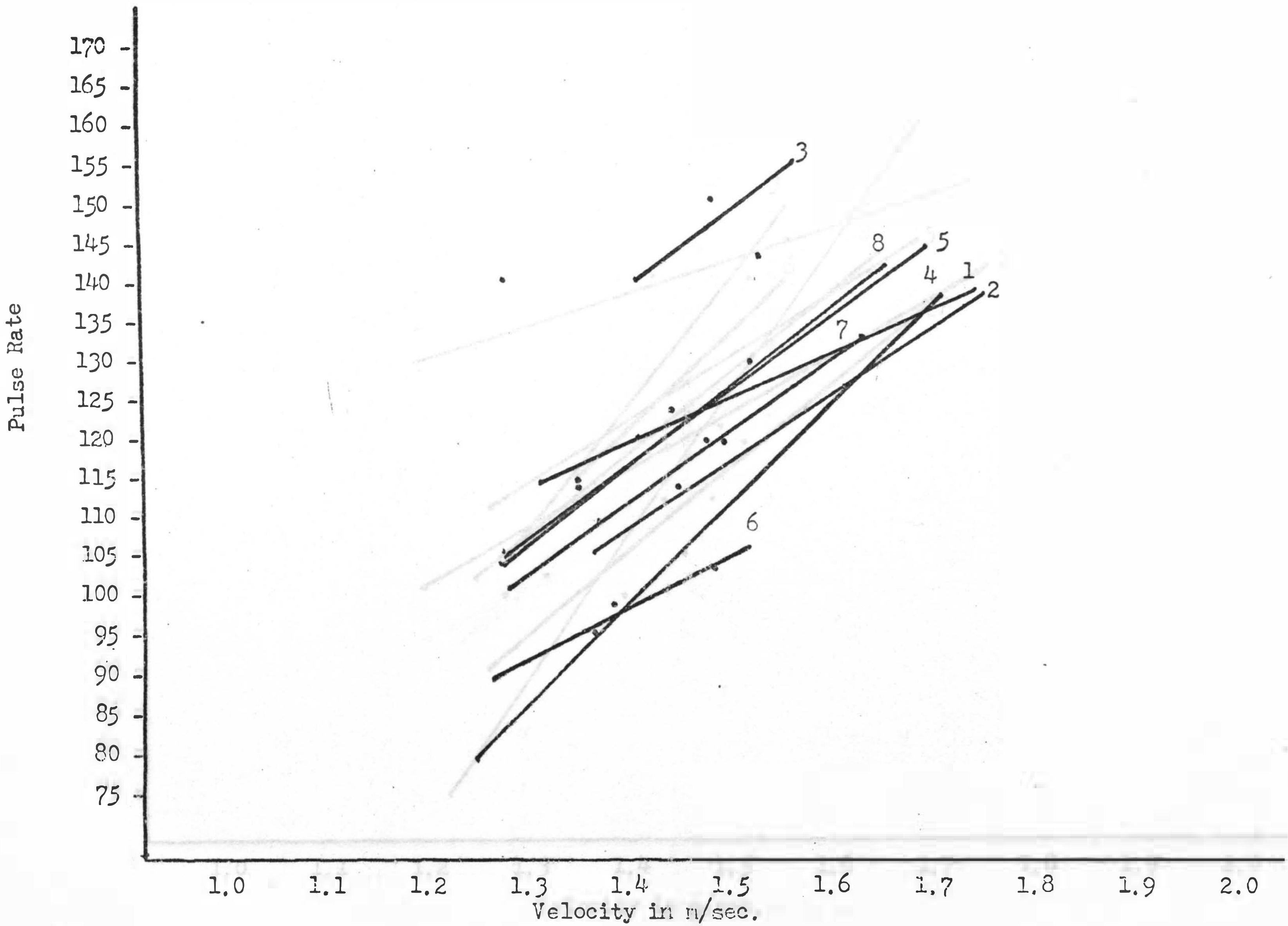


Figure 5. Pulse-Velocity Relationships for Each Individual in Test 2.

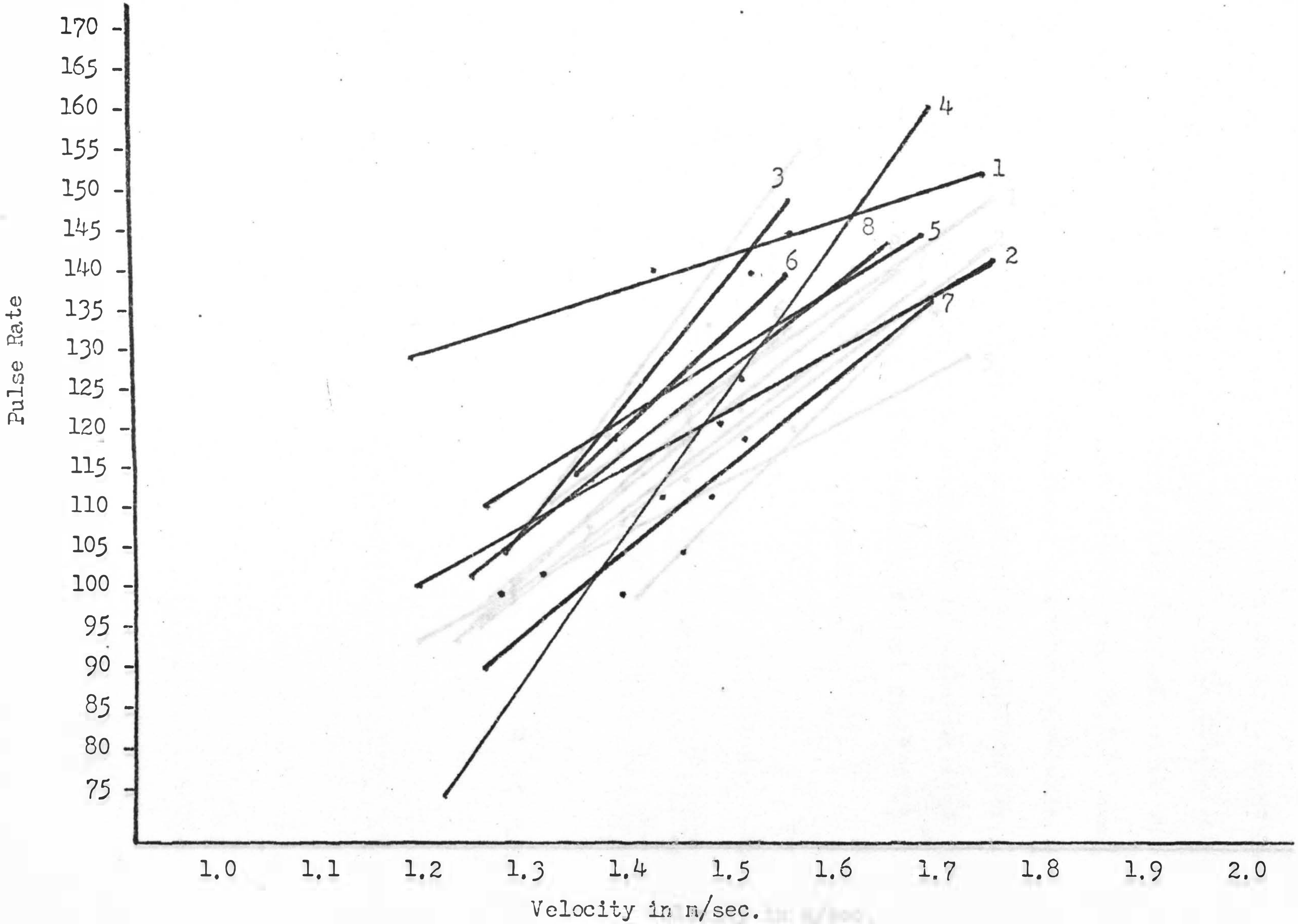
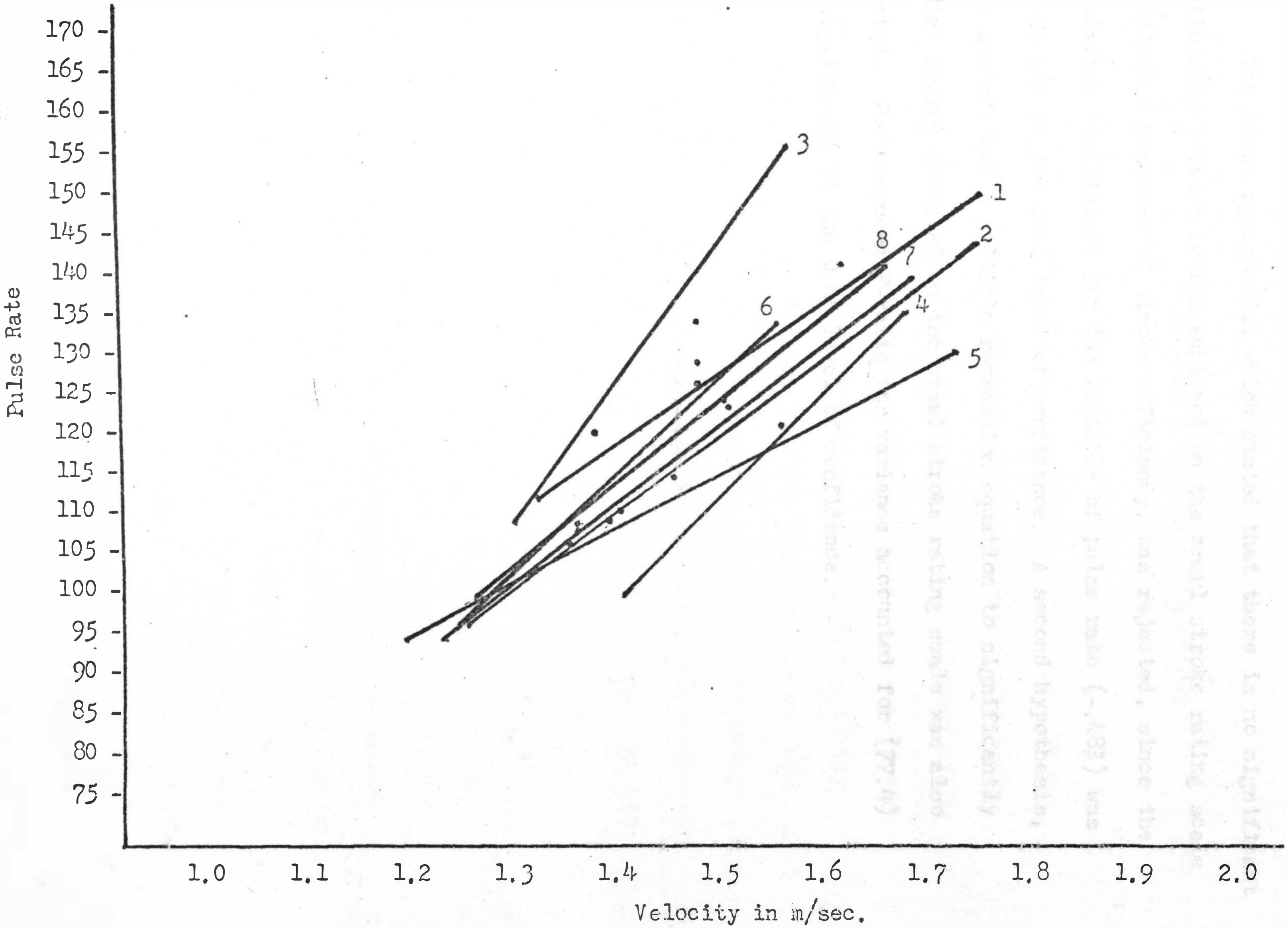


Figure 6. Pulse-Velocity Relationships for Each Individual in Test 3.



The first hypothesis, which stated that there is no significant relationship between scores achieved on the crawl stroke rating scale and selected measures of stroke efficiency, was rejected, since the correlation coefficient for the variable of pulse rate (-.481) was significant at the 0.05 level of confidence. A second hypothesis, which stated that a multiple regression equation to significantly predict scores achieved on the crawl stroke rating scale was also rejected. The computed F-ratio for variance accounted for (77.4) was significant at the 0.05 level of confidence.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Study

The purpose of this investigation was to develop a form rating scale for the crawl stroke to determine stroke efficiency.

The subjects were eight members of the South Dakota State University men's intercollegiate varsity swimming team. All subjects were tested three times for each variable during a 15-day testing period. Testing began on February 10, 1975 and was completed on February 25, 1975. The measures of stroke efficiency selected for use in this study were stroke-velocity, pulse-velocity, and maximal oxygen uptake-velocity. The form rating scale was constructed from principles reported by Counsilman and Haines.[1,2]

Data were collected and recorded in such a manner that relationships between the selected measures of stroke efficiency and the form rating scale could be analyzed. Multiple regression analysis was applied to the data to determine whether a relationship existed. Coefficient of correlation analysis was also applied to the data to determine relationships between all variables. The 0.05 level of confidence was accepted as the minimal level required in order to reject the null hypotheses.

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[1] James E. Counsilman, The Science of Swimming (Englewood Cliffs: Prentice-Hall, Inc., 1968), pp. 7-59.

[2] George Haines, "Freestyle Hints", Swimming World, 14:4, July, 1973.

The results of the coefficient of correlation analysis indicated that only the variable of pulse had a significant relationship to the form rating scale.

The results of the multiple regression analysis indicated that a regression equation using the variables selected for this study could be used to predict achievement of scores on the form rating scale. These variables accounted for 77.4 percent of the variability in the form rating scale.

Conclusions

Within the limitations of this investigation the following conclusions seemed warranted:

1. Subjects having lower maximal oxygen uptake values obtained on a graded tethered swim test will achieve a higher level of efficiency, as determined by the Karpovich formula.

2. As swimming speed increases, efficiency as computed with the aid of the Karpovich formula is proportionately higher.

3. As pulse rate increases, the score obtained through the use of the form rating scale will decrease.

Recommendations

The following recommendations are made for further study:

1. That a similar study be undertaken using a greater number of subjects.

2. That a similar study be conducted over a longer period of time to determine changes which may occur in efficiency throughout the competitive swimming season.

3. That a similar study be completed where other measures of maximal oxygen uptake in addition to the method used in this study be investigated and analysed to find a most valid measure of determining the true maximal oxygen uptake value of a swimmer.

4. Replicate the study using a greater number of judges in order to determine objectivity, reliability, and to improve the accuracy of the crawl stroke rating form.

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APPENDICES

APPENDIX A

CRAWL STROKE RATING SCALE

SWIMMER: ______________________________ TEST # 1 2 3

Frequency of the observance of these traits:

1. Never--does not occur
2. Sometimes--half of the time
3. Always--is constantly occurring

Please check the appropriate square:

ARM STROKE	1	2	3
Pull-bent elbow of 45 to 90 degrees from fingertips to elbow			
-elbow higher in the water than hand or wrist			
-hand follows midline through pull phase			
-constant turnover so pressure is maintained by a hand at all times			
Push-at the end of the pull phase there is a distinct push of the water			
-end of push phase hand is 4-6 inches below water surface			
Recovery-high or bent elbow with elbow coming out first and hand coming out last			
-rotate shoulder forward by reaching with the elbow and shrugging the shoulder forward			
-palm of hand faces toward feet at all times			
-hand enters well out in front of the shoulders between midline of body and shoulders			
-hand enters thumb side down			
BREATHING			
-turn the head to breathe as the opposite hand of natural breathing side enters the water			
-water level between hairline and eyebrows			
-turn the head to breathe rather than lifting head to breathe			
-head returns to original position			
KICK			
-continuous kick (no break in rhythm)			
-kicks from hip with legs and feet extended (no excessive knee flexion)			
-not too deep in the water (feet next to the surface but not out of the water)			

APPENDIX B

INDIVIDUAL MAXIMAL OXYGEN UPTAKE AND EFFICIENCY RATINGS IN EACH OF THREE TRIALS

(liters per minute/milliliters per kilogram per minute/percent)

Subject	T_1	T_2	T_3
R.A.	2.17/29.47/5.59	3.81/52.33/3.18	2.76/37.68/4.39
S.A.	2.85/36.69/5.18	2.61/33.40/5.66	2.64/34.72/5.59
R.F.	3.17/47.47/3.71	3.24/48.23/3.63	3.06/45.75/3.84
M.I.	3.26/37.97/4.53	3.41/40.36/4.33	3.41/40.52/4.33
T.K.	2.73/41.12/5.41	2.37/34.82/6.23	2.28/34.66/6.47
M.R.	3.52/43.73/3.34	2.96/36.60/3.97	2.56/31.6/4.59
M.R.	3.65/50.87/3.79	3.46/48.23/3.99	3.27/45.56/4.23
T.W.	3.10/48.04/3.57	2.75/42.32/4.04	2.68/42.14/4.15

INDIVIDUAL SCORES FOR RATING SCALE
IN EACH OF THREE TRIALS

(Average of Four Coaches Ratings)

Subject	T_1	T_2	T_3
R.A.	50.00	49.50	49.75
S.A.	49.25	48.00	49.00
R.F.	43.25	45.25	45.25
M.I.	49.25	49.25	50.25
T.K.	46.50	47.25	46.50
M.R.	50.50	51.25	51.50
M.R.	49.00	49.25	49.00
T.W.	43.25	48.75	47.75

INDIVIDUAL SCORES FOR PULSE-VELOCITY
ON 50-METER SWIM

(beats per minute/velocity in meters per minute)

Subject	T_1	T_2	T_3
R.A.	116/1.32	128/1.19	112/1.33
	122/1.42	140/1.43	126/1.48
	132/1.53	144/1.56	142/1.62
	142/1.74	152/1.74	150/1.76
S.A.	106/1.28	100/1.20	96/1.27
	106/1.37	102/1.32	106/1.36
	114/1.45	112/1.43	114/1.46
	140/1.75	140/1.75	144/1.75
R.F.	142/1.32	104/1.28	108/1.31
	142/1.42	120/1.38	120/1.38
	152/1.48	140/1.52	134/1.48
	156/1.57	148/1.56	156/1.57
M.I.	80/1.25	74/1.22	100/1.27
	98/1.39	98/1.40	100/1.41
	106/1.52	118/1.52	122/1.56
	138/1.71	160/1.69	136/1.68
T.K.	106/1.28	110/1.27	94/1.20
	114/1.35	112/1.35	108/1.37
	124/1.44	112/1.48	128/1.48
	146/1.69	144/1.69	132/1.72
M.R.	90/1.27	114/1.35	96/1.26
	96/1.37	118/1.39	110/1.41
	104/1.48	126/1.52	120/1.43
	144/1.53	140/1.55	134/1.56
M.R.	102/1.28	90/1.27	94/1.23
	116/1.34	98/1.28	108/1.36
	120/1.49	104/1.45	124/1.51
	134/1.63	136/1.69	140/1.68
T.W.	104/1.27	101/1.25	99/1.27
	110/1.37	114/1.37	110/1.39
	120/1.47	122/1.49	125/1.50
	143/1.64	145/1.65	142/1.65

INDIVIDUAL SCORES FOR STROKE-VELOCITY
IN EACH OF THREE TRIALS

(number of strokes/time in seconds)

Subject	T_1	T_2	T_3
R.A.	19/13.0	18/13.1	19/13.5
S.A.	20/13.0	20/13.0	19/14.2
R.F.	20/14.8	21/15.5	22/14.7
M.I.	22/13.1	22/12.5	23/13.0
T.K.	24/14.5	26/13.6	25/14.5
M.R.	22/14.7	23/14.7	22/14.7
M.R.	24/13.6	23/14.0	24/13.3
T.W.	28/14.6	28/14.6	29/15.1