THE RELATIONSHIP BETWEEN PERFORMANCE IN THE COMPETITIVE BUTTERFLY STROKE IN MALE SWIMMERS AND SELECTED PHYSIOLOGIC AND ANTHROPOMETRIC FACTORS

by

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Chapter 1

INTRODUCTION

Selection of candidates for competitive athletics is a task of critical concern to coaches. College coaches, in particular, need to know which prospects would potentially be the best college performers. Typically, selections are based upon high school performance records, observational techniques, and intuition. Frequently, apparently outstanding prospects recruited by the coach do not develop into successful competitors. Conversely, mediocre prospects who are not vigorously recruited may later emerge as very competent college performers. To increase the accuracy of this selection process, it would be advantageous for coaches to have at their disposal, information on constitutional (body size, proportions and shape) and physical fitness (strength, endurance, metabolic capacity) characteristics which have valid relationships to performance potential of the individual. The specific ways in which these characteristics relate to sports performance are also a concern of theoretical researchers who seek to model performances in various sports and to understand which factors most contribute to differences in performance.

With respect to the sport of swimming, research has been done to generally describe anthropometric traits and levels of fitness in successful performers (Cureton 1951). However, these investigations have not isolated the major underlying traits which give rise to quality performance in swimming. Perhaps extensive variability in the technique (stroke mechanics) of elite swimmers suggests that physical traits and fitness play a minor role. Conversely, a lack of specificity in designing previous research may account for failure to elucidate the role of physical traits and fitness. Investigation of the individual stroke styles (i.e., crawl, backcrawl, butterfly or breaststroke) for a particular competitive distance (i.e., sprint, middle distance or long distance races) within groups of subjects homogeneous for age and swimming experience, might provide clarification.

Faulkner (1966) found that swimmers tend to be taller, heavier, and have less fat than men and women of the same age who are not competitive swimmers. The large vital capacities of swimmers have been noted by some investigators (Cureton 1951). Bloomfield and Sigerseth (1965) found that mean vital capacity (BTPS) was 5.3 L; according to Bloomfield and Sigerseth this value is relatively high. However, the fact still remains that there are few data available to indicate what physiological traits are necessary to support good performance. Research on performance factors in the butterfly events is particularly scarce.

STATEMENT OF THE PROBLEM

The major purpose of this study was to examine the relationship between the performance time in the competitive butterfly event and selected functional factors. Specifically, this study was undertaken to determine if swimming performance can be accurately predicted in either college or young adolescent swimmers from some combination of constitutional and fitness traits.

The subproblems for this investigation were to determine:

1. To what extent can a specific metabolic factor, i.e., maximal oxygen debt, be employed to predict performance time in the competitive 100 yard butterfly swimming event;

2. To what extent can specific pulmonary factors, i.e., vital capacity, timed vital capacity and maximal breathing capacity, be used to predict performance time in the competitive butterfly swimming event and;

3. To what extent can specific anthropometric factors, i.e., a somatotype index, skinfold fat, strength, and bitrochanteric width, be used to predict performance time in the competitive butterfly swimming event.

SIGNIFICANCE OF THE STUDY

At the present time there appears to be much interest focused on the mediocre swimmer, or those that possess special attributes which are not revealed in performance times of the AAU and YMCA swimmer. This writer, being conscious of this phenomenon, endeavors to develop or formulate procedures that will predict the latent abilities in prospective college-age swimmers. Methods and procedures that are feasible insofar as time and cost are concerned, and variables which can predict the performance time in swimmers have not been found in the literature.

MAJOR LIMITATIONS

The following major limitations are recognized to restrict the generalizability of the findings reported in this study:

1. In the College Group, only 11 members of the VPI and SU varsity swimming team were tested. Their age range was 18 to 21 years;

2. There were only 10 boys in the Youth Group. Their age range was 13 to 17 years;

3. The Youth Group included only competitive swimmers with at least 2 years of competitive experience;

4. The Youth Group included only male swimmers from the local AAU swimming teams of Blacksburg and Roanoke County in Southwest Virginia;

5. Performance only in the 100 yard butterfly event was investigated.

DEFINITIONS

Metabolic Factors

Maximal oxygen debt (O_2 debt max): the amount of oxygen consumed in the post-exercise recovery period to reverse the anaerobic reactions of the exercise period (Sinning 1975). Quantitatively, O_2 debt max is the oxygen consumption of the recovery period following the 100 yard butterfly performance, less the resting oxygen consumption for an equivalent resting period.

Pulmonary Factors

Vital capacity (VC): maximum volume of air that can be expelled from the lungs following a maximum inspiration (Astrand and Rodahl 1970).

Timed vital capacity ($TVC_{0.5}$): maximum amount of air that can be expelled in 0.5 sec from the lungs following a maximum inspiration (Astrand and Rodahl 1970).

Maximal breathing capacity (MBC): the maximal volume of air that can be breathed per minute (Consolazio, Johnson and Pecora 1963).

Anthropometric Factors

Abdominal skinfold: a vertical fold taken at the level of and 1 inch lateral to the umbilicus (Sinning 1975).

Bitrochanter: the diameter measurement of the greatest lateral projections of the trochanters of the femurs (hip width) Sinning 1975).

Subscapular skinfold: a skinfold taken immediately below the inferior angle of the scapula at a 45 degree angle with the spine (Sinning 1975).

Thigh skinfold: a fold taken midway between the abdominal skinfold and the top of the patella on the anterior midline of the thigh (Sinning 1975).

Triceps skinfold: vertically oriented skinfold measurement at a point midway between the tips of the acromion and the olecreanon processes at the posterior aspect of the right arm (Sinning 1975).

Somatotype index (SMI): for this investigation, a body type index was formulated from the formula:

$$SMI = \frac{\frac{CD + CG}{BT}}{ASFF}$$

where

CD = chest depth

CG = chest girth

BT = bitrochanter width

and

ASFF = average skinfold fat (mean of the four skinfolds (mm) as described above).

Dominant arm: the subject's most predominantly used arm in performing typical physical feats.

Chapter II

RELATED LITERATURE

INTRODUCTION

In recent years there has been an increasing interest in the field of competitive swimming, as indicated in the literature reviewed later in this chapter. The salient constitutional and physical fitness factors that suggest outstanding potential for performance have not been identified, despite considerable interest among both coaches and human performance researchers. The following chapter contains a selective literature review focusing on the extent to which swimming performance might be predicted from metabolic, pulmonary or anthropometric factors. For organizational purposes only, muscular strength literature has been included under anthropometric factors in this chapter. Studies dealing with limiting factors in swimming or other large muscle activities are also included, where literature specifically related to prediction of swimming performance was unavailable. The chapter is organized as follows:

(a) Metabolic Factors and Performance;

(b) Pulmonary Factors and Performance;

(c) Anthropometric Factors and Performance; and

(d) Summary.

METABOLIC FACTORS AND PERFORMANCE

A large number of investigations have been undertaken to clarify the metabolic events that limit muscular contraction (Hermansen 1969). In the last decade there has been a revival of interest in the basic factors limiting human performance in athletics (Keul 1971). When exercise creates a metabolic need for greater oxygen (0_2) than can be supplied by the cardio-respiratory processes, part of the energy of muscular activity is supplied by the anaerobic mechanism and lactic acid accumulates as the end product of metabolism. Whenever the supply of 0_2 is insufficient to meet demands, an individual is said to contract an oxygen debt (DeVries 1974). In Hermansen's (1969) presentation, it was noted that the use of maximum oxygen debt as a measurement of anaerobic capacity has been considered to be of little importance, due to the fact that several factors are believed to affect the resting oxygen uptake and consequently, the oxygen debt. Despite this, oxygen debt has been measured to determine whether it could be used to distinguish between groups which are supposed to have different abilities to perform short exhaustive exercise. Hermansen used well-trained runners and swimmers for his study. The values for the oxygen debt of trained athletes were compared with oxygen debts of untrained subjects. The results indicated that differences in oxygen debt may reflect differences in a person's ability to perform exhaustive exercise of short duration.

Measurements taken on swimmers have also shown that the oxygen debt may be increased during a training period. Hermansen's study (1969) presented the relationship between oxygen debt and the actual time of performance as the result of training in swimming. Subject L.D. swam the 200 m and subject L.E. swam the 100 m. Both subjects swam their event three times and the results showed an increasing 0_2 debt with improvement in performance. In contrast, Graham and Andrews (1973) found that training did not appear to be a major factor contributing to the wide diversity seen in 0_2 debts. Their study involved six physical education students exercising at three progressive continuous workloads on a treadmill for 15 - 19 min followed by measurement of the 0_2 debt. Five ice hockey forwards, five cross country skiers, five track runners, and five non-athletic control subjects were also tested maximally on one occasion. The cross country skiers and track runners demonstrated greater maximal oxygen uptakes ($P \leq 0.05$) than the control group, but no significant difference could be shown between any of the groups for the 0_2 debt max. Thus, Graham and Andrews concluded that training did not appear to be a major factor contributing to differences seen in 0_2 debts.

Several studies involving the measurements of oxygen debt in man have been done. However, the variability of this measurement within a single individual has not been clearly established (Welch et al. 1970). The possible causes of variations in the 0_2 debt have been extensively examined following both submaximal and maximal exercise (Brooks et al. 1971; Piiper and Spiller 1970). Huss and Cureton (1955) studied the relationships between selected physiological tests in swimmers. Forty-one varsity swimming team candidates were tested using a battery of 52 swimming, cardiovascular, and energy metabolism measures; the latter measures were obtained during all-out tethered swimming. Among the swimming performance criteria, the metabolic variables of oxygen intake, oxygen debt, and the oxygen requirement were most closely related to the 440 yard performance. The gross oxygen debt was relatively more important in explaining differences in the 100 yard swimming performance, accounting for 74.35 percent of the variance contributed by the three variables. They found that oxygen debt, of all the metabolic measures, seemed to be the most closely related to all-out swimming performance.

Katch and Henry's (1972) study, dealing with relationships between estimates of 0_2 debt max, aerobic power, 100 yard sprint, and 2 mile run times revealed substantial individual differences in predictability of performance. Correlation between the 2 mile performance and 0_2 debt max was low (r = 0.31) and only moderate (r = 0.55) between the 2 mile performance and $V0_2$ max. The multiple correlation of 0_2 debt and $V0_2$ max was also only moderate (r = 0.57), implying poor predictability. For the 100 yard sprint, correlations between the criterion measure and these two independent measures (0_2 debt max and $V0_2$ max) were negligible. That study indicated that predictions of individual differences in 2 mile running and sprint performances require more than measured values of max 0_2 debt and aerobic power (max $V0_2$). Katch and Henry (1972) suggest that both max 0_2 debt and max $V0_2$ may be involved as determiners of individual differences. Although neither of these physiological factors has turned out to be a very effective predictor, this does not imply that $V0_2$ max and 0_2 debt max do not set the ultimate limit for endurance performance.

In summary, there has been equivocal evidence reported in the research literature concerning the role of 0_2 debt in human performance. The exact nature of the measure seems poorly understood; however, it is regarded as a gross indicator of the capacity for intense brief exercise. No literature could be found which indicated the relationship of the 0_2 debt max to performance specifically in the 100 yard butterfly event.

PULMONARY FACTORS AND PERFORMANCE

Pulmonary studies on man are numerous. Vital capacity in normal people varies from 1400 to 6500 ml with an average value for males of 4000 ml (Karpovich 1965). There is some relationship between participation in physical work and vital capacity (Karpovich 1965). However, there have been exceptional athletes with low vital capacities and poor ones with large vital capacities (Karpovich 1965). Ness et al. (1974), in their study of cardio-pulmonary function in prospective competitive female swimmers, found no significant differences in any measures of static lung capacity (VC = vital capacity, FRC = functional residual capacity, and TLC = total lung capacity) or dynamic lung volumes ($FEV_{1.0}$ = forced expiratory volume in 1 sec and MVV = maximum voluntary ventilation). In their study (Ness et al. 1974), it was noted, however, that the swimmers' fathers possessed greater FRC and TLC values ($P \leq 0.05$) than the general population. This study revealed that the enhanced functional dimensions of the oxygen transport system in female swimmers were due dminly to genetic endowment and early environmental influences. Whether these qualities are generalizable to male swimmers can only be hypothesized.

Andrews et al. (1972) found that in general, swimmers were taller at a given age and the difference between swimmers and non-swimmers became greater in older children. Swimmers in that study also had larger lung volumes (TLC) as a consequence of larger values for vital capacity. It was suggested by this investigation that training between 8 and 18 years of age promotes physical growth rate, as well as an enhancement of heart and lung functions. In support of that interpretation was the observation that in taller and usually older swimmers, VC frequently showed considerable increase between annual measurements with little change in height. Conversely, it is also possible that this change was coincidental with the development of shoulder girdle muscles which, in boys particularly, suggests a transition to adulthood. It was further reported by Andrews et al. (1972) that VC in the year-round swim training group was greater than in the non-athletic group. Although genetic endowment may have contributed to the superior measurements in their swimmers, training between ages of 8 and 18 years, as stated above, may have had positive influences on stature and cardio-pulmonary function.

Findings by Bloomfield and Sigerseth (1965) revealed that the vital capacity of middle-distance swimmers is significantly greater than that of sprint runners. Cureton (1966) studied lung capacity and concluded it was largely a measure of body size. Cureton's study also showed that high school boys' lung capacity correlated well with McCloy's classification index of body structure (r = 0.86), with height (r = 0.85), with body weight (r = 0.76), and moderately well with chest girth (r = 0.69). There were higher correlations between lung capacity and linear measures of the body than between lung capacity and bulk measures. Cureton (1936), obtained high correlation between the lung capacity and strength of junior high school boys. The relative high correlations that Cureton found in his studies between lung capacity and strength, and lung capacity and linear measures of the body, suggest that these factors could logically be involved as determinants of performance time in the competitive butterfly stroke (Cureton 1956).

Magel and Anderson (1969) studied trained Norwegian swimmers and untrained subjects, finding values significantly higher in trained swimmers than in untrained subjects for static lung volumes (VC, TLC, and FRC), and functional lung capacities ($FEV_{1.0}$, MVV and Ve max). Davis (1955) reported a moderate correlation (r = 0.59) between vital capacity and time in the 200 yard free-style swim. Holmgren and Astrand's (1966) study on pulmonary diffusing capacity revealed that a high diffusing capacity is accompanied by a high aerobic capacity, large lungs with a large ventilatory capacity, and a large cardiovascular system with a large maximal cardiac output. The highest correlation coefficients between lung diffusion capacity and the other variables were found for total hemoglobin, vital capacity, and the measures of the over-all oxygen transport.capacity. Data from Mostyn et al. (1963) provided no indication whether the high diffusing capacity of champion swimmers has been acquired as a result of training or might have been present from childhood. Nevertheless, diffusing capacity in champion swimmers was related to a larger than normal pulmonary capillary blood volume; and their absolute oxygen uptake was also greater, as would be predicted from their larger body size.

In Astrand and Rodahl's (1970) study on male swimmers, mean vital capacities were reported at 5.3 L. They stated that vital capacity had previously been proposed as a method to assess physical work capacity. They found a significant correlation between vital capacity and maximal oxygen uptake in a group of 190 individuals aged 7-30 years. However, they found that individuals with vital capacities of about 4 L may have wide variations in maximal oxygen uptake (i.e., 2.0 to 3.5 L/min). The conclusion they drew, however, was that, to attain a maximal oxygen uptake of 4 L/min or more, one probably must possess a vital capacity of at least 4.5 L.

In summary, although vital capacities vary rather widely in individuals, the influence that vital capacity seems to have on physical work implies there may be some predictive relationship with swimming performance time.

ANTHROPOMETRIC FACTORS AND PERFORMANCE

Structural characteristics of swimmers have long interested human performance researchers. Faulkner (1966) stated that the body build of swimmers has been assessed by somatotype, skinfold, and body density techniques. Cureton (1936) concluded from his somatotyping of Olympic swimmers that top level swimmers tended to be high in mesomorphy. In contrast, Pugh et al. (1960) found that channel swimmers were extremely high in endomorphy. Cureton (1948) noted that the sprint swimmers of world class caliber were high in mesomorphy, and distance swimmers were higher in endomorphy. Cureton also noted that the distance swimmers were also more buoyant and floated closer to the horizontal than the sprinters. In contrast, the findings of Bloomfield and Sigerseth (1965) showed no significant difference in specific gravity of sprinters and distance swimmers.

Few data have been published on the strength of swimmers (Bloomfield and Sigerseth 1956). Faulkner (1966) found that endurance swimmers were not as strong as gymnasts, when scores were adjusted for differences in body weight. However, swimmers do have significantly greater arm strength than other males of the same age and weight. Faulkner (1971) stated that endurance swimmers can exert a force of approximately 70 kg with each arm. Swimming at 85-90 m/min requires a 5-7 kg force/arm stroke or a force equivalent to 7-10 percent of the maximum static strength. Bartels (1971) noted that the modern middle-distance swimmer is primarily a mesomorph structurally, being similar in body structure to the sprinter.

SUMMARY

In summary, selected previous research on the relationships between the independent factors of metabolic capacity, pulmonary function, and anthropometric traits and the dependent measure of physical performance have been reviewed. Low to moderate associations are consistently reported between swimming performance and the 0_2 debt max, aerobic capacity, static lung volumes, functional lung capacities and pulmonary diffusing capacity. Sprint swimmers also appear to be more mesomorphic (muscular build with wide shoulders and narrow hips) than distance swimmers. Equivocal research clouds the relationship of 0_2 debt to vigorous physical performance, but exercise theory suggests that it may still be indicative of metabolic factors which limit brief exhaustive efforts. Little is known of the influence of strength upon swimming performance and there is a notable absence of literature dealing specifically with the 100 yard butterfly performance.

Chapter III

METHODOLOGY

SUBJECTS

Twenty-one male swimmers served as subjects for this investigation; they included 11 members of the VPI & SU varsity swimming teams, and 10 members of the local Blacksburg Community AAU swimming teams and the Roanoke County AAU swimming team. The testing was conducted just after the VPI & SU varsity swimming team had completed its 1974-75 competitive season; the inclusive dates were April 3 to July 4, 1975. The Virginia Tech swimming teams had only 18 days of swimming training during the entire swimming season. It should be noted that the Virginia Tech team did participate in a running and weight lifting program between October 7 and December 12, 1975. The Youth Group subjects swam in meets between September and December, 1975.

Presented in Table 1 are the physical characteristics of the subjects. Descriptive individual data on metabolic, pulmonary and anthropometric measures are presented in Appendices A and B.

CRITERION MEASURE

Upon reporting for the 100 yard butterfly performance test, the subjects were instructed in the butterfly stroke mechanics, starts, and turns. They were told to give a maximal effort and to maintain the highest uniform pace possible during the test; each subject was free

TABLE 1

PHYSICAL CHARACTERISTICS OF SUBJECTS

Group	N	Age (years)	Height (cm)	Weight (kg)
College Group	11	19.6 $\pm$ 1.1	179.9 $\pm$ 3.1	78.6 $\pm$ 7.7
Youth Group	10	13.8 $\pm$ 1.2	167.2 $\pm$ 10.2	57.3 $\pm$ 10.9

Values are means $\pm$ S.D.

to elect the two-beat or one-beat dolphin kick technique. No records were made to identify the differences in technique. The Virginia Tech varsity swimmers swam their event individually, competing against the clock. This procedure was undertaken because the O_2 debt test was administered to each College Group subject immediately after the event was completed. The Youth Group subjects raced against each other as well as the clock. Individuals in the latter category were tested in a group because there was no O_2 debt test administered after the event. The Virginia Tech touch pad electronic timer was used for the Youth Group swimmers. Since each subject swam alone in the College Group, the experimenter recorded their times individually with a stopwatch. All performances were recorded to the nearest 1/10 sec. The subjects were then instructed to swim four lengths of the pool as fast as possible, using the butterfly stroke. To minimize the influence of starting techniques that would enable some subjects to have a starting advantage, the subjects were required to hang onto the pool gutter by their feet, with arms and legs fully extended. At the sound of the gun they pulled with their arms as forcefully as possible. No push-off with the feet was allowed.

Each subject was timed to the nearest 1/10 sec from the time the gun sounded until the touch was made at the last lap. Performance times of all subjects were disclosed. This disclosure was employed to maximize motivation.

INDEPENDENT MEASURES

Measurement of 0_2 Debt Max

For the College Group subjects, the 0_2 debt max procedure was done in connection with the 100 yard butterfly test. The remaining independent measures were taken on other days for the College Group subjects, under standardized conditions in the Human Performance Laboratory. In contrast the Youth Group subjects did not take the 0_2 debt max test, but were given tests on the other independent measures immediately following their criterion performance test.

On arrival at the pool site each subject sat in a chair for 10 min to establish a steady resting oxygen consumption ($V0_2$). This procedure was to insure a uniformly low $V0_2$ baseline for later computation of the 0_2 debt max. At the end of this 10 min rest period, each subject was instructed to enter the pool and stand motionless in the water at a depth of 4 ft. At this time, the mouthpiece was inserted and the noseclip secured over the subject's nose. The subject breathed normally into the gas meter for 5 min. Each subject's inspired airflow (Ve) was thus measured by the Parkinson-Cowan CD-4 dry gas meter for the total 5 min period. Simultaneously, a sample of expired air from the subject was pumped from the mixing chamber into a 1 L aluminum sample bag (bag No. 1) during a 10 sec interval within each min to yield a 50 sec collection by the end of the 5 min resting period.

After each subject completed his resting $V0_2$ consumption test, he was allowed to warm up for the 100 yard butterfly swimming event.

The warmup consisted of stretching exercises and a slow 500 yard swim. This type of warmup was the swimmers' routine during the regular season. It has been stated that this type of activity could be beneficial to the performance in that it may prepare muscles, physiologically, for maximum output (Counselman 1968). It is recognized that elevated muscle temperatures caused by this warmup may have contributed to somewhat higher O_2 debt max values than might otherwise be obtained (Brooks et al. 1971). The warmup was considered necessary, however, to elicit maximal efforts from athletes who are accustomed to warm up before maximal exertion. After the completion of each subject's warmup, his 100 yard butterfly swim was started within 5-10 min.

Before each subject swam the 100 yard event, he was told that, at the end of the swim, he was to hold his breath until the mouthpiece and noseclip could be secured. This procedure was employed to assure that valid O_2 debt measurements would be obtained. Once this step was completed, a 20 min post-swim gas collection was begun.

Oxygen uptake (for O_2 debt max) during recovery was measured for 20 min, using nine expired air collection bags. During the first 2 min of recovery, gas was collected from the middle 20 sec of the 1st and 2nd min in bags No. 2 and 3, respectively. Ventilations for each minute were also taken. For recovery minutes 3 and 4, one sample bag (No. 4) was used to collect aliquots from the middle 10 sec of each min; ventilation was taken for the sum of the 3rd and 4th min. For recovery in the 5th through 10th min, sample bags

No. 5, 6, and 7 were used to collect representative aliquots from minutes 5-6, 7-8, and 9-10, respectively. Three corresponding ventilations were taken at 2 min intervals for minutes 5-6, 7-8, and 9-10. Finally, for minutes 11-20, two collection bags (Nos. 8 and 9) were used to collect expired air samples from minutes 11-15 and 16-20, respectively. Ventilations corresponding to these intervals were obtained as before.

After completion of the 0_2 debt test, the collection bags were carried within 15 min to the Human Performance Laboratory where the expired air samples were measured for oxygen and carbon dioxide content on Beckman OM-11 and LB-2 electronic gas analyzers. Throughout the analysis of the sample bags (0_2 and $C0_2$), the analyzers were calibrated regularly with reference gases, which in turn were analyzed for 0_2 and $C0_2$ content by the Haldane technique. The barometric pressure (mm Hg) and the partial pressure of water vapor (mm Hg) had been determined in the test area so that gas ventilation volumes could be corrected to standardized conditions (STPD). Oxygen consumption calculations were done on an Ollivetti Programma 101 to determine each subject's 0_2 debt. Maximal 0_2 debt was calculated as the sum of recovery $V0_2$ minus baseline $V0_2$ for an equivalent period.

Measurement of Pulmonary Variables

Measurement of VC and $TVC_{0.5}$: Vital capacity and timed vital capacity were measured using the Collins 6 L Timed Vitalometer. The subjects were given several practice trials to minimize learning effects. Vital capacity was then recorded as the highest value from three trials. The investigator administered each test and encouraged maximum effort from each person upon inhalation and exhalation. The subjects were told to exhale as forcefully and rapidly as possible to obtain the highest values. Timed vital capacity was recorded coincident with the VC test, being measured as the largest volume of air exhaled within 0.5 sec, after a maximal inspiration.

Measurement of arm depressor strength: Clarke's (1971) procedure for determining static strength was employed. While lying in a supine position on a strength table, a canvas strap and 1/8 inch cable assembly were fastened to the wrist of the dominant arm. The cable was attached in parallel with the floor, to a wall hook above the subject's head so that the angle between the forearm and cable could be maintained at 90 degrees. The experimenter kept the shoulder flexed at 90 degrees (saggital plane) and the arm flexed at 90 degrees. The upper arm was medially rotated 90 degrees, thereby placing the forearm in a "cross-chest position". A Pacific Scientific Cable Tensiometer was placed on the cable, and subjects were instructed to exert a steady maximal pull for 2 sec in each trial, trying to "depress" the arm. Care was taken by the experimenter to maintain the arm position and stabilize the subject during exertion. The two highest values of three trials were averaged and taken as the strength of the subject.

Measurement of MBC: To determine the MBC, each subject was instructed to place the mouthpiece connected to a Hewlett-Packard

Digital Pneumatach into his mouth. A noseclip was firmly attached to the subject's nose. Each person then inhaled and exhaled for 15 sec at his maximal rate and depth of breathing. The subjects were continuously encouraged during this testing procedure. Two practice trials were given; these were separated by several minutes of rest. Then the results of three experimental trials were recorded from the pneumatach digital display and the highest value of the three trials was accepted.

Measurement of Anthropometric Variables

Measurement of skinfolds: The ability to predict accurately the relative leanness or fatness of both males and females of different ages through the use of various anthropometric measurements has been demonstrated (Wilmore et al. 1970). The method of measurement for skinfolds was to grasp the subject's skinfold between the index finger and thumb, to isolate two layers of skin and the underlying fat, also allowing the fold to follow its natural stress lines as the skin was being lifted (Sinning 1976). All measurements were made on the right side of the body using Harpenden skinfold calipers, which exert a constant pressure of 10 gm/mm. The calipers were applied at a distance of 1 cm from the fingers where the two surfaces of the fold had been grasped. Successive measures were taken at each site until two values which differed by $\pm$ 5% were obtained; the mean of these two values was taken, then recorded as the skinfold thickness. The following sites were used in this investigation: subscapular skinfold, thigh skinfold, triceps skinfold, and abdominal skinfold. The landmarks for locating these sites are described at the end of Chapter I.

Measurement of SMI: Beyond skinfold measures which are described above, it was necessary to measure bitrochanteric diameter, chest depth and chest girth in order to calculate the SMI. For bitrochanteric width, the anthropometer blades were placed in contact with the skin overlying the greatest lateral projections of the trochanters with the subject standing and the feet together. Chest girth was taken by using a cloth tape; measurements were taken from the midpoint between the nipples, 1 cm below the nipples and around the chest cavity with the subject at mid-inspiration in the respiratory cycle. Chest depth was taken by metal calipers; measurements were taken at a site 1 cm below the nipples and 1 cm below the scapula. A somatotype index (SMI) was then estimated by the formula:

$$SMI = \frac{\frac{CD + CG}{BT}}{ASFF}$$

STATISTICAL PROCEDURES

To analyze the data, two statistical techniques were employed. The Pearson product-moment correlation (Roscoe 1969) was used to determine the degree of association between the criterion measure (100 yard butterly performance) and the various independent measures. Subsequently, a step-wise multiple regression (Clarke and Clarke 1972) was used to determine the set of independent measures which would account for the greatest degree of variance in performance.

Throughout the analyses, the .05 level of probability was used.

The data for the two subject groups were treated separately in the analyses. It was hypothesized that if similar relationships were revealed through the separate analyses, then some indirect evidence would be provided that common traits were responsible for differences in performance in both early adolescent and college age male performers.

Chapter IV

RESULTS AND DISCUSSION

INTRODUCTION

The purpose of this study was to determine, for college age and young adolescent swimmers, the relationships between performance in the 100 yard butterfly event and certain independent metabolic, pulmonary and anthropometric measures. A secondary purpose was to determine, for each age group, if some combination of these independent variables could be employed to accurately predict performance times in this swimming event. Data were collected on 11 college age and 10 young adolescent swimmers. Pearson product-moment correlations were done to satisfy the first objective of the study, while separate step-wise multiple regressions were calculated for the two age groups to fulfill the second objective.

For clarity of presentation, this chapter has been organized into three sections. In each section, data are simultaneously presented for both the College Group and the Youth Group. In the first section, descriptive statistics on the criterion performance item and the independent measures are presented. The second section includes the statistically significant ($P \leq .05$) correlations between the criterion measure and the independent variables. The third section contains results of the step-wise multiple linear regressions for the two subject groups, where the independent measures have been used to generate performance prediction equations. In the final section a summary of the results is presented.

DESCRIPTIVE STATISTICS ON PERFORMANCE AND INDEPENDENT MEASURES

Criterion Performance

Table 2 presents means and standard deviations for the 100 yard butterfly swimming performance and for the independent metabolic, pulmonary and anthropometric measures. Data for individual subjects are shown for the College Group and the Youth Group in Appendices A and B, respectively. Inspection of the data in Table 2 indicates that average performance times were substantially faster in the College Group, as might be anticipated. However, the variability in performance within the Youth Group was twice as large as that for the College Group (see SD's in Table 2), indicating that some subjects in the former group were actually faster swimmers than their college counterparts. None of these subjects were exceptional performers when compared to national level competitors within their respective age groups. Outstanding performances for males in the 100 yard butterfly might be as low as 51 sec and 57 sec for college (NCAA) and young adolescent (National Junior AAU) swimmers. These subjects may be judged as average competitive swimmers, when compared to the amateur swimmers in the state of Virginia.

Independent Measures

The independent measure of 0_2 debt max was obtained only for the College Group. It may be recalled that the 0_2 debt max was included in this study as an indicator of the anaerobic demands

TABLE 2

DESCRIPTIVE STATISTICS FOR 100 YARD BUTTERFLY PERFORMANCE AND SELECTED METABOLIC, PULMONARY, AND ANTHROPOMETRIC MEASURES IN COLLEGE GROUP AND YOUTH GROUP SWIMMERS

Variable	College Group		Youth Group	
	Mean	SD	Mean	SD
Butterfly performance (sec)	73.60 ±	7.10	81.70 ±	15.10
O_2 debt max (liters)	2.39 ±	1.13		
Vital capacity (liters)	5.40 ±	0.50	3.80 ±	0.80
Timed vital capacity (% in 0.5 sec)	65.40 ±	7.30	73.70 ±	12.00
Maximal breathing capacity (liters/min)	173.20 ±	22.40	135.20 ±	29.60
Bitrochanter width (cm)	29.30 ±	1.40	25.10 ±	3.70
Sum of skinfold fat (mm)	10.30 ±	2.40	9.70 ±	2.20
Chest depth (cm)	23.20 ±	1.70	19.90 ±	1.60
Chest girth (cm)	38.20 ±	1.60	32.40 ±	2.70
Somatotype index	0.21 ±	0.05	0.21 ±	0.06
Strength (kg)	36.20 ±	6.70	31.20 ±	6.50

associated with the butterfly performance. The capacity to release large amounts of energy within a brief interval (i.e., 50-70 sec) is hypothetically related to the magnitude of the O_2 debt max. Differences in oxygen debt capacity between subjects were examined as possible explanations for corresponding differences in performance. The mean value of 2.39 liters, shown in Table 2, appears quite low when compared to data reported in the literature. Hermansen (1969) reported O_2 debts as high as 10.05 liters in well-trained swimmers, who were measured immediately following exhaustive 100 m and 200 m crawl style swimming. Performance times for Hermansen's subjects were as low as 54.4 sec. A comparison between the present data and those of Hermansen might suggest that the higher anaerobic capacities in his subjects were associated with faster performance times. Alternately, O_2 debts differences in the two studies might also be interpreted as an indication that anaerobic processes are maximally activated in exhaustive efforts lasting closer to 40-50 sec rather than in performances lasting 70-80 sec. Experimentation by Margaria (1964) supports this latter interpretation.

Other possible reasons for low O_2 debt max values in the present subjects are manifold. For example, procedures for measuring O_2 debt are not standardized and differences in the methods for determining baseline and recovery $\dot{V}O_2$ values can have substantial influences on the magnitude of the calculated O_2 debt (Welch et al. 1970). Furthermore, validation studies on the O_2 debt have not been experimentally demonstrated that such procedural differences influence the sensitivity of the O_2 debt test with respect to relationships with phosphorylative or glycolytic capacity of the subject (Welch et al. 1970). Still, other possible explanations for low O_2 debt max values in the present study include low motivation levels in the performers or technical problems with gas collection or gas analyses. However, all subjects indicated that they gave their best effort. With reference to technical factors, this experimenter did not observe that any subject failed to hold his breath between the termination of the swim and connection of the apparatus for the beginning of gas collection. It is possible that unidentified technical error contributed to the particularly low O_2 debt max values (i.e., 1.2 liter) in two subjects who completed the butterfly swim in faster than average times (subjects 3 and 8 in Appendix A).

The high values for the pulmonary measures (VC, $TVC_{0.5}$ and MBC) presented in Table 2 for the College Group are consistent with findings in the literature and support the hypothesis that swimmers tend to possess superior pulmonary function. Astrand and Rodahl (1970) cite mean values in average young men for VC and MBC of 4.2 liters and 140 liters/min, respectively. Corresponding means in the current College Group subjects were 5.4 liters and 173.2 liters/min. One-half second timed vital capacity values are also quite high for these swimmers ($\bar{x}$ = 65.4%), when compared with average adult males whose full one-second timed vital capacity is typically about 80% (Astrand and Rodahl 1970). In all pulmonary measures, the values of the Youth Group subjects were considerably lower than those of the

College Group. These differences probably reflect size and developmental differences in the two groups. It has been documented that VC and pulmonary function vary directly with body size (Astrand and Rodahl 1970; Faulkner 1967). It may be noted that the VC values for the two fastest swimmers in the Youth Group were among the highest for that subject group (see Appendix B). Nevertheless, their VC values were still lower than the mean for the College Group (see Table 2). Based upon these observations, there appears to be little relationship between pulmonary function and brief, intense swimming performance.

The descriptive data on the anthropometric and strength measures (Table 2) are informative to the extent that mean differences between the two groups essentially suggest systematic differences in physical development. In skeletal dimensions (bitrochanteric width, CD and CG) and skinfold fat, the College Group subjects were larger and of the same fat level as compared to the Youth Group subjects. Additionally, the older group expressed higher strength in the arm depressor test but did not differ from the younger group with respect to body proportion, i.e., SMI's were very similar.

STATISTICALLY SIGNIFICANT CORRELATIONS BETWEEN THE CRITERION MEASURE AND THE INDEPENDENT VARIABLES

Correlations were calculated between the criterion measure and all independent measures. These are presented for the College and Youth Groups in Appendices C and D, respectively. Each association was evaluated for possible significance (i.e., a determination of whether the correlation implied a true relationship, significantly different from zero). The r value required for significance was slightly lower in the College Group ($r = 0.60$ @ $P \leq .05$; df = 9) than that required for the Youth Group ($r = 0.63$ @ $P \leq .05$; df = 8), due to the differences in sample size.

For the College Group, examination of the intercorrelations revealed no significant associations between performance and any of the independent variables, with strength showing the highest correlation to performance ($r = 0.56$). The size of the performance vs. strength correlation suggested that, in the College Group, faster performance tended to be modestly related to lower strength levels; the coefficient of determination implied that 31 percent of the variance in performance could be explained by variance in strength. However, taken together, the results suggested that none of the independent measures could account for differences in performance within the College Group.

Inspection of the intercorrelations for independent variables in the College Group (Appendix C) revealed significant associations of ancillary interest to this study. Modest associations between strength and chest circumference ($r = 0.63$) and between maximal breathing capacity and bitrochanter ($r = 0.61$) supported the interpretation that differences in strength and pulmonary function are at least partially dependent on body dimensions.

In the Youth Group, only maximal breathing capacity was found to be significantly correlated with performance ($r = -0.75$), indicating that faster performance times were related to larger MBC values. In contrast to the College Group, it appeared that differences in pulmonary functional capacity (MBC) may account for a considerable degree of variability in brief, exhaustive swimming performance (coefficient of determination = 56 percent). It may be speculated that aerobic processes are more important to performance in this younger group, where event times approached 2 min in slower individuals. Data reviewed by Astrand and Rodahl (1970) indicate up to 50 percent of the energy yield in maximal efforts lasting 2 min may be provided by aerobic mechanisms. In contrast, if the maximal exertion is expended in less time (i.e., as in the somewhat faster College Group performers), then the contribution of aerobic functions sharply diminishes.

Significant intercorrelations between certain independent measures were observed in the Youth Group which reflected interdependencies between body size, strength and pulmonary function (see Appendix D). The interpretation of such associations was described above in the foregoing discussion of intercorrelations for College Group subjects.

MULTIPLE LINEAR REGRESSION EQUATIONS TO PREDICT PERFORMANCE FROM THE INDEPENDENT VARIABLES

Despite a general absence of significant correlations between the criterion performance score on the dependent variables, it was possible that some combination of the latter might account for a substantial degree of variability in performance. Moreover, it was considered that the regression formulas might also be useful in modeling the performance determinants for the 100 yard butterfly event in the two groups.

The step-wise multiple regression procedure systematically isolated those independent variables, in descending order of importance, which could be employed to predict butterfly performance time. The first step isolated the variable which had the highest zero order correlation with performance and assigned both an intercept value and a slope constant to the prediction equation. Simultaneously, the variance shared between that first predictor and the remaining independent measures was parcelled out of the association between those measures and the criterion. This latter step left partial correlations between performance and the remaining independent measures from which the second predictor could be selected. The second step selected, from the matrix of partial correlations, that variable which had the highest relationship with performance. A new intercept and two slope factors were generated for the two predictors in a second equation. Consequently, this step produced a regression formula with two predictors; in a similar way, subsequent steps could be used to construct formulas with three to eight predictors. To evaluate the accuracy of each formula, the multiple correlation and standard error of estimate were examined. If a given formula showed a very high multiple r value, it was interpreted that most of the variance in performance was explained by subject differences in the predictor(s). Concurrently, a small standard error of estimate indicated that the performance could be predicted accurately, within narrow limits. Practical consideration was given to the question of how many variables should be used in a prediction equation not only by examining the multiple r and standard error of estimate, but also by judging the time, equipment and technical skills necessary to satisfy a particular formula.

The results of the regression analyses are presented in Tables 3 and 4. In Table 3, eight formulas are shown for predictions based upon either one, two, three or four predictors. These formulas represent two series of computations. In the first four equations (1-4), 0_2 debt max has been included as a potential independent variable, whereas in the remaining four equations (5-8), 0_2 debt max was excluded. The second approach was used to facilitate direct comparisons with the Youth Group formulas, which did not include 0_2 debt max. Since performance of the College Group subjects varied most as a function of strength, 0_2 debt max was not selected as the first predictor by the step-wise regression technique and consequently formulas 1 and 5 in Table 3 are identical.

The equations in Table 3 indicate that arm depressor strength was the single best predictor of swimming performance in the College Group. With formulas using two predictor variables (equations 2 and 6), 0_2 debt max seemed quite effective, since the multiple 4 value was higher than when a single predictor was used ($r = 0.69$ and 0.72, respectively).

If three or four predictors were used, then the multiple r values

TABLE 3. LINEAR REGRESSION FORMULI FOR PREDICTING 100 YARD BUTTERFLY SWIMMING PERFORMANCE FROM ONE OR MORE INDEPENDENT MEASURES IN COLLEGE GROUP SUBJECTS.

Equation	Equation	Predicted performance (sec)	Regression constant	Estimated partial regression coefficients and predictor variables	Multiple correlation for equation	Standard error of estimate for equation
Formuli including O_2 debt max as a predictor	1	Y =	52.12	+ 0.2692 St*	0.56	± 6.20
	2	Y =	53.18	- 3.0140 XD + 0.3463 St	0.72	± 5.50
	3	Y =	45.32	- 2.647 XD + 42.1392 SMI + 0.3224 St	0.79	± 5.15
	4	Y =	64.46	- 0.9655 XD + 62.6333 SMI ‡ 0.2760 ST - 0.5488 MBC	0.86	± 4.64
Formuli excluding O_2 debt as a predictor	5	Y =	52.12	+ 0.2692 St*	0.56	± 6.20
	6	Y =	42.88	+ 50.3736 SMI + 0.2518 St	0.69	± 5.75
	7	Y =	115.36	+ 76.6722 SMI - 2.7663 Bt + 0.2894 St	0.86	± 4.39
	8	y =	134.09	+ 98.6114 SMI - 2.6689 Bt + 0.2813 St - 4.6859 VC	0.91	± 3.79

Predictor Variables are: Bt = Bitrochanteric width; MBC = Maximal breathing capacity; XD = O_2 debt max; SMI = Somatotype index; St = Strength; and VC = Vital capacity.

*Identical formuli.

TABLE 4. LINEAR REGRESSION FORMULI FOR PREDICTING 100 YARD BUTTERFLY SWIMMING PERFORMANCE FROM ONE OR MORE INDEPENDENT MEASURES IN AGE GROUP SUBJECTS.

Equation	Predicted performance (sec)		Regression constant		Estimated partial regression coefficients and predictor variables	Multiple correlation for equation	Standard error of estimate for equation
1	Y	=	132.83	-	1.5122 MBC	0.75	± 10.60
2	Y	=	123.90	+	0.6624 St - 2.5936 MBC	0.82	± 9.87
3	Y	=	142.21	+	1.0966 St - 8.7983 VC - 3.0234 MBC	0.90	± 8.04
4	Y	=	83.94	+	4.7329 CD + 1.1155 St - 13.9067 VC - 3.5422 MBC	0.95	± 6.27

Predictor Variables are: CD = Chest depth; St = Strength; MBC = Maximal breathing capacity; and VC = Vital capacity.

increased considerably. In the case of formula seven, approximately 74 percent of the variance in swimming performance was accounted for by the SMI, bitrochanter width, and strength, as evidenced by the multiple 4 value of 0.86. Furthermore, equation seven, using only three predictors, had a smaller standard error of estimate ($Sy \cdot x_n = \pm 4.39$) than all other formulas except equation eight. Across all eight equations, these results indicate that strength, the somatotype index, bitrochanteric width, and 0_2 debt max are effective predictors of 100 yard butterfly performance in this particular college age sample of varsity swimmers. It remains to be determined whether these equations would yield accurate predictions in subjects outside this sample.

In general, these results indicated that the fastest swimmers in the College Group tended to have: slightly higher 0_2 debt max values; body proportions which included a large thoracic volume, narrow hips and slightly higher body fatness; and were slightly weaker in shoulder strength than their slower College Group counterparts. A quick, practical index for predicting performance in one of these subjects might include the somatotype index, bitrochanteric width (measured in connection with the SMI) and strength.

The Youth Group formulas in Table 4 suggest that maximal breathing capacity accounted for a considerable degree of the explained variance in performance (r = 0.75). The addition of strength and vital capacity substantially increased the variance explained by the formula (multiple r = 0.90), but did not appreciably increase the precision of the prediction (i.e., compare standard errors of estimate for equations 1 and 3 in Table 4). In this younger group, pulmonary functional capacity seemed relatively more important for prediction of performance than in the college age swimmers. However, the importance of strength was common to both age groups whenever two or more predictors were used. As in the College Group, the Youth Group regression equation suggested that strength levels were inversely related to performance. Subjects weaker in arm depressor strength tended to swim somewhat faster.

Within the Youth Group, a convenient, accurate procedure for prediction of butterfly event performance would utilize equation 3. It is therefore suggested that subjects with high pulmonary functional capacity and lung space and low shoulder strength should be faster swimmers. However, the generalizability of these formulas to swimmerss external to the present sample is not known.

Cross-group comparisons of the regression formulas support the possibility of several generalizations. First, pulmonary function appeared to be relatively more important in explaining differences in performance of pre-adolescent swimmers, whereas body proportions and body composition (SMI) seemed to be uniquely important in college age varsity swimmers. At both ages, competitive swimmers who were faster also tended to be weaker in arm depressor muscle groups.

A substantial degree of variance in performance was not accounted for by the measures examined in this study. As implied by Katch and Henry (1972), the influence of additional factors such as motivation, desire, tolerance to pain or other psychological constructs should be investigated.

Chapter V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The purposes of this study were to determine: (1) for college age and young adolescent male swimmers, the relationship between performance time in the 100 yard competitive butterfly event and selected metabolic, pulmonary and anthropometric measures; and (2) if swimming performance time could be accurately predicted from some combination of the independent variables measured. The independent measures were maximal oxygen debt, vital capacity, one-half second timed vital capacity, maximal breathing capacity, chest depth, chest girth, bitrochanteric width, a somatotype index, and skinfold fat.

Immediately following the 1975 competitive swimming season, 11 VPI & SU varsity swimmers (College Group) and 10 young adolescent club swimmers (Youth Group) from Southwest Virginia participated in this study. Each performed an exhaustive 100 yard butterfly swim in the VPI & SU swimming pool. The 100 yard butterfly was individually administered to the College Group subjects, so that apparent maximal oxygen debts (O_2 debt max) could be measured concurrently with the swim. Starts for the swim were done without a push-off from the side of the pool and times were measured to the nearest 1/10 sec. In contrast, O_2 debt max values were not taken in the Youth Group, and subjects performed the criterion swim in small groups in consecutive lanes of the pool. In both age groups, the importance to the study of maximal swimming performances was emphasized. All subjects reported that they gave their best effort. College Group subjects were tested on the independent variables within the same week in which the butterfly was performed. The O_2 debt max determination, made in connection with the swimming test, was calculated using a 5 min standing-resting VO_2 (oxygen uptake) for the baseline and a 20 min recovery VO_2. Open circuit measurement techniques were employed; all measures were taken in the pool, with the subject standing in 4 feet of water, wearing a low-resistance breathing valve and wearing a noseclip. Immediately after the swim, subjects held their breath until they could be fitted with the metabolic apparatus. Oxygen and carbon dioxide content in expired air samples were analyzed using fast-response electronic instruments. The remaining independent measures were taken in the Human Performance Laboratory under standardized conditions. Average skinfold fat represented the mean of values at the tricep, abdomen, front thigh and subscapular sites. The somatotype index was represented by the formula:

$$SMI = \frac{CD + CG}{\frac{BT}{ASFF}}$$

Youth Group subjects were measured for all independent variables immediately after completing the 100 yard butterfly performance. The O_2 debt max was not taken. All other measures were taken by the same methods used for the College Group.

Data were analyzed for the two groups separately using Pearson product-moment correlation and multiple linear step-wise regression techniques. The .05 level of probability was applied throughout, to the significance of an observed correlation.

Descriptive statistics indicated that average 100 yard butterfly performances were substantially slower in both the College Group ($\bar{x} \pm SD = 73.6 \pm 7.1$ sec) and Youth Group (81.7 ± 15.1 sec) than would be expected in exceptional, national level performers (i.e., 51-57 sec). Nevertheless, there was substantial variability in both groups, particularly in the Youth Group. The fastest individuals in the latter group recorded better times than the average College Group swimmer. With respect to the independent measures, 0_2 debt max values in the College Group were 2.4 ± 1.1 liters. Comparisons between the other independent measures in the two groups indicated that the varsity swimmers tended to have greater lung spaces and lung functional capacities, had greater skeletal size and strength than the young swimmers. However, the two groups were very similar with respect to body proportions and body fat content.

Correlational analyses between the criterion measure (performance) and the independent measures in the College Group failed to disclose any significant relationships, with strength showing the highest non-significant association with performance (r = 0.56). In the Youth Group, maximal breathing capacity (MBC) was found to be significantly related to performance (r = -0.75). No other relationships were statistically significant in this group. However, strength, among the remaining variables, showed the highest correlation with performance (r = -0.47). These analyses indicate that significant variance in performance could not be explained by any of the indices measured in the varsity swimmers, although lower arm depressor strength was somewhat characteristic of the faster performers. In contrast, a considerable degree of variance in performance in the Youth Group was explained by differences in MBC (i.e., 56 percent).

Multiple step-wise regression analyses for the College Group data, using one to four predictors, were done first with and then without the inclusion of the O_2 debt max variable. The step-wise technique resulted in high multiple correlation (r = 0.70) only after at least two predictors were used (O_2 debt max and strength). When O_2 debt max was excluded from the regression, at least three predictors (SMI, bitrochanteric width and strength) were required to achieve a high multiple r. Regression analyses in the Youth Group resulted in a high correlation with performance, when only MBC was used as a predictor. When two (strength and MBC) and three (strength, vital capacity and MBC) were used, the multiple correlation coefficients were raised to 0.82 and 0.90, respectively.

The observed relationships and prediction equations were discussed. Consideration was given to the questions of external generalizability, of isolating performance related traits common to both young adolescent and college varsity swimmers, and of generic differences in factors which might support performance at different age levels of competition.

CONCLUSIONS

Relative to performance time in the competitive butterfly event, the following conclusions were drawn within the scope of this study:

1. The two groups were very similar with respect to body proportions and body fat content;

2. There were no significant relationships between the criterion measure (performance) and the independent measures in the College Group;

3. Although no significant variance was explained by the indices measured in the varsity swimmers, low strength was a characteristic of the faster swimmers;

4. Maximal breathing capacity (MBC) was found to be the only independent measure which significantly related to performance in the Youth Group;

5. Swimmers from both groups who exhibited faster times tend to be weaker in arm depressor muscles;

6. Within the College Group, the step-wise regression technique resulted in high multiple correlations when only two indices were used (O_2 debt and strength);

7. Within the Youth Group, the step-wise regression resulted in high multiple correlations when maximal breathing capacity and strength were utilized (MBC).

RECOMMENDATIONS FOR FURTHER STUDY

As a result of this study, the following recommendations for

1. Further investigation should be made with subjects having had a longer period of conditioning, training and competitive experience during one season;

2. The maximal O_2 debt should be measured in young male swimmers to determine a valid prediction of this variable;

3. Further investigation should be done, utilizing a larger number of subjects from both populations;

4. Further research should be done to determine whether the inclusion of psychological indices, such as pain tolerance and motivation, might increase accuracy of predicting swimming performance;

5. Further research should be done to externally validate the two formulas, trying to predict performance in other samples of youth and college age swimmers from the key predictors.

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APPENDIX A

Descriptive individual data on metabolic, pulmonary and anthropometric measures. (College Group)

Ss	AGE (yr)	HT (cm)	WT (kg)	PFT (sec)	O_2D (L)	SMI	BITC (cm)	CG (cm)	CD (cm)	SSF (mm)	STGH (kg)	$TVC_{0.5}$ (%)	VC (L)	MBC (L/min)
1	20	182.0	83.46	75.0	3.76	0.23	30.7	38.0	20.3	8.2	45.0	65	5.8	172.0
2	20	176.0	85.73	71.4	4.01	0.15	29.6	38.5	22.6	13.5	34.9	71	4.6	164.0
3	20	178.0	70.76	62.3	0.91	0.18	28.8	35.5	22.1	10.8	27.2	67	5.2	154.8
4	21	181.0	81.64	86.6	1.24	0.20	27.4	38.0	23.8	11.0	43.5	72	4.4	124.4
5	19	181.0	77.56	83.6	1.02	0.26	27.9	38.5	23.5	8.2	34.9	61	6.0	168.0
6	21	185.0	92.98	73.5	3.00	0.20	31.6	41.5	24.6	10.2	43.5	75	5.4	196.4
7	21	176.0	77.11	74.1	2.37	0.19	27.9	39.5	22.9	11.3	43.0	53	6.0	186.8
8	19	176.0	68.94	70.8	1.20	0.18	28.7	37.0	21.6	11.3	27.0	62	5.4	163.2
9	18	182.0	84.37	64.8	3.28	0.15	29.0	39.5	23.4	14.0	31.0	75	5.7	198.4
10	18	183.0	70.76	76.5	2.47	0.35	31.5	37.0	23.0	5.5	34.9	60	6.0	202.0
11	19	179.0	71.21	71.0	3.07	0.23	29.1	37.0	27.0	9.2	30.0	58	5.5	178.0

PFT = 100 yard butterfly performance

APPENDIX B

Descriptive individual data on metabolic, pulmonary and anthropometric measures. (Youth Group)

Ss	AGE (yr)	HT (cm)	WT (kg)	PFT (sec)	MBC	VC (L)	$TVC_{0.5}$ (%)	ST	SKFF	CD	CG	BIT	SMI
1	17	165.1	66.22	74.7	162.8	4.8	54	41.2	11.3	20.2	36.5	27.4	0.12
2	13	153.6	40.82	74.7	122.8	2.7	77	24.0	6.5	17.5	29.0	20.7	0.34
3	14	163.8	52.61	79.7	162.8	3.2	90	34.9	9.0	20.4	31.0	20.3	0.28
4	13	182.9	63.95	64.9	162.4	4.4	81	38.5	7.5	20.7	33.5	28.5	0.25
5	14	182.9	78.01	78.5	160.0	4.9	71	33.1	11.5	23.0	35.5	30.3	0.17
6	14	162.6	56.69	78.3	160.0	3.6	86	34.9	13.5	20.9	34.5	20.3	0.20
7	14	172.7	54.43	71.6	122.4	4.0	65	25.3	8.0	19.4	30.5	25.4	0.24
8	13	153.7	44.45	92.2	86.6	3.8	60	22.6	12.0	17.7	28.5	23.4	0.16
9	13	166.4	53.07	104.0	118.8	2.7	85	27.6	9.1	18.8	31.5	26.4	0.20
10	13	168.9	62.59	109.0	86.0	4.1	68	27.2	8.5	20.1	33.5	28.4	0.22

PFT = 100 yard butterfly performance

APPENDIX C

Correlations between 100 yard butterfly swimming performance and the independent variables. (College Group)

Variable	O_2 debt max	SMI	BTC	CG	CD	SKF	ST	$TVC_{0.5}$	VC	MBC
O_2 debt max	-0.24	0.45	0.21	0.19	0.10	0.42	0.56	0.13	0.09	0.36
SMI		-0.13	0.56	0.42	0.06	0.16	0.33	00.22	0.04	0.50
BTC			0.39	-0.24	0.10	0.95*	0.09	-0.46	0.51	0.28
CG				0.21	-0.08	-0.41	0.17	0.21	0.24	0.61
CD					0.20	0.28	0.63	0.36	0.11	0.42
SKF						-0.03	-0.10	-0.03	-0.08	0.16
ST							-0.13	0.48	-0.50	-0.19
$TVC_{0.5}$								0.13	0.00	0.02
VC									-0.57	-0.14
MBC										0.72*

* Significant at $\leq$ .05 level of probability.

APPENDIX D

Correlations between 100 yard butterfly swimming performance and the independent variables. (Youth Group)

Variable	SMI	BIT	CG	CD	SKF	ST	$TVC_{0.5}$	VC	MBC
SMI	-0.15	0.02	-0.21	-0.38	0.04	-0.47	-0.00	-0.39	-0.75
BIT		-0.48	-0.55	-0.32	-0.77	-0.31	0.58	-0.63	-0.06
CG			0.54	0.47	-0.06	0.23	-0.42	0.71*	-0.03
CD				0.81*	0.42	0.81*	-0.12	0.69*	0.58
SKF					0.35	0.67*	0.14	0.67*	0.64
ST						0.26	-0.17	0.33	0.23
$TVC_{0.5}$							0.12	0.50	0.87*
VC								-0.59	0.32
MBC									0.30

* Significant at $\leq$ .05 level of probability.

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THE RELATIONSHIP BETWEEN PERFORMANCE IN THE COMPETITIVE BUTTERFLY STROKE IN MALE SWIMMERS AND SELECTED PHYSIOLOGIC AND ANTHROPOMETRIC FACTORS

by

Theodore A. Manly

(ABSTRACT)

The purpose of this study was to determine the relationship of selected metabolic, pulmonary and anthropometric factors to performance in the 100 yard butterfly swimming event. Physical measurements were taken for 11 varsity swimmers from Virginia Polytechnic Institute and State University and 10 boys aged 13 through 17 who were members of several Blacksburg, Virginia area AAU Youth Group swimming teams.

The performance time for each subject was entered as the dependent variable in a Pearson product correlation coefficient. A step-wise multiple regression computer program was also used. The specific factors of maximal oxygen debt, vital capacity, one-half second timed vital capacity, a special somatotype index, skinfold fat, strength and bitrochanteric were investigated as the independent variables and as possible predictors of performance time. There were no indices measured for the College Group to be of significance at the .05 level of confidence ($P \leq .05$). Maximal breathing capacity was the only predictor in the Youth Group at the .05 level of confidence.

The step-wise multiple regression technique in the College Group

revealed strength, somatotype index, bitrochanteric and 0_2 debt max vital capacity as predictors. The step-wise multiple regression technique was also used with the Youth Group. When four variables were used, then high multiple correlations were found between swimming performance and the prediction equation which utilized the variables of maximal breathing capacity, vital capacity, chest debt and strength.

Since no other variables were found to be of significance in predicting butterfly performance time, it was concluded that covert variables in potential swimmers need further investigation.