The Relationship of Freestyle Sprinting Ability in Swimming to Selected Measurable Traits

Keith Charles Sutton

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THE RELATIONSHIP OF FREESTYLE SPRINTING ABILITY IN SWIMMING TO SELECTED MEASURABLE TRAITS

BY

KEITH CHARLES SUTTON

A thesis submitted in partial fulfillment of the requirements for the degree Master of Science, Major in Health, Physical Education and Recreation, South Dakota State University

1975

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THE RELATIONSHIP OF FREESTYLE SPRINTING ABILITY IN SWIMMING TO SELECTED MEASURABLE TRAITS

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Thesis/Advisor  Date

Head, Health, Physical Education and Recreation Department  Date
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ACKNOWLEDGMENTS

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A special thanks is due to the author's mother, Mrs. Mildred Sutton, for her understanding and encouragement.

KCS
CHAPTER I
INTRODUCTION

Significance of the Study

In the sport of competitive swimming, athletes dedicate themselves to becoming proficient in propelling their bodies through water. Participants realize that the swimmer who can speed through the race faster than his competitor will win. The very nature of the sport dictates the need for proper application of specific fundamentals and stroke mechanics.

Counsilman points out that swimming strokes are based on "certain mechanical principles which apply directly to swimming."¹ Counsilman's investigation of Bernoulli's Principle, or the lift principle in biomechanics, explains how Newton's Third Law, action-reaction, can be met without the swimmer pulling his arm straight backward.² Counsilman states, "Greater efficiency in water is achieved by moving a large amount of water a short distance than by moving a small amount of water a great distance."³ Also, the champion swimmers in his study moved their hands in elliptical patterns and changed the pitch of their hands. It was found that the flow of water over the knuckle side of their hands moved


³Ibid.
faster than the water on the palm side. To illustrate his theory, Counsilman effectively applied Bernoulli's Principle in an analogy between three types of pulling motions of a swimmer's arm and three forms of navigational locomotion. Schleinhaufl called the Counsilman study "the first accurate analysis of swimming propulsion."

The present writer accepts the application of the above biomechanical principles for use in coaching speed swimmers. It follows that if these were properly applied the swimmer would theoretically reach optimum speed. However, many physical differences between individual swimmers make it particularly difficult for an individual to apply the principles correctly. For example, when applying the action-reaction law, a swimmer may lack the proper flexibility in the shoulder girdle to allow for the correct arm pull. The arms could be weak and as a result lack strength necessary for effective propulsion.

On the other hand, certain physical characteristics might enhance the correct application of a law. Having very large hands may be an asset when employing Bernoulli's Principle. Accepting the laws of physics as fact leaves the physical traits of the competitor to be investigated. A comparison between specific physical traits and

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4 Counsilman, op. cit., p. 4.


swimming speed would serve to identify those characteristics most influential to swimming speed.

Through reading previous studies, corresponding and talking with respected swimming coaches, and drawing from personal experience, the present writer identified and tested physical traits thought to influence a swimmer's speed. Although muscular strength of the arms and good flexibility have long been accepted by most coaches as an asset to the speed swimmer, the other variables were selected on the basis of their anticipated relationship to swimming speed.7,8

Statement of the Problem

The purpose of this study was to investigate, by means of objective tests, the relationship of selected physical characteristics to performance by swimmers in a forty-five yard freestyle sprint.

Hypotheses

1. There will be no significant relationship between selected anatomical measurements and motor responses and speed in freestyle swimming in a forty-five yard sprint.

2. A multiple regression equation to predict speed in swimming in a forty-five yard sprint event cannot be developed.

Limitations and Delimitations

1. Only the front freestyle crawl stroke was swum for data purposes in this study.

2. The variables were only correlated with the swim over the distance of forty-five yards.

3. Only seventeen subjects were tested and all subjects had at least two seasons of competitive swimming experience.

4. No attempt was made to control psychological factors which may have affected the subjects' performances.

5. Physical parameters selected for this study were limited to the following: speed of movement of the arms, per cent body fat, muscular strength of the arms, muscular endurance of the arms, arm strength to body weight ratio, stroke frequency, stroke length, vertical power jump, arm rotation flexibility, shoulder flexion, and cross-chest extension.

6. Because of scheduling conflicts it was not possible to use a rotational design in sequencing test items.

Definition of Terms

Stroke Frequency. Stroke frequency has been defined as "the number of arm cycles performed per second, where one arm cycle consists of the complete stroke of each arm."^9

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Stroke Length. Stroke length has been defined as "the distance covered during one arm cycle."\(^{10}\)

Muscular Strength. Muscular strength is defined as "the ability of a muscle or a group of muscles to overcome resistance or create tension—push, pull, or lift."\(^{11}\)

Muscular Endurance. Muscular endurance is defined as "the ability of muscles to perform a task many times."\(^{12}\)

Flexibility. Flexibility is defined as "the range of movement in a joint. The freer the movement the more flexibility the joint has."\(^{13}\)

Freestyle. For the purpose of this study, the freestyle refers to the front crawl style of swimming.

Speed of Movement Time. Speed of movement time has been defined as "the rate at which a person can propel his body, or parts of his body, through space."\(^{14}\)

Leg Power. Leg power has been defined as "the ability of the legs to provide the inertia to propel the body through space."\(^{15}\)

\(^{10}\)Ibid.

\(^{11}\)Counsilman, op. cit., p. 276.

\(^{12}\)Ibid.


\(^{15}\)Ibid.
Hand Size. For the purpose of this study, hand size refers to the sum of the length and width of both hands.

Arm Span. For the purpose of this study, arm span refers to the length between a subject's finger tips when his arms are held at a ninety-degree angle from the side of his body.

Per Cent Body Fat. Body fat is the weight in pounds of an individual's body tissue that is in excess of lean body weight. 16

Lean Body Weight. As used in this study it is a description of fat free weight. 17


17 Ibid.
CHAPTER II

REVIEW OF RELATED LITERATURE

Considerable research has been completed in the area of testing general motor ability and ability in specific athletic activities. However, few studies have been completed that touched briefly on all phases of swimming or upon specific areas that appear to be definite factors related to swimming speed. The review of literature in this chapter is concerned with those studies which deal with swimming proficiency and with research dealing specifically with the variables being investigated in this study.

Literature Related to Flexibility of the Shoulder Girdle

One of the early leaders in flexibility measurement was Cureton, who devised a test of flexibility which included trunk flexion, trunk extension, shoulder elevation, and ankle flexion. For the trunk and the shoulder measurements, Cureton used a linear system of measurement employing sliding calipers. Ankle flexion was measured by measuring the distances between two marks on the paper representing the flexed and extended positions. Cureton standardized his tests and established percentile rankings. His test is not considered to be a truly valid measure.1

Benson measured flexion and extension of knee and ankle, and abduction of the shoulder using a 360-degree protractor. His measures

were also used for treatment of injuries, and, therefore, no records of normal use were kept.²

The first instrument to measure several joints for flexibility was a flat circular dial developed by Leighton in 1941. His flexometer consisted of a dial 4½ inches in diameter, marked off in degrees (360), and a weighted needle. To operate effectively, the dial had to be held on edge. It was mounted to a strap for fastening to a body part.³ A revised model of the flexometer has both a weighted needle and a weighted dial.⁴

Leighton used the flexometer to study male athletes ages 10 to 18 to determine flexibility of various age groups and to compare athletes of different sports in flexibility. The subjects in his study showed a definite downward trend in flexibility from ages 10 to 16. From 16 to 18 years of age the flexibility varied. Leighton noted that this change may have been the result of changes in activity and not because of age. Using 16-year-olds as a reference point, Leighton found swimmers and baseball players to have the highest degree of flexibility in the 30 different measures. The pattern trend was quite similar for these two groups; that is, they were high and low in


flexibility on the same tests with few exceptions. They were low in shoulder flexion and extension and hip abduction and adduction. Swimmers were neither high nor low in trunk rotation. 5

Leighton states:

There appears to be a flexibility pattern in each case or group studied which parallels the skills and habits of body movement present. There is evidence that it may not be possible to develop skills to a high degree without laying the groundwork of a proper flexibility pattern for the skills. 6

Successful swimming coaches from around the world recognize good flexibility as an important phase of swimming. Counsilman believes that physical conditioning required for good swimming performance is made up of three major components: (1) strength, (2) endurance, and (3) flexibility. 7 He states, "A dry land exercise program, when properly designed and followed, can build strength and flexibility faster than these traits can be built by training with swimming alone." 8 Counsilman continues his support for flexibility by adding, "Flexibility, or mobility, is a desirable trait for an athlete because it permits maximum exploitation of strength, speed, and coordination." He continues, "In swimming, the particular stroke is the determining factor." 9

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7Ibid.

8Ibid.

9Counsilman, op cit., pp. 303-311.
In studies conducted at Indiana University, Counsilman's results differed from those reported by Leighton in his studies dealing with various varsity sports. Counsilman concluded that members of the varsity swimming team are more flexible in the shoulders and ankles than any other group of athletes tested.\(^\text{10}\)

Gallagher contends flexibility is a component of muscular fitness. In regard to swimmers he states, "It is becoming increasingly difficult to reach world class without super flexibility."\(^\text{11}\) He continued observing, "The ability of the extension of a joint to move over a greater range with apparent ease depends upon the 'looseness' of the joint and the physical characteristics of the muscles acting as prime movers."\(^\text{12}\) Gallagher adds, "This is why some characteristics of the ectomorph are desirable (super flexible types)."\(^\text{13}\) In reference to world-record-setter Roland Matthes, Gallagher notes, "His backstroke wins and world records depend upon his super flexibility."\(^\text{14}\)

Easterling used a daily flexibility program in training his swimmers. He writes, "Often a swimmer is restricted by a lack of range flexibility."

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\(^{10}\) Counsilman, op cit., pp. 303-311.


\(^{12}\) Ibid.

\(^{13}\) Ibid.

\(^{14}\) Ibid.
of motion. Through flexibility drills this can be expanded and will aid in prolonging fatigue and will produce more efficiency."\(^\text{15}\)

Results of Hampton's study found that college freshmen in a class of swimming showed a significant increase of agility and flexibility after four weeks of class participation.\(^\text{16}\) Hampton adds:

Since it is difficult to determine how much flexion is good or bad for an individual, the coach and student must evaluate the degree needed in each specific joint in terms of ease of performance and safety in the activity or part of the body that is involved. A loss in flexibility is frequently noticed as being one of the first signs of getting out of shape.\(^\text{17}\)

Several devices have been suggested for testing flexibility, but Harris states, "The Leighton flexometer appears to be the most objective instrument for measuring joint action."\(^\text{18}\) In her review of literature, she reported that many of its users found it to be highly valid with reliability estimates of .889 to .997.\(^\text{19}\)


\(^{17}\)Ibid.


\(^{19}\)Ibid.
Montoye believed flexibility to be specific for each of the various body joints in both sexes.  

He reported that Forbes obtained reliability coefficients ranging from .901 to .983 when the Leighton flexometer was used for thirty different flexibility measures in a test-retest situation.

Literature Related to the Vertical Jump

Although the vertical jump is defined as a motor element, it is in fact a composite of a number of different factors operating together to produce an explosive effort. The vertical jump is the single test most often used by coaches in determining general athletic ability.

A comprehensive study by Hutto refers to the following factors as basic to athletic power: general strength, dead weight (that weight not contributing to power), velocity of speed of muscle contraction, a structural factor in the form of a lever system, arm strength, and an artifact. There is a general agreement by researchers that these components are integrated and work together under the influence of a

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21 Ibid.


coordination factor. The relative importance of each of these factors has been estimated through factor analysis studies. In a study conducted by Gray, Start, and Glencross, the jump reach test, standing broad jump, squat jump, and the modified vertical power were compared with a criterion measure (vertical power jump). The modified vertical power jump was determined to be the best test of leg power because it showed a reliability measure of .977 and validity of .989 when correlated with the criterion.

Henry states that the Sargent Jump Test, first validated by L. W. Sargent, was a test of neuromuscular efficiency involving strength, speed and coordination, and driving power. In 1932 McCloy experimentally validated the Sargent Jump Test and stated that it was the best single test available for predicting power.

Lately several tests have been devised to measure the factor that is termed power. The sixty-yard dash has been used as a test of power, but since this test is more characteristic of speed, most authorities do not consider it to be an adequate test of power.

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28 Ibid.
Johnson and Nelson wrote that athletic power tests are quite practical for the majority of schools and have been widely used in physical fitness and motor ability testing programs because power includes the important factors of strength and speed of movement. Other vertical jump tests include coordination factors that influence the results. To be a true physical measure of the ability of the legs to project the body vertically into the air, it is of fundamental importance that the jumping technique be carefully controlled and that the measure involved be accurately obtained. The fundamental assumption which must be met is that the force which projects the body vertically upward against gravity is only that of the legs.

Gray, Start and Glencross found a coefficient of .981 that supported the evidence which indicated that there was a high consistency or objectivity in scoring the Vertical Power Jump regardless of whether the recorder be trained or untrained. They concluded that the modified vertical power jump should be used when measuring leg power because of its high reliability of .977 and its high validity .989 when compared to


the jump reach test, standing broad jump, and the squat jump (Sargent Jump). 31

Gray, Start, and Glencross developed a formula to express the amount of work done in foot-pounds per second for the legs. 32

It reads:  Work = \( \frac{W \times H}{12} \)

\( W \) = weight of subject in pounds

\( H \) = difference between tip-toe reach and maximum jump reach

According to Burley and Anderson, leg power is more closely related to some sports (swimming, track and basketball) than to others, and power "as measured by the jump and reach test is an important component of athletic ability and is closely associated with athletic success." 33

Literature Related to Reaction Time and Speed of Movement

Burpee and Stroll designed an experiment to test an individual's quick and accurate response to situations in sports. Small and large muscle responses of four groups of subjects were measured, each group having a different level of success as a participant in physical activities. Burpee and Stroll concluded that there was a significant negative relationship between small-muscle reaction time and successful participation in physical education activities. 34

Fast small-muscle

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31 Ibid.

32 Ibid.


reaction time was an important factor in attaining success in these activities, and there was a significant negative correlation between large-muscle reaction time and success in physical activities.  

Beise and Peasely found that the skilled group showed a significant difference over the unskilled in reaction time of large muscles, speed of running, and agility. The skilled group also had greater stability in reaction time, regardless of the condition under which the stimulus was given.  

Westerlund and Tuttle conducted a study of 22 varsity track men running short, middle distance, and distance events to determine relationships between running events and reaction time. The reaction time of champions was less than any other group regardless of distance, and there was a high degree of relationship between speed in running 75 yards and reaction time. Using a finger response testing device, they found the degree of relationship to be r=.863. In another study completed the following year by Lautenback and Tuttle, a similar

35 Ibid.


38 Ibid.
conclusion was reached. This study showed a correlation coefficient of .915 between speed in sprinting and reflex time.\textsuperscript{39}

A study completed by Keller found that the reaction time of athletes in baseball, basketball, football and track was significantly better than those in swimming, gymnastics, and wrestling. It was also found that a positive relationship existed between success in athletic skills and the ability to move the body quickly.\textsuperscript{40} But Erickson observed, "The relationship between reaction time and success in athletics is a point of controversy and is not definite, although some studies indicated a positive relationship between the two."\textsuperscript{41}

Smith found reaction time and speed of movement time to be greater when the muscle was partially contracted than when it was completely relaxed.\textsuperscript{42}

A study to determine the difference between speed of movement and reaction time in females and males was conducted by Hodgkins. She studied 930 men, women, and children from age six to eighty-four to

\begin{footnotesize}


\textsuperscript{41}E. Erickson, "A Study to Determine the Relationship between Certain Psychological Capacities and Success in Coaching Football," (unpublished Doctoral dissertation, Boston University, Boston, 1953), pp. 44-45.

\end{footnotesize}
determine differences between males and females in reaction time and speed of movement time, and to ascertain if a relationship exists between the two. The results showed the following: (1) Males were faster than females in both areas; (2) no relationship was found between reaction time and speed of movement time; (3) both males and females increased in reaction time and speed of movement time until early adulthood and then decreased; and (4) males maintained peak speed of movement for a longer time, but females maintained peak speed in reaction time for a longer time.  

The Nelson Reaction Timer was used by Johnson and Nelson in tests of reaction time and speed of movement. They found reliability coefficients of .89 when measuring reaction time and .75 when measuring speed of movement time in college men. Face validity was accepted as long as no attempt was made to separate reaction time and speed of movement.  

Stroke Frequency and Stroke Length

Although very few studies have been completed on stroke frequency and stroke length in relationship to swimming performance, coaches consider these factors to be very important. Tallman states, "Eventually, we should develop the body of knowledge that would give

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44 Johnson and Nelson, op. cit., pp. 28-36.
us the information that could indicate the optimum stroke rate for a given swimmer."  

Talbot writes, "Sprinters of world class do not get in as many strokes per lap as one would think. A high stroke rate is important but it is just as important for the strokes to be completed fully. The speed of movement of the arms coupled with this important point is when we begin to understand speed swimming."  

East pointed out the lack of related research in the introduction of his study by stating, "An extensive search of the English language literature failed to reveal any studies on either stroke frequency or stroke length in swimming."  

The purpose of East's study was "to investigate the relationships between stroke frequency, stroke length and performance in swimming."  

He filmed the performance of all competitors in each 110-yard event at the New Zealand Amateur Swimming Association's 1969 National Swimming championships. Then he computed stroke frequencies and stroke lengths for each subject in each event. Then, the means, standard deviations and ranges were computed for the number of cycles executed in lap I and lap II, and for the total number of cycles over the total distance. The Pearson product-moment correlation coefficients between stroke

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48 Ibid.
frequency and time, and stroke length and time for each event were calculated, as well as regression equations. Significant correlations were found in four events: the men's freestyle, the women and men's butterfly and the men's backstroke. East then computed optimum values for both stroke frequency and stroke length for particular times within the recorded time range for that event.

East's results regarding the men's 110-yard freestyle event suggests that "to improve performance stroke frequency should increase while stroke length decreases slightly." East concludes his study by writing, "There exist other variables such as certain anthropometric measurements which may affect both stroke frequency and stroke length. In view of the results of the present study, it would seem that an attempt to examine such factors might be usefully attempted in a future study." Tallman believes that stroke frequency is a factor in swimming. He states:

Over the past ten years, during which I have been checking stroke rates, I can see a trend towards a faster rate. I am not sure that the trend would be statistically significant but without a doubt, we are seeing faster turn-overs. In another ten years, I might be able to say that stroke rates are definitely getting faster. But I don't feel the evidence to date is all that conclusive.

Daland, in an interview with Colwin, stated that he believes stroke length and stroke frequency depend on: (1) The distance to be

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50 Ibid.

51 Tallman, op. cit. p. 47.
faced, (2) The physique of the swimmer—whether he or she is large or small, long armed or short armed, (3) On the style of the swimmer, and (4) On the swimmers condition.  

Percent Body Fat

Morclose and Miller state that different athletic events "require different proportions of fat to muscle for maximum performance. Distance swimmers need a certain amount of fat distributed near the skin surface to diminish the heat loss to the water."  

Karpovich and Sinning listed several different ways to determine the percent of body fat of a person. The methods of assessment included the injection of chemicals that are selectively absorbed by different body compartments; another employed a dilution technique in which helium replaced air surrounding the subject while he sat in an air-tight chamber of a known volume. Still others they cited were more practical, such as underwater weighing. Underwater weighing is based on Archimedes' Principle: an immersed floating body is buoyed up by a force equal to the weight of the water it displaces.  

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55 Ibid.
Two general approaches have been used for estimating body fat from anthropometric measures. Behnke's technique is based on the concept that a given skeletal structure "reflects a relatively constant lean body mass."\(^{56}\) The second of the two anthropometric measurements, that of calibrating skinfolds, was used to determine percent body fat in his study. "The measurement of skinfolds is based on the knowledge that approximately 50 percent of the deposited fat is stored in specialized cells within the subcutaneous areas."\(^{57}\)

By using the skinfold test, Karpovich and Sinning found the following percentages of fat on each group of athletes: fifteen track team members, 9.4; seven middle-distance and long-distance runners, 8.0; seventeen baseball players, 12.1; six tennis players, 14.6; and twelve spring football participants, 14.5.\(^{58}\)

Sloan states that the measuring of body fat and body density has been considered a fairly accurate way of predicting and determining the condition of individuals throughout a season of play.\(^{59}\) Thompson, Buskirk, and Goldman bring attention to the skinfold method as one deserving more emphasis in physical education research. The skinfold

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\(^{56}\)Ibid.

\(^{57}\)Karpovich and Sinning, op. cit., p. 307.

\(^{58}\)Ibid.

procedure is a rapid, precise, and an inexpensive method for estimating body fat. 60

Muscular Strength of the Arms and Muscular Endurance of the Arms

Gambril states, "It has long been my belief that strength is a very important factor in fast swimming. Certainly style and endurance cannot be separated from strength in determining what yields speed." 61

A review of related literature shows general agreement with Gambril in that strength and endurance are key factors to top performances. Carlile writes that before 1948 "every swimming trainer in the world" did not want to slow swimmers down by getting them "muscle-bound" with exercises for strength. 62 Carlile continues, "Now, however, practical experience has proved them wrong and there are few top swimmers in the world who do not work for strength out of the water in addition to their strenuous training in the water." 63 Talbot writes, "To reach the top these days in swimming, it is essential to spend a lot of time on weight-lifting and on calisthenics. Swimming alone cannot make the body strong enough to produce world class times." 64


63 Ibid.

64 Talbot, op. cit., p. 62.
Counciliman writes, "The physical conditioning required for good swimming performance is made up of three major components: (1) strength, (2) endurance, and (3) flexibility." Counciliman adds that a dry land exercise program can build strength and that exercises can be designed for the acquisition of muscular endurance. 65

Campbell investigated the relationship of arm and shoulder strength and endurance in swimming the freestyle crawl. He tested the arms and shoulder girth strength with a power-pull test involving holding a thirty-pound barbell until the subject was exhausted. The arms' proportional force and the whole strokes proportional force were tested by having the subject pull against the spring at zero velocity for ten seconds. The best effort was recorded after the initial jerk. Time was taken on each subject for 50-yard and 200-yard swims. A table of correlation and inter-correlation was developed for the barbell pull-ups and arms alone with the whole stroke, the height, the weight, and the age of the subject. He concluded that the arm and shoulder strength is highly related to the speed of the swimmer in the 50-yard freestyle and that the arms are more important to propulsion than are the legs. Arm strength yielded a correlation of .77, the whole stroke propulsive force a correlation of .77, and the propulsive force of the arms alone a correlation of .85. 66

65 Counciliman, op. cit., pp. 276-281.

66 Cameron Robert Campbell, "A Study of Relationship of the Arm and Shoulder Strength and the Endurance of the Freestyle Swimming," Master's thesis (State University of Iowa, 1948).
Thompson divided his subjects into four groups: no exercise, only weight, only swimming, and swimming and weight training. There was no speed improvement by the group which had no exercise and by the one that had only weight training; however, there were significant gains by the groups which had only a swimming program and the group that had a swimming and a weight-training program.67

Hutchinson divided his subjects into a controlled group that swam twice a week and into an experimental group which exercised in addition to two swims per week. The exercises consisted of the press, squat, curl, deadlift, supine press, toe risers, upright rowing, sit-ups, and pull-overs. He found no significant difference between the two groups in swimming time for the 100-yard front crawl.68

Hofer studied strength and its relationship to swimming, using girls as her subjects. She concluded that the measurement of shoulder strength with the use of the cable tensiometer is an insignificant predictor of swimming speed in the front crawl. She also concluded that her female subjects obtained more power from the arm stroke in the front crawl than they did from the leg kick.69

Davis used a weight-training program for the arm, shoulder, and abdominal muscle groups with seventeen male swimmers. He concluded that all subjects improved their swimming times on 25-yard and 50-yard sprints. 70

Karpovich reported that males with good crawl strokes have 70 per cent of their power coming from their arms and 30 per cent from their legs, but poor crawl swimmers derive 77 per cent of their power from their arms and 23 per cent from their legs. 71

Janson experimented with three different training programs: only swimming, only weight training, and a combination of the two. He found that all programs improved swimming times on the forty-yard sprint and concluded that no program used was superior to any of the others. He noted that weight training alone did improve swimming times. 72

Councilman stated that a subject pulling a sizable amount of weight could create a large propulsive force, but a subject who pulled a lesser weight would create a less propulsive force. He suggested


that development of arm strength would be an effective method of
developing a greater forward propulsive force. 73

Difficulty has been encountered in attempts to develop tests to
measure endurance found in prolonged running and swimming. "Endurance
is the most difficult aspect of fitness to measure." 74

Faulkner, in a review of literature found "little data" published
on the strength of swimmers and no definitive study on the strength
requirements for swimming. He states a swimmer of 76 kg averages 136
kg on a 90-degree bent arm pull or 1.78 kg per kilogram of body weight.
Faulkner noted that this is greater than the pull of the average college
freshman and compares favorably with the limited data on other athletes.
Faulkner cites Bloomfield and Sigerseth for obtaining mean scores of
74 kg for sprinters and 67 kg for middle-distance swimmers. 75

Faulkner adds, "The best prediction of maximum endurance appears
to be the percentage of maximum strength involved in each contraction.
Such a relationship has been determined between strength per pound of
body weight and muscular endurance in a sample of thirty physical

73 James Edward Counsilman, "An Analysis of the Application of
Force in Two Types of Crawl Strokes," (Doctoral dissertation, State
University of Iowa, 1951).

74 M. Gladys Scott and Esther French, Better Teaching Through
and Evaluation in Physical Education, (Dubuque: Wm. C. Brown Company,

75 John A. Faulkner, What Research Tells the Coach About
education majors." His results showed that the 90-degree bent arm pull score divided by body weight correlated .90 with the maximum number of pull-ups performed. In relationship to freestyle sprinters, he notes that the force of each pull is approximately 9 kg sprinting and 1.7 kg swimming distance.\textsuperscript{76}

Hand Size

Councilman was concerned with two aspects of the hand: (1) the amount of resistance it makes in the water and (2) the hands sensitivity to pressure. In regard to the resistance the hand creates in the water, Councilman's results showed that "cupping of the hand does reduce the pull considerably." He added that spreading the fingers slightly may produce a bit more pull than a closed-finger hand; however, more muscular energy will be expended by the wrist and finger flexor muscles when the fingers are spread.\textsuperscript{77} Although Councilman did prove that different sizes of the same hand did affect the amount of resistance created, he did not state that a big hand will create more resistance than a smaller hand.

At one point, Councilman felt that the trait that distinguished a good natural swimmer from an average or poor swimmer was "the sensitivity of his hands to pressure changes of the water when he was pulling his hands through the water."\textsuperscript{78} He tested the sensitivity of

\textsuperscript{76}Ibid.

\textsuperscript{77}Councilman, op. cit., pp. 9-12.

\textsuperscript{78}Ibid.
two Olympic swimmers and that of two poor swimmers by placing varying weights on their hands which they were to distinguish. The results of this particular test showed the Olympians to have a much higher ability in separating the weights than the other two.79

79Counsilman, op. cit., pp. 9-12.
CHAPTER III
METHODS AND PROCEDURES

Organization of the Study

Variables which the present investigator identified as being closely related to speed in freestyle swimming were selected. Data were collected by measuring each subject with respect to hand size, arm span, speed of movement, percent body fat, muscular endurance of the arms, muscular strength of the arms, arm strength to body weight ratio, stroke frequency, stroke length, vertical power jump, arm rotation flexibility, shoulder flexibility, and cross-chest extension to backward flexion. Two tests of each independent variable were administered. Testing began July 20, 1972, and ended July 26, 1972.

Source of the Data

Seventeen male subjects participated in the study and were selected on the basis of previous competitive swimming experience. All subjects had at least two seasons of competitive swimming and ranged in ages from 17 to 22 years. No attempt was made to rate the subjects as to swimming ability. Table I indicates the characteristics of the subjects.

Collection of the Data

Subjects who were tested were members of three separate swimming teams: the South Dakota State University Varsity Swim Team, the Brookings A.A.U. Swim Team, and the Sioux Falls YMCA Swim Team. Members participating from the two Brookings clubs were tested in the
<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Height (Centimeters)</th>
<th>Weight (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. J.A.</td>
<td>21</td>
<td>183</td>
<td>186</td>
</tr>
<tr>
<td>2. B.A.</td>
<td>19</td>
<td>176.5</td>
<td>160.5</td>
</tr>
<tr>
<td>3. S.A.</td>
<td>18</td>
<td>181</td>
<td>173</td>
</tr>
<tr>
<td>4. S.C.</td>
<td>20</td>
<td>189</td>
<td>185</td>
</tr>
<tr>
<td>5. G.F.</td>
<td>17</td>
<td>178.5</td>
<td>140</td>
</tr>
<tr>
<td>6. J.F.</td>
<td>18</td>
<td>181.75</td>
<td>162</td>
</tr>
<tr>
<td>7. S.J.</td>
<td>18</td>
<td>169</td>
<td>141</td>
</tr>
<tr>
<td>8. B.M.</td>
<td>22</td>
<td>178.5</td>
<td>194</td>
</tr>
<tr>
<td>9. D.M.</td>
<td>19</td>
<td>172.5</td>
<td>133</td>
</tr>
<tr>
<td>10. J.M.</td>
<td>21</td>
<td>181</td>
<td>184</td>
</tr>
<tr>
<td>11. M.P.</td>
<td>17</td>
<td>179</td>
<td>148</td>
</tr>
<tr>
<td>12. M.R.</td>
<td>18</td>
<td>180</td>
<td>184</td>
</tr>
<tr>
<td>13. D.S.</td>
<td>17</td>
<td>176</td>
<td>145</td>
</tr>
<tr>
<td>14. P.U.</td>
<td>20</td>
<td>169</td>
<td>146</td>
</tr>
<tr>
<td>15. F.W.</td>
<td>18</td>
<td>175</td>
<td>129</td>
</tr>
<tr>
<td>16. J.W.</td>
<td>17</td>
<td>178.5</td>
<td>132</td>
</tr>
<tr>
<td>17. T.W.</td>
<td>22</td>
<td>171.5</td>
<td>139</td>
</tr>
</tbody>
</table>
Human Performance Laboratory located in the South Dakota State University Gymnasium. Swim tests were completed at the Brookings Municipal Swimming Pool. Members of the Sioux Falls YMCA Swim Team were tested in the weight room at the Sioux Falls YMCA; the swim tests were completed at Frank Olson Swimming Pool in Sioux Falls. Test dates and times were set for each subject prior to each test. The subjects were asked not to participate in any strenuous type of activity prior to the testing. All tests were sequenced so that participation in one test did not influence results in another.

The following procedure was used when administering the laboratory tests. On the first day:

1. The subjects reported for testing in shorts, T-shirt, and tennis shoes.
2. The subject, with shoes off, was weighed to the nearest pound and then his height measured in centimeters.
3. Speed of movement test was administered.
4. Hand size was measured.
5. Arm span was measured.
6. Muscular endurance of the arms test was performed by the subject.

On the second day:

1. The flexibility tests were administered.
2. Vertical power jump test was administered.
3. Percent body fat was determined.
4. Muscular strength test was completed.
All laboratory tests were administered in the afternoons. The four swimming trials were timed in the forenoons, two the first morning and two the second morning. The subjects were given a minimum of fifteen minutes between each time trial.

Prior to the swimming test, a demonstration and explanation of the push-off start and the type of stroke was provided. The starting position used in this study required the subject to be in the water, with both feet planted on the wall and one hand clasping the gutter while keeping the head above the surface of the water.

An attempt was made, however, to sequence the test items so that serial order effects were avoided. Raw data for all variables for each subject appear in Appendix A.

**Arm Span.** Arm span was measured for each subject in centimeters. For this measurement, the subject was instructed to wet his finger tips and abduct both arms to a 90-degree angle and to stretch them as wide as possible, touching his finger tips to a black board. The evaluator put a chalk mark at the tip of the outermost finger print for each hand; a tape measure was stretched between the two chalk marks, and a measurement was recorded in centimeters.

**Flexibility of the Shoulder.** Three separate tests were administered to measure the flexibility of the shoulder. A Leighton Flexometer was utilized in these measurements to determine the degrees of movement. Montoye reported that Forbes obtained reliability coefficients ranging from .901 to .983 when the Leighton Flexometer was used for thirty
different flexibility measures in a test-retest situation. This instrument measures degrees of movement.

The Flexometer consists of two independently rotating indicators, both suspended on the same axis, one indicator being a floating dial four and one-half inches in diameter with two sets of numbers running in opposite directions, dividing the outside edge into 360 degrees. The other indicator is a pointer which identifies the degrees of movement. Both pointer and dial are free to turn, or can be locked into position. To measure flexibility of a joint or combination of joints, the researcher straps the instrument on the moving part being tested. The dial is locked at one extreme position and the pointer is locked at the other extreme position. By reading the dial, the researcher can record the range of movement in degrees.

The first test of shoulder flexibility measured arm rotation from pronation of the hand to supination of the hand. The Leighton Flexometer was strapped to the subject's closed fist. The subject was told to stand erect and to abduct his arm vertically in the frontal plane until it was at a 90-degree angle to the body. He was subsequently instructed to hyper-supinate his arm, and at the point of maximal rotation, the dial of the flexometer was locked. The subject was then instructed to hyper-pronate his arm and at the point of maximal lateral rotation the pointer of the flexometer was locked. A reading of the

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flexometer was taken and recorded in degrees of arm rotation. The test was repeated on the opposite arm.

The second test of shoulder flexibility measured degrees of movement from maximal forward and upward flexion of the arm in a sagittal plane to the arm's maximal downward and backward extension in the same plane of movement. The flexometer was strapped around the midpoint of the subject's biceps. He was then instructed to sit on a bench and brace his vertebral column and head against a wall and to flex the humerus in the sagittal plane as far forward and upward as possible, while keeping the elbow in a locked position. At this point the dial on the flexometer was locked. The subject was then instructed to extend his arm downward and backward as if to circumduct his arm, keeping the elbow in a locked position. When his arm had been extended as far back as possible, the pointer was locked and a reading was recorded in degrees of arm forward flexion and backward extension. The test was then repeated for the opposite arm.

The third test of shoulder movement also utilized the Leighton Flexometer, while strapped to the humerus of the subject. This test measured the range of motion of the humerus in horizontal flexion, when adducted forward across the chest in the transverse plane and abucted the arms horizontally backward in the transverse plane until its movement was retarded by a lack of further flexibility. This action


\(^3\)Ibid.
would not be unlike the movement of the arms when a person tries to cross his elbows in front and in back of himself. After attaching the flexometer, the subject was asked to assume a supine position on a table with his arm extending over the edge of the table. The subject was then told to flex his arm so it would move horizontally across his chest in the transverse plane. The dial of the flexometer was locked when full horizontal cross-chest flexion was reached. The subject was then instructed to maintain his body position and extend his arm distally backward in a transverse plane so that it would be dorsally extended as far as possible. At this point the flexometer pointer was locked; a reading was taken and recorded in degrees of horizontal flexion and extension. The test was then repeated on the opposite arm.

In each of the three flexibility tests, measurements were recorded after having three individual readings on the flexometer recording the same degrees of movement.

Measure of Speed of Movement. The Nelson Speed of Movement Test was used for this test. The subject was instructed to sit facing a table with his fingers resting on the edge of the table. The palms were facing each other and positioned with the inside edge of the little fingers along two lines spaced twelve inches apart. The Nelson Reaction Timer was held by the tester near its top so that it hung at a point midway between the subject's palms. The Base Line was held in a position level with the upper edge of the subject's hands.

After the preparatory command of "ready," the stick timer was released, and the subject attempted to stop its fall as quickly as possible by clapping his hands together. The tester made sure that the subject did not move his hands up or down nor look at the tester's hand.
The subject was given twenty trials with his final score being the mean of the middle ten trials after the five fastest and five slowest trials had been discarded. Each score was recorded to the nearest one hundredth of a second and recorded as speed of movement time.4

**Vertical Power Jump.** Power, in this study, refers to muscle power of the legs. The Vertical Power Jump was used in measuring the subject's leg power. The equipment utilized was a jump board marked off in half inches and chalk dust. The subject was instructed to keep one hand behind the back touching the top of his gym shorts; the other hand and fingers were extended vertically with the palm of the hand pronated outward. The subject stood on his toes as high as possible and touched the jump board with the chalked outstretched hand. This height was measured and recorded as the reaching height. Chalk dust was again applied to the subject's fingers; he squatted down, keeping his head and back straight, jumped vertically as high as possible, and touched the jump board with the chalked fingers. Each subject was allowed three trials; the greatest height was recorded. The number of inches between the reach and the jump marks, measured to the nearest quarter of an inch, was the score recorded.5

**Measurement of Hand Size.** Hand size was measured for both length and width on the metric scale to the nearest centimeter. For the measurement of the length, the subject was instructed to wet his

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5 Ibid., p. 91.
hand on a wet towel provided for that purpose, and to put his hand print on a blackboard. The subject was instructed to keep his wrist at a 90-degree angle when making the print. The tester then placed a chalk mark at the upper and lower extremes of the print. The distance between the two chalk marks was recorded to the nearest millimeter. Both the right and left hands were measured.

For the measurement of the width, a Vernier Caliper was used. The subject was instructed to lay his hand flat on a table. The measurement was taken across the back of the hand from the head of the carponmetacarpal joint of the index finger to carpometacarpal joint of the little finger. The measurements were recorded to the nearest millimeter. The final hand size for each hand consisted of the sum of the width and length of each hand. The final hand size recorded was the mean score for the right and left hands.6

**Stroke Frequency.** The stroke frequency of each swimmer was recorded as each subject swam his forty-five-yard sprints. A count was recorded for the number of strokes taken during the swim. Each arm stroke consisted of one complete rotation of each arm. The number of arm strokes recorded were divided into the time it took the subject to swim the distance. This stroke frequency method gave the number of strokes taken per second.7

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Stroke Length. The stroke length of each swimmer was recorded as each subject swam his forty-five-yard sprints. A count was taken of the number of strokes taken during the swim. Each arm stroke consisted of one complete rotation of each arm. The number of arm strokes recorded were divided into the distance swum. The distance was forty-five yards. This stroke length method gave the distance the swimmer moved for each stroke he took. Recording was in yards per stroke.\(^8\)

Muscular Endurance of the Arms. Difficulty has been encountered in attempts to develop tests to measure endurance found in prolonged swimming and running. "Endurance is the most difficult aspect of fitness to measure."\(^9\)

The pull-up test was given to the subjects for a test of muscular endurance of the arms. The following formula was used to determine muscular endurance: Work = Force \(\times\) Distance, with force being the subject's body weight and distance being the distance the subject pulled up times the number of repetitions done.

Subjects were instructed to start each pull-up from a straight-arm hang position, then pull themselves up until their chin touched the bar. As soon as it touched, a pull-up was counted; if it did not touch

\(^8\)Ibid.

the bar, it was not counted. They were instructed to do as many pull-ups as possible.

Distance moved in each pull-up was calculated by measuring the distance from the bar to the greater trochanter of the femur while the subject was in the straight-arm position and again when the subject was in the flexed arm position during the time his chin was in contact with the bar. The distance in centimeters was then determined by subtracting the distance in the flexed-arm position from the distance in the straight-arm position. This difference was multiplied by the number of repetitions completed and recorded as distance.

Force was measured by weighing the subjects. Both the force and the distance were then multiplied together to calculate work which was recorded as muscular endurance of the arms. Data were recorded in foot-pounds.

Muscular Strength of the Arms. A revised pull-up test was used to measure muscular strength of the subject's arms. The formula for calculating strength in pounds was:

\[
\text{Work} = (\text{Body Weight} + \text{Added Weight}) \times \text{Distance}.
\]

To measure distance, the subject assumed a hanging position from a horizontal bar. The bar was grasped with an overhand grip. The arms were extended at the elbow; the feet hung free of the floor or any other support. A measurement from the greater trochanter of the femur was reached by sighting a right-angle board from the greater trochanter to a scale on the vertical support for the pull-up bar. This measurement was recorded in inches to the nearest half inch.
After the extended arm position was measured, the subject pulled-up to a flexed-arm position with the chin placed over the bar and the head held in a horizontal position. A measurement from the greater trochanter of the femur was read by sighting a right-angle board from the greater trochanter to a scale on the vertical support for the pull-up bar. This measurement was recorded in inches to the nearest one half inch.

The difference between the extended-arm and flexed-arm positions was recorded. This difference represented the body displacement in a vertical plane and "Distance" in the formula.

The measurement of "Body weight + Added weight" was secured thus: A belt with a chain to which weights could be affixed was buckled around the subject's waist. The subject was given three attempts at determining his one repetition maximum. A two-minute rest was given between each trial. The subject affixed the amount of weight on the belt with which he felt he could do one complete pull-up. Measures were taken to prevent any excessive body swing during the pull-up. The same instructions were given for this test that were given when measuring "Distance." If the subject and the investigator felt that one repetition maximum was performed during one of the three attempts, it was accepted for scoring purposes. The body weight and the added weight on the belt were added together and recorded as "Weight." If after three attempts it was the feeling of the subject and the investigator that a true maximum had not been reached, the subject was instructed to come back the next day and perform three more such attempts. When it was the feeling of the subject and the investigator that a true "weight" had been deter-
mined as one repetition maximum, the amount was placed into the formula, and the formula was then carried out to determine "Work" of 'Muscular Strength of the Arms.'

**Arm Strength/Body-Weight Ratio.** A ratio was between the total pounds resulting from the arm strength measurement and the total pounds of the subject resulting from a body weight measurement. Total arm strength was divided by total weight of the body to compute the ratio. All subjects were weighed while wearing gym trunks.

**Measurement of Percent Body Fat.** Percent body fat was measured according to a procedure developed by Forsyth. Forsyth measured body density of 50 male college athletes by the underwater-weighing technique. He also obtained 17 anthropometric measurements on each subject, using a combination of skeletal diameters and skinfold measurements. Ten regression equations were developed from six different combinations of the raw data obtained from the 50 subjects. For the present study the equation which exhibited a combination of a multiple R (0.86) and a standard error of estimate (.005) was used.10

\[
\text{Body Density} = 1.02415 - .00169X_{15} + .00444X_1 - .00130X_{12}
\]

- \(X_{15}\) = diagonal skinfold at the medial border of the right scapula.
- \(X_1\) = height (decimeters)
- \(X_{12}\) = abdominal skinfold midway between the umbilicus and the iliac crest.

Two skin fold measurements were taken using the Lange Skinfold Calipers. The measurements were taken of the subject's right side. The subject's skin was grasped firmly with the thumb and forefinger of the investigator's left hand. The width of the skin was kept small but contained a definite fold. The calipers were placed as near the crest of the fold as possible. The calipers were placed approximately one centimeter away from the tester's thumb and forefinger. A recording was taken to the nearest one-half millimeter and recorded.

Measurements were taken at the medial border of the right scapula and midway between the umbilicus and the iliac crest. Measurements at both sites were taken and recorded when the investigator had two like measurements. The abdominal skin fold was recorded as \( x_{12} \) and the scapula skinfold was recorded as \( x_{15} \).

Height of the subject was taken and recorded in centimeters. The subjects were measured in their stocking feet.

The following equation was used to convert body density to percent body fat:

\[
\text{Percent Body Fat} = \frac{4.57}{\text{BD}} - 4.412^{11}
\]

"Forty-five-Yard Freestyle Sprint. Each subject swam four, forty-five-yard freestyle sprint time trials to determine his times. The time trials were conducted in the Brookings Municipal Pool, a forty-five-

yard, eight-lane outdoor pool and the Frank Olson Pool in Sioux Falls, a fifty-meter, eight-lane outdoor pool. The fifty-meter pool was marked off in order to get accurate measurements in the forty-five-yard sprint. Prior to the swimming test, a demonstration and explanation of the push-off start and the type of stroke was provided.

The starting position used in this study required the subjects to be in the water, with both feet planted on the wall and one clasping the gutter while keeping their head above the surface of the water. At no time were the swimmers allowed to run on or jump off the bottom of the pool.

The subjects were instructed to come into the ready position at the command "Take your marks" and to push off and begin swimming as fast as they could upon hearing the whistle. They were instructed to swim the entire distance as fast as they could. Time was recorded from the start to the instant any part of the subject's body crossed the finish plane. Each subject was given a fifteen-minute rest between each of his two daily time trials. The fastest of the four time trials was used in this study.

Four testers were used in administering this test: Two investigators timed the event and two counted the number of strokes taken by the subject. Time was recorded to the nearest tenth of a second.

The following equations were used to convert the stroke count to stroke frequency and stroke length:

\[
\text{Stroke Frequency} = \frac{\text{number of strokes}}{\text{time}}
\]

\[
\text{Stroke Length} = \frac{\text{forty-five yards}}{\text{number of strokes}}
\]
CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Organization of the Data for Analysis

Thirteen independent variables were identified as possible contributors to success in freestyle sprinting. The independent variables measured were hand size, arm span, speed of movement, muscular strength of the arms, muscular endurance of the arms, muscular strength to body weight ratio, stroke frequency, stroke length, vertical power jump, shoulder flexion, arm rotation flexibility, and cross-chest extension. The dependent variable was the speed recorded for swimming a freestyle sprint a distance of forty-five yards. The means and standard deviations for all of the variables are found in Table II. Appendix A contains the raw data for these variables.

To analyze the data, the researcher used a multiple correlation and multiple regression statistical procedure.¹ This was used to compute the intercorrelations between the thirteen independent variables and the correlation between the independent and dependent variables. A multiple regression equation was developed beginning with a one variable equation and adding one additional variable in each succeeding step in order to increase the accuracy of the prediction. For each step a standard error of estimate, a multiple correlation and variance

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$ Hand Size (centimeters)</td>
<td>27.447</td>
<td>1.175</td>
</tr>
<tr>
<td>$X_2$ Arm Span (centimeters)</td>
<td>184.559</td>
<td>6.461</td>
</tr>
<tr>
<td>$X_3$ Speed of Movement (seconds)</td>
<td>24.388</td>
<td>2.251</td>
</tr>
<tr>
<td>$X_4$ Percent Body Fat (percent)</td>
<td>12.703</td>
<td>6.511</td>
</tr>
<tr>
<td>$X_5$ Muscular Strength of the Arms (foot pounds)</td>
<td>436.353</td>
<td>65.333</td>
</tr>
<tr>
<td>$X_6$ Muscular Endurance of the Arms (foot pounds)</td>
<td>3581.765</td>
<td>1191.835</td>
</tr>
<tr>
<td>$X_7$ Arm Strength to Body Weight</td>
<td>2.780</td>
<td>0.367</td>
</tr>
<tr>
<td>$X_8$ Strokes per Second</td>
<td>1.722</td>
<td>0.254</td>
</tr>
<tr>
<td>$X_9$ Yards per Stroke</td>
<td>1.035</td>
<td>0.114</td>
</tr>
<tr>
<td>$X_{10}$ Vertical Power Jump (inches)</td>
<td>20.853</td>
<td>2.446</td>
</tr>
<tr>
<td>$X_{11}$ Arm Rotation (degrees)</td>
<td>279.412</td>
<td>30.484</td>
</tr>
<tr>
<td>$X_{12}$ Shoulder Flexion (degrees)</td>
<td>189.745</td>
<td>15.821</td>
</tr>
<tr>
<td>$X_{13}$ Cross-chest Extension (degrees)</td>
<td>182.471</td>
<td>15.649</td>
</tr>
<tr>
<td>$Y_1$ Swimming Speed (seconds)</td>
<td>25.165</td>
<td>2.098</td>
</tr>
</tbody>
</table>
accounted for in that step were computed. An electronic computer was used to facilitate speed and accuracy during this process.

Analysis of the Data

None of the thirteen independent variables were found to correlate significantly with swimming speed in the freestyle sprint. Eleven of the seventy-eight interrelationships were significant beyond the .05 level of confidence. The interrelationships included hand size to arm span (.71); hand size to stroke frequency (.83); arm span to muscular endurance (-.55); speed of movement to shoulder flexion (-.51); muscular strength to muscular endurance (.51); muscular strength to arm strength to body weight ratio (.52); muscular endurance to arm strength to body weight ratio (.55); stroke frequency to arm strength (-.66); arm rotation to shoulder flexion (.54); shoulder flexion to cross-chest extension (.56); and arm rotation to cross-chest extension (.66). The correlation matrix is presented in Table III.

The regression equation for speed in the freestyle sprint for forty-five yards is shown in Table IV. According to the variance accounted for by the addition of each new variable to the equation, no combination of variables examined could be used to predict swimming performance.

Discussion of the Results

In correlating the thirteen independent variables to the dependent variable, the present investigator found no correlations that were significant beyond the .05 level of confidence. In this study
TABLE III
CORRELATION MATRIX OF INDEPENDENT VARIABLES
TO SWIMMING SPEED

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**1 Hand Size  
2 Arm Span  
3 Speed of Movement  
4 Percent Body Fat  
5 Muscular Strength  
6 Muscular Endurance  
7 Arm Strength/Body Weight  
8 Stroke Frequency  
9 Stroke Length  
10 Vertical Jump  
11 Arm Rotation  
12 Shoulder Flexion  
13 Cross-Chest Extension  
Y Time of Swim

*(.05 level of confidence = .48)  
(.01 level of confidence = .61)
### TABLE IV

Regression Equations Developed, Their Standard Error of Estimate, Multiple Correlation and Variance Accounted For by the Addition of Each Variable

<table>
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<tr>
<th>Regression Equation</th>
<th>Standard Error of Estimate</th>
<th>Multiple Correlation</th>
<th>Variance Accounted*</th>
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<tr>
<td>1. ( Y = -0.13X_2 + 49.48 )</td>
<td>1.980</td>
<td>.406</td>
<td>11.598</td>
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<tr>
<td>2. ( Y = -0.12X_2 - 0.04X_{12} + 54.71 )</td>
<td>1.981</td>
<td>.518</td>
<td>7.598</td>
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<td>3. ( Y = -0.10X_2 - 0.04X_{12} - 1.87X_8 + 54.28 )</td>
<td>1.928</td>
<td>.560</td>
<td>3.204</td>
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<tr>
<td>4. ( Y = -0.18X_2 - 0.02X_{12} - 3.54X_8 - 0.00X_6 + 72.30 )</td>
<td>1.817</td>
<td>.661</td>
<td>8.714</td>
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<tr>
<td>5. ( Y = -0.19X_2 - 0.04X_{12} - 5.10X_8 - 0.00X_6 + 0.03X_{11} + )</td>
<td>1.759</td>
<td>.719</td>
<td>5.581</td>
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<tr>
<td>6. ( Y = -0.22X_2 - 0.03X_{12} - 5.61X_8 - 0.00X_6 + 0.03X_{11} + ) ( .21X_3 + 70.83 )</td>
<td>1.784</td>
<td>.740</td>
<td>2.204</td>
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<td>7. ( Y = -0.23X_2 - 0.02X_{12} - 5.90X_8 - 0.00X_6 + 0.03X_{11} + ) ( .20X_3 - 0.06X_4 + 73.55 )</td>
<td>1.827</td>
<td>.757</td>
<td>1.779</td>
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<tr>
<td>8. ( Y = -0.25X_2 - 0.01X_{12} - 6.80X_8 - 0.00X_6 + 0.03X_{11} + ) ( .25X_3 - 0.07X_4 - 1.14X_{10} + 79.28 )</td>
<td>1.893</td>
<td>.770</td>
<td>1.365</td>
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<tr>
<td>9. ( Y = -0.20X_2 - 0.01X_{12} - 4.75X_8 - 0.00X_6 + 0.02X_{11} + ) ( .30X_3 - 0.09X_4 - 1.16X_{10} + 5.6X_9 + 80.79 )</td>
<td>1.984</td>
<td>.780</td>
<td>1.110</td>
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TABLE IV (Continued)

<table>
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<th>Multiple Correlation</th>
<th>Variance Accounted*</th>
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<td>10. $Y = -0.29X_2 - 0.01X_{12} - 2.84X_8 - 0.00X_6 + 0.03X_{11} +$</td>
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<td>$0.39X_3 + 0.10X_4 - 0.11X_{10} + 9.62X_9 - 0.04X_{13} +$</td>
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<td>$73.68$</td>
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<td>11. $Y = -0.25X_2 - 0.02X_{12} - 1.00X_8 - 0.00X_6 + 0.02X_{11} +$</td>
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<td>$0.37X_3 + 0.12X_4 - 0.06X_{10} + 13.13X_9 - 0.04X_{13} +$</td>
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<td>$0.35X_1 + 70.70$</td>
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<td>$2.301$</td>
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<tr>
<td>12. $Y = -0.26X_2 - 0.01X_{12} - 1.25X_8 - 0.00X_6 + 0.02X_{11} +$</td>
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<tr>
<td>$0.38X_3 - 0.12X_4 - 0.08X_{10} + 12.55X_9 - 0.04X_{13} +$</td>
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<td>$0.30X_1 + 0.00X_5 + 72.70$</td>
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<td>$2.570$</td>
<td>$.790$</td>
<td>$.038$</td>
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<td>13. $Y = -0.26X_2 - 0.01X_{12} - 1.25X_8 - 0.00X_6 + 0.02X_{11} +$</td>
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<td>$0.38X_3 - 0.12X_4 - 0.08X_{10} + 12.86X_9 - 0.04X_{13} +$</td>
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<td>$0.50X_1 + 0.00X_5 + 71.78$</td>
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<tr>
<td>$2.968$</td>
<td>$.790$</td>
<td>$.001$</td>
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*Total Variance 70.419  (Refer to Table III for identification of independent variables.)
MS Variance 13.211
Minimum Variance needed to contribute significantly to the equation = 13.211 x 18.51 = 244.536.
$F_{.05} (1,2) = 18.51$
a coefficient of .48 was required to achieve significance at .05 level of confidence.

In reviewing the literature, the present writer found few studies that correlated freestyle sprinting ability with the same or similar variables as those used in this study. The areas which have been investigated in other studies were stroke frequency, stroke length, flexibility, muscular strength of the arms, and muscular endurance of the arms.

**Stroke Frequency.** Although stroke frequency was not of sufficient magnitude to be significant, it suggested that faster stroke frequency may be a trait possessed by freestyle sprinters. The variable of stroke frequency was assigned a coefficient of -.37. The findings of East support this concept. East recommended that stroke frequency must be increased to improve performance.² After evaluating stroke rates over a ten-year period, Tallman reported a trend toward faster stroking in the freestyle sprints.³ Talbot suggested that a higher stroke rate is important for world class sprinters.⁴

**Stroke Length.** The variable of stroke length had a negative intercorrelation (-.83) with stroke frequency, which was well above the coefficient of .61 required for the .01 level. Stroke length correlated

very low (.05), however, with freestyle sprinting. East stated that swimmers should slightly decrease their stroke length to reach optimum speed. Neither the present investigator nor East could identify other studies related to stroke frequency and stroke length.¹

**Flexibility.** Flexibility of the shoulders showed a small correlation with freestyle sprinting in this study. The three different flexibility measures received correlation coefficients of .38 for vertical flexibility in the sagittal plane, -.14 for arm rotation and -.32 for horizontal flexion and extension in the transverse plane. Although the present researcher found no other studies which established that flexibility is related to proficiency in freestyle sprinting, it is generally acknowledged by coaching authorities to be a desirable trait for swimmers.²,³,⁴

**Muscular Strength.** The review of the literature suggested a high correlation between muscular strength and freestyle sprinting. Many coaches advocate the use of resistive exercises and the importance

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¹East, op. cit., p. 69.


of strength in training the freestyle sprinter. In contrast to this concept the present investigator observed no significant correlation since muscular strength obtained a coefficient of -.18. Cameron reported a high correlation (.77) between shoulder and arm strength and speed of swimmers in a fifty-yard freestyle, while Karpovich attributed as much as 77 per cent of the swimmers' propulsion to the arms.

Muscular Endurance. Muscular endurance, generally regarded as an important trait in swimming, showed a correlation coefficient of only .02. Endurance is quite likely a greater factor in a longer race. This characteristic was not the case in the present study, however, as the mean time for the swims in this test was 25.2 seconds.

Arm Strength to Body Weight Ratio. Arm strength to body weight had a correlation of .13 which was lower than the correlation for arm

11Talbot, op. cit., p. 62.
12Counselman, op. cit., p. 62.
15Gambril, op. cit., p. 76.
strength alone. This writer anticipated the reverse, as it seemed reasonable to conclude that if two swimmers are equal in strength the lightest one would be the fastest. Although the results of this study suggest that this is not the case, the correlations could be coincidental.

The low correlation of the vertical power jump test (9.18) was not in agreement with the findings of Burley and Anderson, who reported that leg power is more closely related to certain sports, such as swimming, than to others.17

The present researcher found no related studies directly correlating hand size, arm span, speed of movement, and percent body fat to freestyle sprinting. Arm span came closer to reaching significance than any of the variables (−.41). This finding contradicts the low correlation observed between stroke length and the dependent variable (.05).

Hand Size. Hand size had the third highest correlation (−.34). Hand size and arm span had an intercorrelation that was significant at the .01 level of confidence (.71). Hand size had an even higher intercorrelation to stroke frequency, reaching .83 in comparison to the .61 required for significance at the .01 level.

These data suggest that large hands may be a desirable trait. Counsilman supported the concept upon which this relationship is based when he stated that greater efficiency in water is achieved by moving

a large amount of water a short distance than by moving a small amount of water a great distance."\(^{18}\)

The investigator had anticipated a greater correlation between all of the independent variables and freestyle sprinting. It is not known whether another combination of the variables considered in the present study would have correlated to a higher degree with freestyle sprinting. Present computer software does not include a deleted option capability which would account for a larger percent of the variance. The study would also be improved by testing a much larger number of subjects. Perhaps more than one kind of test should be used to measure each variable.

The first hypothesis, which stated that there was no significant relationship between selected anatomical measurements and motor responses and speed in freestyle swimming in a forty-five-yard sprint, was not rejected. The present researcher also failed to reject the second hypothesis, which stated that a multiple regression equation to predict speed in swimming in a forty-five-yard sprint event cannot be developed, since none of the computed F ratios for variances accounted for were significant at the .05 level of confidence.

---

Summary

The purpose of this study was to investigate, by means of objective tests, the relationship of hand size, arm span, speed of movement, muscular strength of the arms, muscular endurance of the arms, arm strength to body weight ratio, vertical power jump, percent body fat, flexibility of the shoulder, arm rotation, cross-chest extension, stroke frequency, and stroke length to performance by swimmers in a forty-five-yard freestyle sprint.

Seventeen subjects from the South Dakota State University varsity swimming team, the Brookings A.A.U. Swim Team, and the Sioux Falls YMCA swimming team were tested on thirteen independent anatomical measurements and motor responses. From the correlations between the dependent variables and the independent variable, a correlation matrix and regression equations were developed for the purpose of predicting success in freestyle sprinting.

The results revealed that none of the independent variables correlated significantly with freestyle sprinting. No regression equation was developed which would allow one to predict ability in freestyle sprinting.

Conclusions

Based upon the results of this study the investigator concludes:
1. The combination of traits which include hand size, arm span, speed of movement, stroke frequency, stroke length, muscular strength of the arms, muscular endurance of the arms, arm strength to body weight ratio, vertical power jump, percent body fat, flexibility of the shoulder, arm rotation, and cross-chest extension cannot be used to predict swimming performance in freestyle sprinting.

Recommendations for Further Study

Based on the findings of this study the investigator proposes the following recommendations for further study:

1. That a study be conducted using a similar statistical design and procedure, but with a larger number of subjects.

2. That a similar study be conducted employing a statistical procedure capable of determining another order of entry which might indicate a group of traits which provide greater predictive power.

3. That a study be conducted to determine whether selected independent variables in the present investigation might be related to stroke frequency and stroke length.
BIBLIOGRAPHY

A. BOOKS


B. PERIODICALS


C. UNPUBLISHED MATERIALS


Erickson, E. "A Study to Determine the Relationship between Certain Psychological Capacities and Success in Coaching Football," Doctoral dissertation, Boston University, Boston, 1953.


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**APPENDIX**
### APPENDIX A

#### TABLE V

**THE RAW DATA, MEANS AND STANDARD DEVIATIONS OF THE THIRTEEN INDEPENDENT VARIABLES AND THE ONE DEPENDENT VARIABLE FOR THE SEVENTEEN SWIMMERS**

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| X        | 27.4      | 134.6    | 24.4              | 12.70            | 436.35                      | 3581                         | 2.78            | 1.72        | 1.04          | 20.9         | 279               | 189                     | 132          | 25.2         |
| SD       | 1.2       | 6.5      | 2.25              | 6.5              | 55.33                       | 1192                         | 1.37            | 0.54        | 0.74          | 2.41         | 30.5              | 15.8                    | 15.6         | 2.1          |