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Development of Cardiovascular Fitness in Swimming by the Interval Training Method

Donald LeRoy Cleman
Central Washington University

DEVELOPMENT OF CARDIOVASCULAR FITNESS IN SWIMMING BY THE INTERVAL TRAINING METHOD

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Donald LeRoy Cleman

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Everett A. Irish, COMMITTEE CHAIRMAN

L. E. Reynolds

E. Oakland

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CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

The purpose of this study was to formulate an understanding of the role that cardiovascular fitness plays in competitive swimming. The intent of the author was to evaluate the fitness of the members of the Y.M.C.A. Swim Team, Yakima, Washington. The swim team was tested with a battery of cardiovascular tests, and one strength test purported to measure physical fitness of individuals based on norms. The swimmers were again tested one year from the pre-test, and the data was analyzed to show an increase or decrease in fitness by the addition of interval training mixed with overdistance work. The overdistance workouts had been the method of training up to the time the pre-test was given.

I. THE PROBLEM

Statement of the problem. It was the purpose of this study (1) to evaluate the physical fitness of swimmers; (2) to evaluate the cardiovascular-respiratory responses and strength to a swimming program; and (3) to present various physical fitness test results which were administered to a sampling of boys and girls ranging from ages seven to fifteen. The age-old problem is whether or not a coach is developing in youth the elements of physical fitness which a sport is said to develop. The swimmers were tested before a major change in workouts was introduced, and then were tested again one year later under the "new" type of workout. The major difference in the workouts was the introduction of interval-type training.

Swimming has been said by many authorities to build a symmetrical body, and is an activity which incorporates all the muscle groups of the body. The author will attempt to demonstrate that the above statement is justified, and that swimming also is one of the prime sports for the development of over-all physical fitness.

Importance of the study. Competitive swimming has a definite place in the physical education program, both in colleges and the public schools. The different events and skills characteristic of competitive swimming programs, together with training practices and procedures which are followed in preparation for the sport, are of tremendous value in promoting physical fitness. Continual emphasis upon the importance of these practices tends to build up desirable physical and mental habits in the boys and girls who participate.

The more extensively a facility is used, whether it be a pool, a classroom or other educational area, the more economical our educational plants become. No other facility receives intensive use, seven days a week, year around, by popular demand, than a swimming pool when properly administered. Figure 1 is used to illustrate the above (1:35):

Hours Used Per Week	Swimming Pool	Gymnasium	Auditorium	Cafeteria
September-June	49¼	34	20	13
July-August	45	--	--	--
Approximate total hours used for other activities	15	39	30	30

FIGURE 1

COMPARISON OF UTILIZATION OF FACILITIES

The importance is many-fold. First, seven thousand human beings drown per year. Second, the most logical place for instruction to take place is in the school which all persons are required to attend. Third, drowning ranks second among all causes of accidental death among boys and girls between the ages of five to fourteen years, and third among the fifteen to twenty-four age group. Fourth, the physical fitness factor certainly cannot be overlooked.

It is not the intent of the author to present a complete exposition of the physiology of endurance, but rather to show the effect of swimming on the body, related to cardiovascular endurance and strength.

Research by Salit and Tuttle (2:253) indicates that men who participate in vigorous physical activity are superior to less active individuals with respect to certain circulatory adjustments to exercise.

Vigorous swimming develops all-around strength and endurance, especially when several strokes are used and the distance gradually is increased. Only a few sports, such as strenuous swimming or handball, produce all-around development of strength and endurance. Many popular sports which are classified as carry-over sports, such as archery, bowling and golf, are of little value for endurance or strength (3:33).

Lloyd and Eastwood (4:293) found that the school accident incidence of swimming was only .6 per 1,000 exposures, which is probably as safe as sitting in the classroom.

> These are three significant values which may be derived from swimming: recreational potential, health benefits and the survival or self-preservation aspects. Truly it qualifies as the leading recreational activity from the standpoint of participation. Few physical education activities rate with swimming as a physical developer. To many, swimming represents one of the finest types of exercise utilizing most of the major muscles of the body (4:294).

There are several bases for program organization. In some schools little effort or time has been devoted to planning the program, with the result that it is a hit and miss program, and a large fraction of the students are non-competitive.

The familiar statement, "All roads lead to Rome," indicates the position which the administrators hold in the swimming program.

The author believes that all people should have an opportunity to learn to swim. The most logical place for this to occur, as stated above, is in the school which all are required to attend. More and more school districts have introduced swimming as part of their physical education program, and many others undoubtedly will do so in the future.

Today swimming has begun to take its place with other sports. There still remains a great need, not so much for the development of champions, but for the swimming instruction of all children of this nation and of the world. The author hopes that history may be able to record that this need has been fulfilled.

<u>Limitations of the study</u>. The following are recognized as limitations of the study:

1. The tests were administered at different times

of the day, on three consecutive days.

2. The review of the literature indicates that many tests which purport to measure physical fitness fall short of the goal.

3. During this study, the examiner did not maintain a control group.

4. A percentage of the subjects who were tested on the pre-test are no longer with the swimming team. This will tend to give low reliability on the Mx scores for the post-test.

5. The author realizes the implication of not maintaining a control group before the workouts were changed. The pre-test results were based on norms for age, height and weight; even though some of the subjects had been swimming some months before the pre-test, the results show an above normal strength index and normal or below normal cardiovascular fitness index and endurance index. Your attention is directed to Table I, page 66, in the Appendix. Nevertheless, if the increase or decrease shown by the post-test is significant to rule out maturation and other such factors, the study will show a significant increase above the normal expected rate of improvement by the old conventional method of training, such as long, slow swims and overdistance work.

Continued research in the field of physical fitness is needed in the area of aquatics. It appears from this study that a measuring device is needed to adequately measure cardiovascular endurance in swimming.

The usefulness of measurements of functional or physiological efficiency is seriously limited by inadequate validation. In the field of cardiovascular tests, many measurements of validity have been based on criteria related to medical diagnosis (5:32).

The ability of an organism to continuously maintain a relatively high work out-put without damage may be considered endurance.

General muscular endurance is probably not a determining factor in the pulse-ratio test. Initial strength may be a small positive factor.

II. DEFINITIONS OF TERMS USED

Endurance. The ability to sustain prolonged activity. Swimming is essentially an endurance sport. Coaches and physical educators agree on this point. Any swimming race over fifty yards requires unusual endurance. Swimming in itself is an excellent endurance exercise.[a]

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[a]From remarks by T. K. Cureton at Yakima, Washington, Y.M.C.A. Swim and Physical Fitness Clinic, March, 1962.

Cardiovascular Function. Ability of a muscle to perform depends upon the efficiency of the circulatory system. This term is closely related with the measure of physiological efficiency, organic condition, athletic condition, physical fitness and endurance.

Cardio-Respiratory endurance. The ability of the heart to convey oxygenated blood to the muscles.

Systolic surge. The highest level to which the arterial blood pressure rises following the systolic ejection of blood from the left ventricle, the contraction phase of the heart muscle.

Diastolic pressure. The lowest level to which the arterial blood pressure falls in the interval between successive heart beats.

Dynamometer. An apparatus for testing muscular strength.

Wet spirometer. An apparatus used to measure lung capacity.

Strength index. The strength index is the gross score obtained from the six strength tests, plus lung capacity. The strength index is not a measure of physical fitness, but is a measure of general athletic ability.

Physical fitness index. A score derived from comparing an achieved strength index with a norm based upon the individual sex, weight and age. It is not a measure of basic physical fitness elements.

Heartometer (Cameronometer). Visually and accurately indicates systolic and diastolic blood pressure readings, and pulse beats per second, from the extremeties without the use of a stethoscope.

Drop-off index. Dr. T. K. Cureton developed this index to complete the index. The subject swims all out for one hundred yards, any stroke. The total time is taken, noting the first lap time and last lap time. It is possible to predict the ideal time by the index.

Norms. Standard points of reference to determine judgments or for determining relation. A norm is not necessarily an average (6:55).

III. OVERVIEW OF REMAINDER OF THESIS

Chapter II will contain a review of the literature pertaining to the thesis problem. Chapter III contains the procedures used in this investigation of the thesis problem, including statistical methods used. Chapter IV contains the results of the thesis problem, involving the complete evaluation of data collected. Chapter V contains the summary, conclusions and suggested recommendations found through the evaluation of the thesis. The appendix contains the results in table form of the analysis of significance of the pre-test and post-test involving the test criteria used in the evaluation of the problem.

CHAPTER II

REVIEW OF THE LITERATURE

> The most ideal time for beginning an organized program in swimming, diving and water safety for all pupils, all things considered, is in the upper, elementary or beginning junior high school grades. To provide for the aquatic program, therefore, all junior high schools should be equipped with swimming pools (7:185).

To overlook the past and its impact upon current practices is to ignore knowledge which can give perspective to an evaluation of the present. Therefore, a review of the historical background of the activity is in order.

> The earliest period in which the ability to swim is known to have been acquired and utilized was about 9000 B.C. Pictures portraying the actions of swimmers were inscribed on the rock walls of coves of the Wadi Sori in the Libyan Desert. Thus the beginning (8:3,4).

> A major portion of the credit for enlarging the restricted scope of education must go to Jean Jacques Rousseau. He held that education was the birthright of all and not alone of the few. He proposed that physical education is equally as important as education of the mind. He favored offering to girls the same training given to boys and included swimming in his recommendations. In America, Benjamin Franklin, who had experimented with paddles to be attached to the hands of swimmers, recommended that swimming be a part of the curriculum of schools in the United States (8:11).

In terms of its value to the physical, mental and moral welfare of students, swimming takes a high rank as an activity for great potential educational importance. As a form of all-around exercise, it has far-reaching physiological significance, as well as specific values in the development of strength and endurance, grace and co-ordination.

> Of the activities which had been learned in physical education and used in leisure time by more than 50 students, swimming had the highest percentage of use in present leisure, basketball having the smallest percentage of use in students' leisure (9:295).

There is an increasing acceptance of the need for every child to learn to swim at an early age. These and other factors, including the steadily decreasing costs of swimming pool construction and operation due to technical advances, will undoubtedly result in more participation in swimming in the future.

Whenever it is possible to include swimming in the program it should be done, because it is one of the most valuable activities in physical education.

> The work which Irwin and his co-workers did with swimming at the University of Chicago Laboratory school indicates that swimming instruction can be very successfully carried on throughout the elementary grades (10:91).

William Ralph LaPorte compiled a list of physical education activities together with time allotments, which meets acceptable criteria for physical education programs in the junior high school (11:332):

Sport	Boys (Weeks)	Girls (Weeks)
Aquatics: Swimming, Diving, Life Saving	18	18
Team Sports: Court and Diamond Games: Volleyball, Softball, Basketball	18	12
Gymnastics: Tumbling, Pyramids, Body Mechanics, Apparatus, Relays, Stunts	12	12

FIGURE 2

TIME ALLOTMENTS FOR PHYSICAL EDUCATION ACTIVITIES

LaPorte reports a study by Beckner of the interests of boys in five junior high schools, which are ranked with expert judgment of the all-around value of these activities. It serves to indicate that students' interests follow closely the activities judged most valuable for them by physical education experts (10:98).

The author has elaborated at some length on the importance of a swimming program in the public schools. The author shall now review statistical studies performed in the field of swimming and cardiovascular fitness. It is not the intent to present a complete exposition of the physiology of endurance, but rather to stress the significance of the essential activity on the circulatory-respiratory system.

The body consists of 208 bones held together and moved by 639 muscles. In a 150-pound man, his bones weigh about twenty-one pounds, and the muscles more than sixty pounds, as stated by Steinhaus (3:4). Five or six quarts of blood pumped through hundreds of miles of blood vessels bring oxygen and food to all parts of the body and dispose of wastes. At rest the circulatory system makes about one complete trip per minute. Steinhaus points out that during exercise the circulation may increase nine times, and even at rest the heart handles about thirteen tons of blood in twenty-four hours.

Steinhaus further states that if a muscle is never required to exert itself to more than one-third of its maximum, it will not grow at all, and if less than one-third, it will actually get weaker (3:5).

The heart of a trained athlete beats fifty to sixty times per minute. That of a non-athlete must contract seventy to ninety times to do the same amount of work (3:8). The athlete's heart is not weak because it beats slowly, but rather is stronger, since it is able to perform more work at a slower rate. The heart that beats sixty beats per minute compared to the heart that beats eighty times per minute, over a period of one year, would show that the sixty-beat heart receives eighteen days more rest in a year than the eighty-beat heart.

The normal pulse rate varies considerably according to age, sex, weight, height and individual peculiarities. At birth the rate is 130-140 per minute; with advancing years the rate decreases gradually. Between the ages of nine and ten it falls to ninety; at age twenty it is about seventy-four, and at thirty years of age it is between sixty-six and seventy-six. In the top-functioning athletes, the pulse rate is as low as thirty-six.

Reliability for the Schneider test by the test-re-test method is as high as .86 (12:567) and .89 (13:214). Recent research indicates that the test is related to endurance criteria, however, there is some question as to the degree of reliability. McCloy (14:290) obtained a correlation of .43. In its present state, evidence is not sufficient to justify its use in physical education to evaluate endurance.

Morehouse (15:232-233) states the athlete with great endurance is characterized by a greater respiratory capacity (maximum ventilation) by the ability to withstand greater stress. The Skeletal and Cardiac muscles become stronger and more efficient. At rest the differences between the athlete with a high level of endurance and an individual with poor endurance are negligible.

AGE	SYSTOLIC PRESSURE	DIASTOLIC PRESSURE
10	103	70
15	113	75

FIGURE 3

INFLUENCE OF AGE ON BLOOD PRESSURE

It has been demonstrated that a season of physical training brings about alterations in the response of the heart. It has been shown by Cook and Pembrey, Schneider and others (16:78) that the heart of a physically well-trained man has a slower resting rate, increases less as a result of exercise, and recovers more quickly after exercise than the heart of a healthy, untrained individual.

Crampton Blood Ptosis Test (17:529) was one of the earliest of the cardiovascular tests proposed to evaluate the physical condition of the individual. The results of the test are based on the change in sitting and standing heart rate and systolic blood pressure. This test was used in the analysis of this problem.

McCloy (14:291) points out that the Crampton test seems to reflect changes in sickness, but does not reflect difference in athletic condition.

Rogers Physical Fitness Index Battery contains test items for two basic elements of physical fitness, muscular strength and muscular endurance. It does not contain items which measure the circulatory-respiratory type of endurance so important in prolonged swimming, running and the like. The intercorrelations between the strength of various muscles tested are fairly high as shown by the following Figure 4 (18:183-213):

	Grip Strength	Back Strength	Leg Strength	Arm Strength	Lung Capacity
Grip Strength	--	.61	.65	.61	.52
Back Strength	.61	--	.67	.60	.54
Leg Strength	.65	.67	--	.58	.30
Arm Strength	.61	.60	.58	--	.06
Lung Capacity	.52	.54	.30	.06	--

FIGURE 4

INTERCORRELATIONS BETWEEN STRENGTH TESTS

Specific fitness is defined as fitness for various forms of specific muscular coordination, skills and strength (19:212).

In 1928, Schwartz, Britton and Thompson (20:16), published reliability coefficients of blood-pressure measurements that were so low as to be valueless for accurate testing:

RELIABILITY COEFFICIENTS

r = .90 to .99 - Excellent

r = .80 to .89 - Fair, Good

r = .70 to .79 - Fair, Poor

r = .60 to .69 - Poor

Pulse Rate	.71
Increase after Exercise	.36
Change Two Minutes after Exercise	.10
Systolic Blood Pressure	.65
Diastolic Blood Pressure	.46
Pulse Pressure	.46
Difference Between Standing and Lying	.41
Crampton	.18

What changes have occurred in the swimmer's muscles that permit him to have greater endurance? Counsilman (25:15) states that when laboratory animals, which were run in cages for several hours a day over a period of two months, were examined, it was found that there was an increase in the number of capillaries up to forty percent in active muscle. The increase in the number of capillaries could account to a large extent for the increase in endurance noticed in the animals, and that a similar vascularization occurs in man under the same condition is likely.

The effect of training might be an increase in the diastolic blood pressure. In the case of untrained persons during exhaustive exercise, the blood pressure may drop below the resting level.

> Runners who have been forced to drop from a race due to exhaustion have been found to have blood pressure below their resting levels (26:9).

Another major factor in circulatory-respiratory endurance is as the term implies: respiration efficiency.

Vital lung capacity does increase somewhat with training; the main increase in respiratory efficiency is in the composition of the blood and alveoli of the lungs.

As a result of training, the alveoli in animals have been reported to develop partitions which increase the amount of surface area exposed to the air in the lungs, thereby increasing the rate of oxygen exchange (26:9).

A great deal of discussion and philosophical writing has been presented in an effort to establish objectives in competitive swimming, but little has been done to determine just how various training methods contribute to those objectives. Most coaches will agree that good cardiovascular condition, physical fitness, motor fitness and strength are valuable outcomes of competitive swimming programs.

Davis concludes from his research the following results (27:399-405):

1. General physical fitness, motor fitness, gross strength and swimming time all evidenced highly significant improvements.

2. All test items of the various test batteries, with the exception of grip strength, showed improvement well beyond the .01 level of confidence.

3. The highest significant relationships obtained between swimming time and all variables studied were lung capacity and various gross strength measures.

4. No significant differences were found for cardiovascular condition.

5. Five weeks of training, testing the first week and then testing the last week of thirty male college students who could swim 200 yards, but not varsity material, resulted in the following data obtained by Davis (27:399-405), as shown in Figure 5:

	Mean Before	Mean After	Diff. Between Means	t
Rogers Strength Index	2929.50	3336.10	406.60	10.78
Rogers PFI Test	101.43	114.57	13.14	9.52
Schneider Cardiovascular Test	11.77	12.47	.70	1.03
Navy Standard PFI	49.02	56.95	7.93	10.43
Lung Capacity (Rogers)	311.03	320.00	8.97	3.72
Arm Strength (Rogers)	575.10	700.20	125.10	11.69
Leg Lift (Rogers)	1365.50	1515.67	150.17	4.12
Back Lift (Rogers)	426.33	544.50	118.7	9.12

FIGURE 5

COMPARISON OF ROGERS PHYSICAL FITNESS TEST
WITH SWIMMERS IN THE DAVIS STUDY

The heart rate at birth is more rapid (130-150 times per minute), but gradually decreases in the normal child to 80-100 at three years of age, and 79-90 at twelve years (28:458-459).

There is a slight decrease in pulse rate with age beyond the twelve-year period in boys (29:1-45).

During these pubertal periods the heart rate is slightly faster for girls than boys (30:n.p.).

Systolic, diastolic and pulse pressure are influenced not only by exercise, but also by age, time of day, climate, sleep, height and weight, respiration, digestion, metabolism, drugs, position of the body, and nervous factors. The normal range for young adults is (31:349):

Systolic	110-125 mm. Hg.
Diastolic	65-90 mm. Hg.
Pulse Pressure	35-55 mm. Hg.
Capillary	15-40 mm. Hg.

Presently the general use of cardiovascular tests in physical education is quite limited. However, testing can make a contribution in terms of locating individuals who are extremely low in terms of cardiovascular fitness.

Highly trained swimmers and runners show pulse waves with high amplitude, low dicrotic notch, and strong secondary waves, associated with fast and adequate filling of the heart.

Rifenberick (32:95-98) states that according to evidence resulting from his study, there is no doubt as to the close relationship existing between the physical ratings obtained by the physical capacity test (PFI) and the pulse-ratio test. The lowest correlation of the two tests was found to be .80 and the highest .94. The least proof of comparison available for the time and personnel allotted was as follows:

For 12-18 Year Olds:

Score of 50 or less	Very Poor Condition
Score of 51-60	Poor
Score of 61-70	Fair
Score of 71-80	Good
Score of 81-90	Excellent
Score of 91 or more	Superior

However, Steinhaus (3:8) cites that the trained athlete has a lower resting pulse rate, and the trained heart accelerates less in exercise or when assuming the upright position. Steinhaus cites, also, perfect agreement in the literature that the trained individual has a larger minute volume at rest as compared with the untrained (minute volume = pulse rate x stroke volume).

It is generally considered a sign of fitness if the systolic pressure remains unchanged or rises slightly while changing from lying to the standing position.

In the McCurdy-Larson experiment (38:11), good swimming time is associated with higher standing diastolic pressure, and the moderately higher sitting pulse pressures divided by sitting systolic pressure values:

$$X = \frac{\text{Standing Diastolic Blood Pressure} + \text{Sitting Pulse Pressure}}{\text{Sitting Systolic Blood Pressure}}$$

The statistical equation **including** standing diastolic pressures, breath holding twenty seconds after exercise, vital capacity, and sitting pulse pressure ÷ sitting systolic pressure is valid as an index of the functional condition of circulatory-respiratory system for endurance swimming (38:11), as shown in Figure 6:

STRENGTH TESTS	CARDIOVASCULAR TESTS	
	Schneider	Crampton
Physical Fitness Index	.003	.07
Strength Index	- .03	.07
Arm Strength	- .04	.12
Right Plus Left Grips	.04	.08
Lung Capacity	.02	.06
Leg Strength	- .03	.11
Back Strength	- .01	- .04

FIGURE 6

RELATIONSHIP BETWEEN STRENGTH TESTS AND CARDIOVASCULAR TESTS IN TERMS OF COEFFICIENTS OF CORRELATION

Pulse Wave Measurements. In using the Heartometer, there are several sources of error that must be taken into consideration. One error comes from the tightness of the cuff and another is the amount of air in the cuff. Cureton (23:228) suggests that by standardizing the pressure in the cuff at 80 mm. Hg. air pressure, we would find less variability by adjusting the air pressure in the cuff for each swimmer by increasing or decreasing the pressure until the largest wave on the chart occurred. Usually this happens about 80-90 mm. Hg. cuff pressure. Figure 7, page 27, illustrates the functioning of the normal Heartometer pattern (23:229).

The systolic amplitude has been reported by Cureton (23:232-233) and Henry (22:29) to differentiate athletes and non-athletes.

The resting heart has significant validity as a test of the effect of athletic training (r = .76) (22:29).

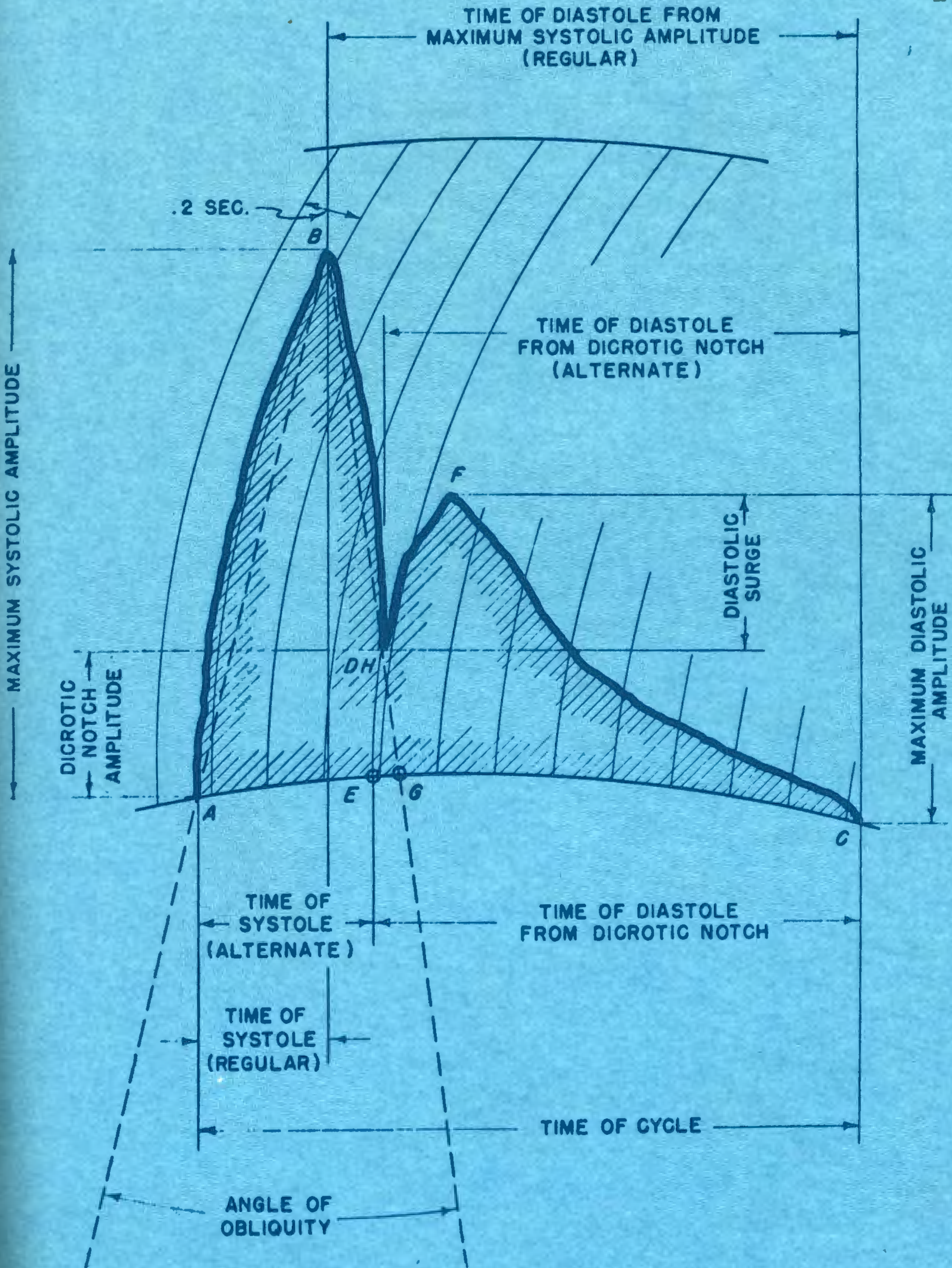


FIGURE 7

NORMAL FUNCTIONING OF THE NORMAL HEARTOMETER PATTERN

> It seems very clear that competitive endurance improves as the raw score of the Barach Index gets smaller. The full meaning of the pulse wave is not completely worked out, but it is clear that it has predictive value for endurance performance. (23:228)

On blood pressures, the Heartometer is more sensitive than the human ear, especially on "soft sound" and "weak pulse." Re-test reliability coefficients are as follows in Figure 8 (21:232-280):

	Same Operator	Two Different Operators
Systolic Pulse Wave Amplitude	.909 (N=97)	.730 (N=71)
Heart Rate	.996 (N=97)	---
Dicrotic Notch Amplitude	.823 (N=97)	.789 (N=71)
Diastolic Surge	.878 (N=48)	.814 (N=71)
Diastolic Pulse Wave Amplitude	.768 (N=48)	.820 (N=71)

FIGURE 8

ANALYSIS OF RELIABILITY OF THE HEARTOMETER READINGS USING SAME OPERATOR AND USING TWO DIFFERENT OPERATORS

The best results taken with the Heartometer were found when the cuff pressure was standardized at 80 mm. Hg. on young, healthy subjects, both male and female.

The Tuttle-Dickinson (35:73) test was based on the ability of the heart to compensate for exercise. The pulse-ratio is defined as the ratio of the pulse rate after exercise to the normal sitting pulse rate. It is found by dividing the total pulse for two minutes immediately following a known amount of exercise by the normal sitting pulse for one minute. It has also been shown that the individual who is physically trained so that he possesses considerable endurance, will be less affected by a given amount of exercise than one in poor condition. It is on these facts that the pulse-ratio has been proven reliable as a measure of physical efficiency, present condition and endurance.

It has been shown by McCloy, Cureton and Van Dolen that lung capacity is of little significance as an element of strength (36:45).

The McCurdy-Larson Efficiency Test is the most significant in indicating the physiological changes due to training and to illness. The McCurdy-Larson Organic Efficiency Test is the most valued test of cardiovascular efficiency according to selected criteria, as stated by Dane (37:98-112).

CHAPTER III

PROCEDURES OF INVESTIGATION

For the purpose of this study, thirty swimmers ranging in age from seven to sixteen and currently members of the Yakima, Washington, Y.M.C.A. Swim Team were used. These swimmers had been actively engaged in a competitive program for the previous three to fourteen months. The water work had consisted of long, slow endurance-type swims, i.e., 2 x 800 yards continuous swim, kicks and pulls (arms alone), and some sprint work. The emphasis was on distance work. The team worked out two hours per day, five days each week, or a total of ten hours per week.

All of the subjects were tested with the following, on the dates indicated:

I. Rogers Physical Capacity Test, August 13-14, 1962.

II. Schneider Cardiovascular Endurance Test, August 13-14, 1962.

III. Barach Energy Index, August 13-14, 1962.

IV. Crampton Blood Ptosis, August 13, 1962.

V. Cureton's Endurance Test in Speed Swimming, July 30,1962.

VI. Cameron Cardiovascular Diagnosis (Heartometer), August 15-16,1962.

I. THE ROGERS PHYSICAL CAPACITY TEST:

A. Classification of test: Strength.

B. Purpose of test: Strength index to classify pupils into homogeneous groups according to strength.

1. Physical Fitness Index: To indicate basic strength as a phase of physical fitness evaluation.

2. Test Items: Right and left grip, back lift, leg lift, push-ups, pull-ups, and lung capacity.

3. Strength Index: Correlates about .85 with an athletic index.

C. Validity based upon face validity: Correlations of .65 with medical judgments.

D. Reliability: Corrected self-correlations of the various test items range from .96 to .99, and for the entire battery are about .94.

E. Test Administration:

1. Equipment: Wet spirometer, hand dynamometer, back and leg dynamometer, parallel bars, bench for girls' modified push-ups.

2. Leadership: One adult leader with assistants to conduct the various specific test items.

F. Scoring Test Results:

1. Specific instructions on scoring are to be found in Clarke text (18:184-209).
2. Add the following measures to arrive at the strength index:
    a. Lung capacity (cubic inches)
    b. Right grip (pounds)
    c. Left grip (pounds)
    d. Back lift (pounds)
    e. Leg lift (pounds)
    f. Arm strength $(\frac{W}{10} + H - 60)\ (C + D)$

G. Limitations of Rogers Physical Capacity Test: The author should mention that muscle soreness resulted from the use of this test. Some hematoma was evident in the forearms and calves of the subjects; this soreness persisted for five days. It would be well to administer this test last in a battery of two or more tests. The time elapsed in administering this test to thirty swimmers was two hours.

II. SCHNEIDER TEST OF CARDIOVASCULAR ENDURANCE:

A. Classification of test: Circulatory-Respiratory.

B. Purpose of test: To assess the general cardiovascular condition at rest and after mild exercise.

C. Validity: Group averages show progressive improvement in the Schneider Index according to rated levels of fitness. Prediction co-efficients for endurance criteria range from .33 to .81.

D. Reliability: Ranges from .68 to .86 in various studies.

E. Objectivity: Routinely is about .80.

F. Test Administration: Carefully described in Cureton's Physical Fitness Workbook (21:115-122).

1. Equipment: Requires stop watch or timer, stethoscope and sphygmomanometer.
2. Leadership: Trained examiner.
3. Group Procedure: This is an individual test, and cannot be given in groups unless an examiner is available for each two or three subjects. Each subject requires about fifteen minutes for careful work.

G. Limitations: Requires careful training of the examiners and most careful standardization of the testing conditions. The Schneider Test was administered to all members of the swimming team. A registered nurse administered the blood pressures with the sphygmomanometer and pulse rate, and did the scoring.

III. BARACH ENERGY INDEX:

A. Classification of test: Cardiovascular.

B. Purpose of test: To assess the general cardiovascular condition and energy of the heart.

C. Validity: Unknown.

D. Reliability: Unknown.

E. Test Administration: Carefully described in Cureton's Physical Fitness Workbook (21:115-122).

1. Equipment: Stop watch and sphygmomanometer.

2. Leadership: Trained examiner.

3. Group Procedure: This is an individual test and cannot be given in groups unless an examiner is available for each two or three subjects. Each subject requires about fifteen minutes for careful work.

F. Limitations: Requires careful training of the examiner, and most careful standardization of testing conditions.

IV. CRAMPTON BLOOD PTOSIS TEST:

A. Classification of test: Cardiovascular.

B. Purpose of test: To assess the general cardiovascular condition of the individual.

C. Validity: Unknown.

D. Reliability: Unknown.

E. Objectivity: Routinely is about N=.80.

F. Test Administration: Carefully described in Clarke's Application of Measurement (18:184-209).

1. Equipment: Required stop watch, stethoscope and sphygmomanometer.

2. Leadership: Trained examiner.

3. Group Procedure: This is an individual test and cannot be given in groups unless an examiner is available for each two or three subjects. Each subject requires about fifteen minutes for careful results.

G. Limitations: Requires careful training of the examiner and careful standardization of testing conditions.

V. CURETON TEST FOR ENDURANCE IN SPEED SWIMMING:

A. Classification of test: Endurance and speed.

B. Purpose of test:

1. To classify swimmers as to endurance.

2. Motivation of the swimmer.

3. To classify the amount of improvement during the season.
4. Test Items: Time of first lap minus time of last lap of 100-yard sprint (any stroke) = drop-off index.
5. Endurance: Correlates .74 with the McCurdy-Larson organic endurance index.

C. Reliability: r = .90 for speed and .77 for endurance.

D. Objectivity: .99.

E. Test Administration: Described in Cureton's Physical Fitness Workbook (21:115-122):

1. Equipment: Stop watch and 60'-70' pool.
2. Leadership: Coach.
3. Group Procedure: This is an individual test, but can be administered quickly. Each subject requires one to two minutes.

F. Limitations: None.

VI. CAMERON CARDIOVASCULAR DIAGNOSIS (HEARTOMETER):

A. Classification of test: Visual appreciation of increase or decrease in heart picture, graphically illustrated. The systolic applitude has been reported by Cureton (21:115-122) and Henry (22:46).

B. Purpose of test: Easy method of obtaining a graphic record of brachial pulse wave, pulse rate, diastolic blood pressure, systolic blood pressure and pulse pressure.

C. Procedures of construction: The Heartometer gives a good correlation between stroke volume and pulse pressure, r = .78 (23:228).

D. Test Administration:

1. Equipment: Cameron Heartometer.
2. Leadership: Trained examiner.
3. Group Procedure: This is an individual test and cannot be given in groups. Each subject requires about fifteen minutes.

E. Scoring of test: The systolic blood pressure, standing and sitting, and diastolic sitting blood pressure, are graphed and calculated. The pulse pressure sitting, standing, and after exercise, are calculated, and the angle of obliquity, diastolic surge.

F. Limitations: The Heartometer standing pulse rate and standing systolic blood pressure were correlated and the results were .809 positive correlation. The instrument is able to predict fitness; this is evident by the many studies presented (23:228) and (24:57), but considerable training in its use is needed to receive reliable results. The Heartometer graph and cardiac cycle appear in the Appendix, page An analysis and comparison of Heartometer readings appears in Chapter IV.

COLLECTION OF DATA

The evaluation of the cardiovascular condition of each swimmer tested in this study was made by comparing his scores with the range of scores in acceptable rating tables for the Schneider Index, Barach Index, Crampton Index, and Cureton Swimming Endurance Index.

The author should mention the importance of enlisting help from the parents of the subjects, without whose help, assistance and encouragement this thesis would not have been possible.

The final administration of the instruments, which embodied several minor changes, was made in a like manner. A total of twenty post-test subjects were utilized; absence of ten subjects between pre-test and post-test is noted. The results of this investigation appear in Chapter IV.

CHAPTER IV

RESULTS AND ANALYSIS OF DATA

<u>Analysis of Rogers Physical Capacity Test</u>. This analysis of data shows no increase between pre- and post-test on the total Physical Fitness Index, but it must be pointed out that the team is well above the normal limits in both pre- and post-tests, indicating above-average individuals with regard to strength capacity in the Y.M.C.A. Swim Team. The analysis shows no relation to interval training in regard to strength increase. One subject (Vincent) increased in strength from a Physical Fitness Index of 101 to 143; this came about primarily by the increase in arm strength. The author expresses the opinion that interval swimming increases arm strength beyond the expected limits of normal maturation. To point out the decline in arm strength of the female subjects, the author should mention that at the culmination of the pre-test, some female subjects experienced severe muscle pain and swelling of the arms (biceps and pectoralis muscles). The team is in competition two days after the post-test, and the author feels that the girls held back on the test in fear of repeating the experience of the pre-test.

The reader's attention is directed to the Appendix,

Table I, page , for the Analysis of Significance of the Rogers Physical Capacity Test. The median Physical Fitness Index score as stated by Clarke and Carter (41:1-3), for a random population is 100; the first and third quartile are 85-115, a standard deviation from the mean of 15. The Y.M.C.A. Swim Team had a mean of 128, which is two standard deviations above the mean, lacking two numbers. The girls scored 148, which is three standard deviations above the mean. The author re-states the opinion that interval training had little effect on an increase in strength, as shown by the analysis of data.

Analysis of Schneider Cardiovascular Test. The Schneider test resulted from work during World War I with 2,000 aviators. Reliability (test-retest) has been determined by McFarland and Huddleson (r = .89), and Cureton (r = .86) (12:497-599).

Among the larger correlations found with the Schneider test were:

Mile Run: r = .650

Two-Mile Run: r = .631

1000-yard time minus (10x100 yd. time): r = .551

Three and one-half Mile Steeplechase: r = .500

Composite of four endurance runs: r = .806

Breathholding time after exercise for five minutes: r = .622 (12:497-599).

The Schneider test (42:1507) is a more comprehensive cardiovascular test. Here again the pulse rate sitting and standing, and after exercise and at rest, are taken, along with sitting systole and standing systole.

The Schneider test was administered to thirty members on pre-test and twenty on post-test. The analysis shows a decrease in sitting pulse for boys, indicating agreement with Cureton and Clarke. The Energy Index shows improvement of forty percent between pre- and post-test, indicating an increase in cardiovascular fitness. The reader's attention is directed to the Appendix, Table II, page 68, for the Analysis of Significance of the Schneider Test. The norms are well within the range of above-average cardiovascular fitness, shown by the Y.M.C.A. Swim Team. A score of nine indicates a deficiency and a score of eighteen is perfect.

Analysis of the Barach Energy Index. Another early cardiovascular test is the Barach Energy Index (43:525). This test purports to measure the energy expended by the heart. The systole gives the energy factor in the peripheral resistance; pulse rate indicates the number of systoles and diastoles occurring in a minute. All measures are obtained with the subject in a sitting position. Scoring for the Barach Index is as follows:

$$\text{Energy Index} = \frac{\text{Pulse Rate (Systolic Pressure + Diastolic)}}{100}$$

According to Barach's early studies, a robust person will have an energy index varying from 110-160. The upper limit of fitness is considered to be 200; the lower limit 90. Those scoring above 200 may be hypertensed; those below 90 may be hypotensed. With 200 men, Cureton's mean energy index was 141; the range was 70 to 220 (43:526),(33:n.p.).

Exercise, when continued for a long period of time, is good for the heart. The heart is a muscle, and muscles increase in size if worked to capacity. Trained hearts are larger, stronger, slower and steadier. The old-fashioned idea that exercise injures the heart is erroneous; there was found no scientific evidence of this in medical research (43:525). It is true, however, that a heart already damaged can be further damaged by abuse of strenuous exercise.

The data showed an agreement with the literature; the Y.M.C.A. Swim Team showed an increase in the Index of 117-137, clearly showing an increase in cardiovascular fitness. The reader's attention is directed to the Appendix, Table III, page 69.

Analysis of the Crampton Blood Ptosis Test. The Crampton Test (17:529) was one of the earliest of the cardiovascular tests proposed to evaluate general condition of the individual. The principle of the test is based on changes in heart rate and systolic pressure upon standing from reclining position. Directions are as follows:

1. The subject sits until his pulse is constant. A constant rate is reached when two repeated 15-second counts are the same.

2. While sitting, the pulse count and sitting systolic pressures are taken and recorded.

3. The subject stands and the pulse and systolic pressures are taken and recorded.

Crampton maintains that most people in good condition will score between 60-100.

M for Swim Team - 74 pre-test; 81 post-test

Range was 30-100 pre-test; 60-95 post-test

Grade A - 90% or over

Grade B - 80-90%

Grade C - 70-80%

Crampton found that an increase in heart rate from sitting to standing results in an increase of heart rate from 0-44. Also, variation in the systolic blood pressure ranged from -10 mm. Hg. to +10 mm. Hg.

Crampton indicated a rise of 8-10 mm. Hg. in systolic pressure in athletic individuals upon standing. The systolic pressure fails to rise in poor-conditioned individuals; in fact, it may fall as much as 10 mm. Hg. The pulse rates for subjects in good condition failed to increase on standing, whereas in less fit individuals it increased as much as 44 beats per second.

The Crampton Blood Ptosis Test was administered to ten boys and ten girls, with a resulting increase of seventy percent between the pre- and post-test. The reader's attention is directed to the Appendix, Table IV, page 70, for an analysis of results. The results indicate an increase in cardiovascular efficiency between pre- and post-test.

Analysis of the Cureton Endurance Test in Speed Swimming. Cureton, seeking an endurance index for swimmers, used the slowing up in seconds, computing cumulatively from lap to lap when a distance of one hundred yards is swum as hard as possible, from start to finish. This index is called the "drop-off" (39:126).

Cureton's test for endurance in speed swimming correlates .75 with the McCurdy-Larson test of organic efficiency. Reliability coefficients are .90 for speed and .77 for endurance. Strength seems to be reflected in the short speed test, and endurance is shown by a drop-off in speed over a longer distance. The reliability coefficient of this drop-off factor is .77, which is not very high. Using a table of intercorrelations, Cureton found four factors. Test items were combined by regression technique to determine the tests best able to predict their respective criteria; a composite criteria of all four factors was also established. The multiple correlations with the factors are listed below (34:106-112):

I. Lateral Muscular Endurance: r = .838

II. Limb Locomotive Muscular Endurance: r = .846

III. Arm Extension Endurance: r = .733

IV. Running Endurance: r = .760

V. All-Around Muscular Endurance A: r = .893

VI. All-Around Muscular Endurance B: r = .876

VII. All-Around Muscular Endurance C: r = .885

VIII. All-Around Muscular Endurance D: r = .924

The analysis of data clearly shows the development of the endurance factor so necessary in competitive swimming. The improvement between subjects shows an increase of eighty-eight percent from pre-test to post-test in relation to time in swimming 100 yards and the drop-off index. The reader's attention is directed to Figure 9, page 49; notice Subject Vincent's pre- and post-test Cureton drop-off index. Table V, page 71, in the Appendix, also shows an analysis of this data in tabular form.

Analysis of Cameron Cardiovascular Diagnosis (Heartometer). Figure 7, page 27, is typical of a normal cardiac cycle with the use of the Cameron Heartometer. It represents the aortic rebound or dicrotic notch accentuation at F. The physiological basis for such accentuation is probably due to a stiffening of the "aortic ring" (40:74).

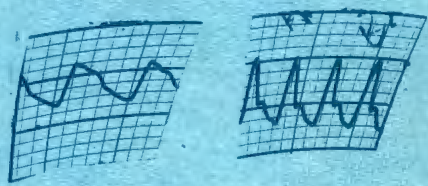
An accentuation of the aortic notch is generally present in athletes, even those under twenty years of age. It is well known that the heart in extreme exercise has to work harder and circulate from five to six times the normal amount of blood. Therefore, due to this increased work, the musculature of the heart, including the ring of the aortic valve, is under greater tension and there is generally present in the heartometer tracing a considerable aortic rebound. This may be present many years after the subject has ceased athletic activity.

The results obtained with the Cameron Heartometer tracings agree with other studies, (23; 27 and 40). It is significant to note that the systolic surge increased in height (M = 6 cm.; R 2-8 cm.), which indicates the development of the heart muscle to quickly and forcefully eject its contents to the surrounding periphery. The analysis of the dicrotic notch indicates the development of elasticity of the arterial walls, which corroborates the findings of Cureton, Davis, et al, that the dicrotic notch is present in conditioned athletes and very rarely seen in non-conditioned athletes.

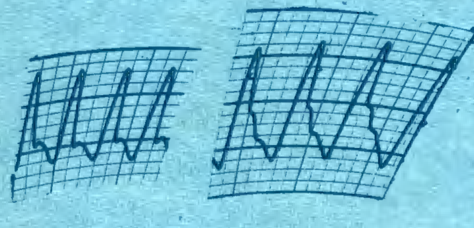
The reader's attention is again directed to Figure 9, page 49. In the analysis of the findings, it is important to note the pattern of the pre-test as compared with the post-test. The pattern shows a definite increase in the number of cm. during systole, the beginning of a dicrotic notch in some, and a definite dicrotic notch in the last case (Subject S. Sutliff). The analysis of the data clearly shows an increase in cardiovascular efficiency from the pre-test to the post-test, indicating that interval training imposed the needed stimulant for the development of a typical graphic picture showing cardiovascular conditioning. The author wishes to re-state that five of the pictured subjects in Figure 9 had been participating in the competitive program one to one and one-half years before the pre-test was administered. The comparison of Subject Vincent with the remaining subjects' patterns clearly shows the impact which interval training placed on the development of cardiovascular fitness. It is clear that the fitness development under the overdistance type of workout was far inferior in developing systolic surge amplitude and the dicrotic notch, which are the outcomes hoped for in correct cardiovascular conditioning.

The reader's attention is also directed to Figure 10 on page 50; this figure illustrates the development of the typical Heartometer graph of a conditioned heart. Notice the amplitude of the systolic surge, the amplitude of the dicrotic notch, and the pulse rate at sitting, standing and after exercise. This subject has been swimming competitively for three and one-half years. The graphic tracings during exercise clearly show the ability of this subject's heart to respond to exercise very quickly.

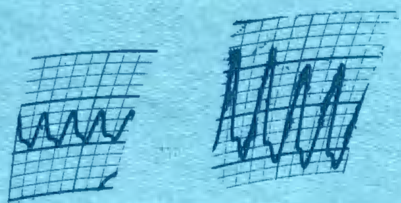
The author is convinced, as shown by the analysis of data in the Appendix, Tables VI and VII, pages 72 and 73, that the impact of interval training has had a tremendous effect on the cardiovascular fitness of the Y.M.C.A. swim team.



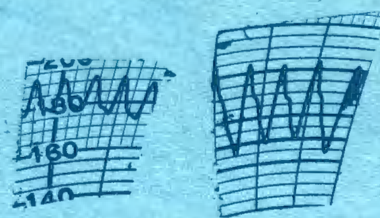
(Male)
VINCENT: Pre-Test - Age 8
Post-Test- Age 9
CURETON DROP-OFF INDEX:
Pre-Test :10.3 Post-Test :3.1
TIME 100 YD. SPRINT CRAWL:
Pre - 1:47.6 Post - 1:13.8



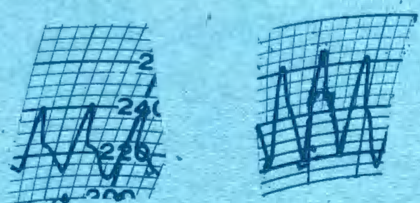
(Female)
BELAIR: Pre-Test - Age 12
Post-Test- Age 13
CURETON DROP-OFF INDEX:
Pre-Test :4.6 Post-Test :2.5
TIME 100 YD. SPRINT CRAWL:
Pre - 1:11.6 Post - 1:06.2



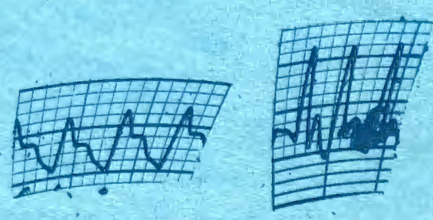
(Female)
STEVENSON: Pre-Test - Age 14
Post-Test- Age 15
TIME 100 YD. SPRINT BREAST:
Pre - 1:32.0 Post - 1:26.6



(Female)
MILLER: Pre-Test - Age 12
Post-Test- Age 13
CURETON DROP-OFF INDEX:
Pre-Test :8.6 Post-Test :5.0
TIME 100 YD. SPRINT CRAWL:
Pre - 1:31.0 Post - 1:21.0



(Male)
P. SUTLIFF: Pre-Test - Age 11
Post-Test- Age 12



(Male)
S. SUTLIFF: Pre-Test - Age 13
Post-Test- Age 14
CURETON DROP-OFF INDEX:
Pre-Test :4.6 Post-Test :2.7
TIME 100 YD. SPRINT CRAWL:
Pre - 1:07.6 Post - 1:02.6

FIGURE 9
GRAPHIC ANALYSIS OF THE CAMERON HEARTOMETER TRACINGS
INDICATING IMPROVEMENT BETWEEN PRE- AND POST-TESTS

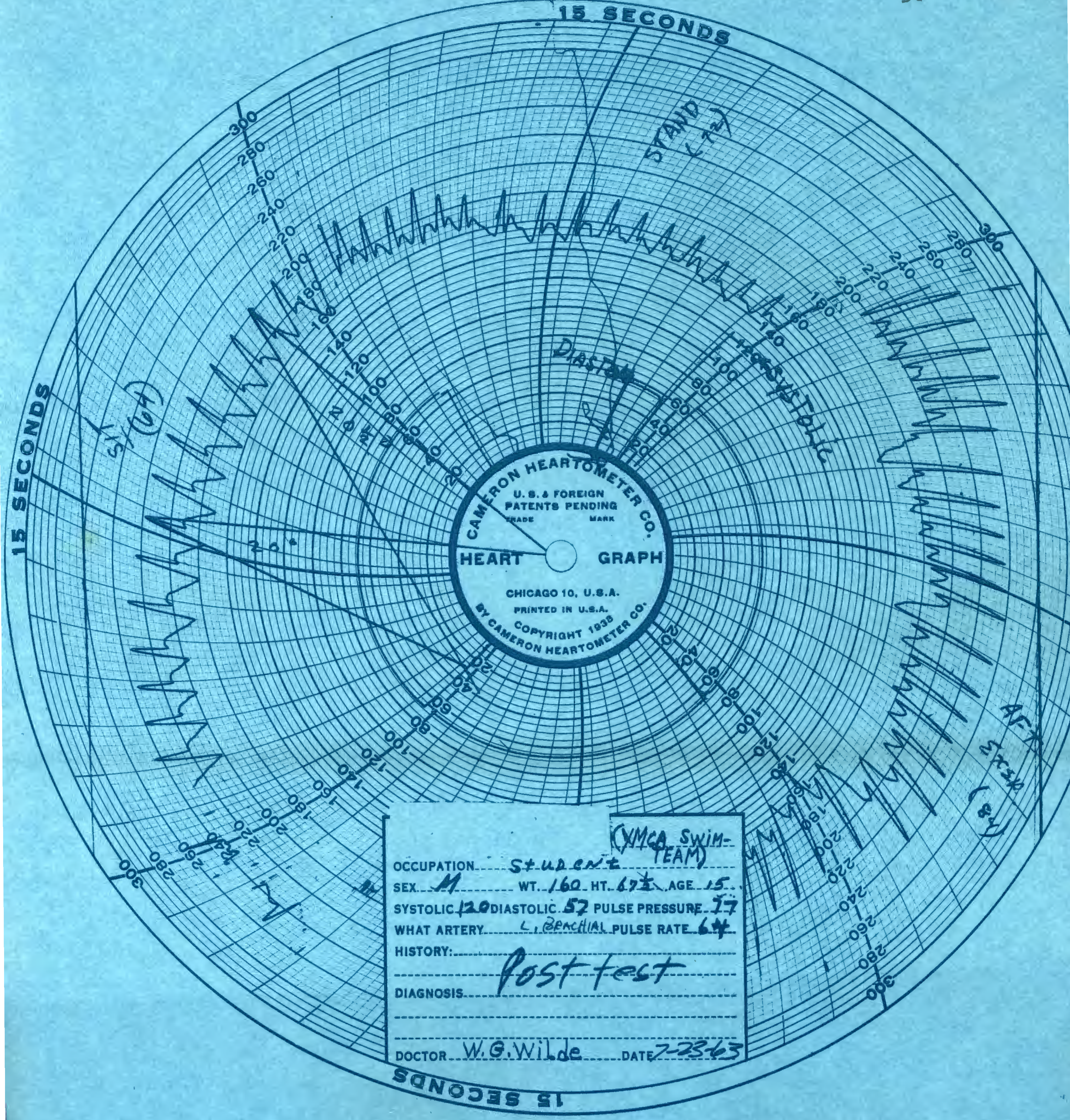


FIGURE 10
ANALYSIS OBTAINED BY THE CAMERON HEARTOMETER TRACING INDICATING SYSTOLIC AND DIASTOLIC PRESSURES, PULSE RATE, SYSTOLIC AMPLITUDE AND DICROTIC NOTCH

The author performed nineteen correlations with items of blood pressure and pulse rates, and cardiovascular tests against the Rogers Physical Fitness Index Test. The results are as follows:

An r of .95 was obtained between sitting pulse rate taken with Heartometer and Cureton endurance sitting pulse rate.

An r of .8797 was obtained between Cureton endurance standing pulse rate and Heartometer standing pulse rate.

An r of .836 was obtained between the Barach Energy Index and Rogers Physical Fitness Index.

An r of .809 was obtained between standing pulse rate Heartometer and standing systolic blood pressure (Heartometer).

An r of .777 was obtained between the sitting pulse rate (Heartometer) and standing pulse pressure (Heartometer).

An r of .452 was obtained between sitting pulse (Heartometer) and Rogers Physical Fitness Index.

An r of .451 was obtained between the standing pulse rate (cuff) and standing pulse rate (Heartometer).

An r of .4496 was obtained between standing pulse rate with the Heartometer against standing pulse rate taken manually.

An r of .394 was obtained between Schneider sitting pulse rate and Cureton endurance sitting pulse rate taken manually.

An r of .3935 was obtained between supine pulse rate and sitting pulse rate Cureton endurance.

An r of .3488 was obtained between standing pulse and standing systolic blood pressure with a cuff.

An r of .2636 was obtained between sitting pulse Heartometer with supine pulse taken manually.

An r of .2568 was obtained between sitting pulse rate and standing systolic blood pressure with a cuff.

An r of .198 was obtained between Barach energy index and Crampton blood ptosis.

An r of .185 was obtained between the Rogers physical fitness index and standing systolic blood pressure (cuff).

An r of .170 was obtained between the Rogers physical fitness index and the sitting pulse rate (cuff).

An r of .160 was obtained between standing systolic blood pressure (Heartometer) and Rogers physical fitness index.

An r of .1516 was obtained between Schneider standing pulse rate and Cureton endurance standing pulse rate.

An r of .1250 was obtained between standing systolic blood pressure with the Heartometer and standing systolic blood pressure with a cuff.

The results are significant between the Barach Energy Index and Rogers Physical Fitness Index, with a correlation of .836. This indicates there is a close relationship between cardiovascular fitness and strength, or possibly strength and cardiovascular fitness. The author believes that the old proverb, "Which comes first, the chicken or the egg," is still a debatable question concerning strength with its relationship to cardio-vascular fitness. A closer relationship between blood pressures taken with the Heartometer and blood pressures taken with the sphygmomanometer was expected, but a correlation of r = .125 was found, indicating a poor reliability of one method.

CHAPTER V

SUMMARY

The results have clearly shown an increase in (1) endurance, (2) strength, and (3) cardiac function shown graphically by the Heartometer.

In order to reiterate this point -- interval vs. overdistance training related to cardiovascular fitness -- let me sight one case. Test Subject Vincent became a member of the swim team one week before the pre-test. His Rogers Physical Fitness Index on pre-test was 101, and post-test was 143; the Barach Test was 83 pre-test, and 64 post-test; the Schneider Test was 11 on pre-test, and 15 on post-test; and the Cureton Swimming Endurance Test, drop-off index, was 10.3 on pre-test, and 3.1 on post-test. Vincent's time for the 100-yard crawl on pre-test was 1:47.6, and on post-test was 1:13.6. This boy did not develop bad habits which are usually seen in swimmers who train with overdistance work. He was subjected only to interval training with very little overdistance work, and was able to maintain the mental attitude needed to endure the interval training method. The other members had been accustomed to overdistance work and bad habits developed, which glared like a lighthouse at midnight, during interval training. Subject Vincent has made greater improvement in a shorter time than the members who have been swimming two years, as compared to his one year.

This would indicate that overdistance-type workouts lead to normal physical development, as indicated by the pre-test, and that interval training (under-distance) points the way for accelerated increase in improvement in a shorter period of time, leading to an increase in cardiovascular and strength fitness of the individual, as shown by the results of the post-tests.

The individuals tested on the Rogers Physical Fitness Test did not show a significant increase in strength, but rather failed to increase in strength at all.

CONCLUSIONS

The purpose of the present study was to determine whether the cardiovascular endurance factor was contributed to by competitive swimming. The test group consisted of thirty boys and girls currently participating in the competitive swimming program at the Y.M.C.A., Yakima, Washington. The ages were $\bar{R}$ = 7-16 Years. It is interesting to note the significance in improvement between subjects. The data shows a gross change in cardiovascular and endurance indexes, and no increase in strength as a team.

1. Table II revealed that an increase of Team Mx 11 was found in cardiovascular endurance, as illustrated by the Schneider test.

2. Table I revealed a decrease in strength of six percent, as demonstrated by the Rogers Physical Capacity Test. However, this is still three standard deviations above the mean.

3. An increase in systolic amplitude was quite evident between pre-test (6 cm.) and post-test (11 cm.), indicating myocardia efficiency increase through interval training as compared with the pre-test.

4. The most striking increase was shown in the Swimming Endurance Test by T. K. Cureton (34:106-112). The percentile rankings of the subjects increased from 72 on pre-test to 83 on post-test. The data is located in Appendix, Table V; the significant increase can only be contributed to interval-type training.

5. The pulse rate sitting and standing became lower, because under the overdistance-type workout, this degree of increase was not achieved, indicating greater increase in cardiovascular efficiency. The data is located in Appendix, Table VI.

6. The blood pressure reading, systolic, showed an ever-increasing improvement from pre-test mm. Hg. to post-test mm. Hg.

7. The Cameron Heartometer readings of blood pressure and pulse rate correlated r = .1250 with blood pressures taken with the sphygmomanometer, indicating an unreliability in one method.

As mentioned earlier, the question of improvement in swimming vs. improvement in cardiovascular endurance is a debatable question. A correlation of r = .8797 was found between Cureton's endurance test and the Rogers strength test. It is possible that strength plays a big role in swimming ability.

However, the endurance as measured by the swimming endurance test by Cureton indicates an increase in endurance of some kind, i.e., if improvement be cardio-vascular strength or general fitness of the individuals, is a question not answered by this investigation, although this study indicates conclusively that a significant increase in swimming ability (speed) has striking significance between pre- and post-test. The normal rate of improvement was surpassed by sixty percent, indicating that the addition of interval pace and underdistance work is far superior to overdistance work.

RECOMMENDATIONS

The following recommendations are an outcome of this investigation and its results:

1. A convenient test to measure cardiovascular endurance for swimmers should be devised.

2. Further research should be begun on developing norms for age group swimmers, related to cardiovascular endurance. The norms should be equated by age, height and weight.

The growth of age group swimming throughout the United States has shown the need for practical tests to determine the effect of the training sessions upon physical fitness of the individual swimmer.

B I B L I O G R A P H Y

BIBLIOGRAPHY

1. Jackson, Robert C. "An Analysis of Swimming in the Educational Program," Swimming Pool Age, New York: Bethlehem Central High School, February, 1956, p. 35.

2. Salit, Elisabeth Powell, and W. W. Tuttle. "The Validity of Heart Rate and Blood Pressure Determinations as Measures of Physical Fitness," Research Quarterly, Vol. XV, No. 3, October, 1944, p. 253.

3. Steinhaus, A. H. How to Keep Fit and Like It. Second Edition. Chicago: The Dartnell Corp., 1957.

4. Shaw, John H., Carl A. Troester, Jr., and Milton A. Gabrielsen. Individual Sports. Philadelphia: W. B. Saunders Co., 1956.

5. Frank, Henry M., and Frank L. Kleeberger. "The Validity of the Pulse-Ratio Test of Cardiac Efficiency," Research Quarterly, Vol. IX, No. 1, March, 1938, p. 32.

6. Rogers, Frederick Rand. Fundamental Administrative Measures in Physical Education. Newton, Mass: The Pleiades Co., 1932.

7. Scott, Harry A., and Richard Westkaemper. From Program to Facilities in Physical Education. New York: Harper & Bros., 1958.

8. Torney, John A., Jr. Swimming. New York: McGraw-Hill Book Co., Inc., 1950.

9. Savage, Howard J. "The Carnegie Foundation for the Advancement of Teaching," American College of Athletics Bulletin No. 23, 1929, p. 295.

10. Voltmer, Edward F., and Arthur A. Esslinger. The Organization and Administration of Physical Education. New York: Appleton-Century-Crofts, Inc., 1949.

11. LaPorte, W. R. The Physical Education Curriculum. Fifth Edition. Los Angeles: The University of Southern California Press, 1951.

12. McFarland, R. A., and J. H. Huddleston. "Neuro-circulatory Reactions in Psychoneuroses Studied by Schneider Method," American Journal of Psychiatry, Vol. LXXXXIII, No. 3, 1936, pp. 497-599.

13. Cureton, Thomas K., et al. "Endurance of Young Men," Washington Society for Research in Child Development, Vol. X, No. 1, 1945, p. 214.

14. McCloy, Charles H., and Norma D. Young. Tests and Measurements in Health and Physical Education. New York: Appleton-Century-Crofts, Inc., 1954.

15. Morehouse, Laurence E., and Augustus T. Miller. Physiology of Exercise. St. Louis: The C. V. Mosby Co., 1953.

16. Tuttle, W. W., and F. H. Walker. "The Effect of a Season of Training and Competition on the Response of the Hearts of High School Boys," Research Quarterly, Vol. XI, No. 4, December, 1940, p. 78.

17. Crampton, C. Ward. "A Test of Condition: Preliminary Report," Medical News, Vol. LXXXVii, September, 1905, p. 529.

18. Clarke, H. Harrison. Application of Measurement. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960.

19. Gallagher, J. R., and L. Brouha. "Yale Journal of Biology and Medicine," Research Quarterly, Vol. XV, 1943.

20. Schwartz, L., R.H. Britton and L. R. Thompson. "Studies in Physical Development and Posture," Public Health Bulletin No. 179, Washington: United States Public Health Service, 1928, p. 16.

21. Cureton, T. K. Physical Fitness Appraisal and Guidance. Third Edition. St. Louis: C. V. Mosby Co., 1947.

22. Henry, F. M. "Influence of Athletic Training on the Resting Cardiovascular System," Research Quarterly, Vol. XXV, No. 28,1954, pp. 29-46.

23. Cureton, T. K. Physical Fitness of Champion Athletes. Urbana, Illinois: The University of Illinois Press, 1951.

24. Michael, Ernest D., and Arthur J. Gallon. "Pulse Wave and Blood Pressure Changes Occurring During a Physical Training Program," Research Quarterly, Vol. XXXI, No. 1, March, 1960, p. 57.

25. Counsilman, James. "The Physiological Effects of Training," The Athletic Journal, New York: 1955, p.15.

26. McCloy, Charles H. "An Outline of Physiology of Exercise," State University of Iowa, 1947, p. 9. (Mimeographed.)

27. Davis,Jack F. "Effects of Training and Conditioning for Middle Distance Swimming Upon Various Physical Measures," Research Quarterly, Vol. XXX, No. 4, December, 1959, pp. 399-405.

28. Larson, Leonard A. "Cardiovascular-Respiration Function in Relation to Physical Fitness," Research Quarterly, Vol. XII, No. 2, May, 1941, pp. 458-459.

29. Seham, M., and G. Egerer. "A Study of Normal Children of School Age," American Journal of Diseases of Children, Vol. XXV, 1923, pp. 1-45.

30. Ferguson, W. "A Normative Study of McCurdy-Larson Organic Efficiency Test for Adolescent Boys (Ages 13½ to 17½ Inclusive," Springfield College: Master Thesis, July, 1939. Unpublished.

31. Lea and Febiger. The Physiology of Exercise. Philadelphia, 1939.

32. Rifenberick, Robert H. "A Comparison of Physical Fitness Ratings as Determined by the Pulse Ratio Tests and Rogers Test of Physical Fitness," Research Quarterly, Vol. XIII, No. 1, March, 1942, pp. 95-98.

33. Hunsicker, Paul A. "A Validation of Cardiovascular Test by Cardiac Output Measurements," Doctor of Philosophy Dissertation, University of Illinois, 1950. Unpublished.

34. Cureton, T. K. "A Test for Endurance in Speed Swimming," Supp. to Research Quarterly, American Physical Education Association, Vol. XI, No. 2, May, 1935, pp. 106-112.

35. Tuttle, W. W., and Russell Dickinson. "A Simplification of the Pulse-Ratio Technique for Rating Physical Education and Present Condition," Research Quarterly, Vol. IX, No. 2, May, 1938, p. 73.

36. Cozens, Fred W. "Strength Tests as a Measure of General Athletic Ability in College Men," Research Quarterly, Vol. XI, No. 1, March, 1940, p. 45.

37. Dane, C. W. "A Study of Circulatory-Respiratory Changes as Indicated by the McCurdy-Larson Organic Efficiency Test in Relation to Physiological Age," Research Quarterly, Vol. XV, No. 2, May, 1944, pp. 98-112.

38. McCurdy, J. H. and L. A. Larson. "The Validity of Circulatory-Respiratory Measures as an Index of Endurance in Conditioning in Swimming," Research Quarterly, Vol. XI, No. 3, October, 1940, p. 11.

39. Henry, Franklin, and Daniel Farmer. "Conditioning Ratings and Endurance Measures," Research Quarterly, Vol. XX, No. 2, May, 1949, p. 126.

40. Cameron, Will J., and Alex S. Cameron. Visual and Graphic Methods of Cardiovascular Diagnosis. Cameron Heartometer Company: 1954.

41. Clarke, H. Harrison. Application of Measurements to Health and Physical Education. Prentice-Hall: 1959, pp. 1-3.

42. Schneider, E. C. "A Cardiovascular Rating as a Measure of Physical Fitness and Efficiency," Journal of the American Medical Association, Vol. LXXIV, No. 5, May 29,1920, p. 1507.

43. Barach, J. H. "The Energy Index," *Journal of American Medical Association*, Vol. LXII, February 14, 1914, pp. 525-526.

A P P E N D I X

TABLE I

ANALYSIS OF SIGNIFICANCE OF ROGERS PHYSICAL INDEX-CAPACITY TEST BETWEEN PRE- AND POST-TEST

		BOYS[a]		GIRLS[b]		TEAM[c]	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
AGE (Years)	PRE-	8-15	11	7-16	12.6	7-16	11.8
	POST-	9-16	12.4	8-15	11.4	8-16	11.9
WEIGHT (Pounds)	PRE-	64-144	99	49-134	95	49-144	97
	POST-	68-162	103	51-126	85	51-162	94
HEIGHT (Inches)	PRE-	51-67	56	49-68	59	49-68	57.5
	POST-	53-69	62	49-69	58	49-69	60
PULL-UP	PRE-	0-10	6	10-140	52	0-140	29
	POST-	1-10	7	14-85	42	1-85	25
PUSH-UP	PRE-	0-18	9	4-57	22	0-22	15.5
	POST-	1-28	13	11-43	28	1-43	20
ARM STRENGTH (Pounds)	PRE-	9-523	173	249-1957	763	9-1957	468
	POST-	120-616	240	238-853	530	120-853	385
LEG LIFT (Pounds)	PRE-	230-1140	800	120-1000	530	120-1140	651.5
	POST-	325-1065	622	100-655	393	100-1065	508
BACK LIFT (Pounds)	PRE-	60-320	250	60-300	154	60-320	202
	POST-	50-400	218	40-260	152	40-400	185
LEFT GRIP (Pounds)	PRE-	32-119	66	20-80	53	32-199	59.5
	POST-	33-129	73	22-90	51	22-129	62
RIGHT GRIP (Pounds)	PRE-	34-119	66	35-83	59	34-119	62.5
	POST-	37-128	76	21-88	54	21-128	65

TABLE I (Continued)

		BOYS[a]		GIRLS[b]		TEAM[c]	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
LUNG CAPACITY (cc.)	PRE-	128-2501	151	128-2451	176	128-2501	163.5
	POST-	128-3546	214	92-1894	145	92-3546	180
S. I.	PRE-	593-2488	1331	612-2962	1727	593-2962	1529
	POST-	697-2624	1446	529-2104	1326	529-2624	1386
N.S.I.	PRE-	621-2004	1148	392-2017	1125	392-2017	1365
	POST-	593-2546	1394	392-1647	939	392-2546	1166
P.F.I.	PRE-	71-165	115	71-262	153	71-263	134
	POST-	77-143	106	110-205	148	77-205	128

[a]Boys - Pre-Test (N=15)
Post-Test (N=10)

[b]Girls - Pre-Test (N=15)
Post-Test (N=10)

[c]Team - Pre-Test (N=30)
Post-Test (N=20)

TABLE II

ANALYSIS OF SIGNIFICANCE OF SCHNEIDER CARDIOVASCULAR TEST BETWEEN PRE- AND POST-TEST TAKEN WITH SPHYGMOMANOMETER

		Boys[a]		Girls[b]		Team[c]	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
Sitting Pulse Rate Beats/Sec.	PRE-	68-88	75	66-108	79	66-108	77
	POST-	60-80	70	78-108	99	60-108	72
Standing Pulse Rate Beats/Sec.	PRE-	80-120	89	84-120	93	80-120	91
	POST-	68-108	86	84-120	100	68-120	93
Sitting Systolic Blood Pressure mm. Hg.	PRE-	74-122	94	82-120	99	74-122	96.5
	POST-	90-122	107	89-132	105	89-132	97
Standing Systolic Blood Pressure mm. Hg.	PRE-	68-118	98	84-126	105	68-126	102
	POST-	97-130	115	102-130	116	97-130	115
Pulse Rate After Exercise Beats/Sec.	PRE-	90-140	106	96-166	117	90-140	112
	POST-	84-120	105	100-146	120	84-146	92
Pulse Rate After Exercise Return to Standing Norm. Beats/Sec.	PRE-	30-124	58.7	30-124	57.9	30-124	58.3
	POST-	2-124	42	5-75	39	2-124	49
Index of Cardiovascular Fitness	PRE-	5-16	8	4-15	11	4-16	10
	POST-	8-18	12	6-11	9	6-18	11
AGE (Years)	PRE-	8-15	11	7-16	12.6	7-16	11.8
	POST-	9-16	12.4	8-15	11.4	8-16	11.9

[a]Boys - Pre-Test (N=15)
Post-Test (N=10)

[b]Girls - Pre-Test (N=15)
Post-Test (N=10)

[c]Team - Pre-Test (N=30)
Post-Test (N=20)

TABLE III

ANALYSIS OF SIGNIFICANCE OF BARACH ENERGY INDEX BETWEEN PRE- AND POST-TEST

		BOYS[a]		GIRLS[b]		TEAM[c]	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
Sitting Pulse Manual Beats/Sec.	PRE-	60-84	74	66-96	75	60-96	74
	POST-	60-80	70	72-108	78	60-108	74
Sitting Systolic Blood Pressure Sphygmo-manometer mm. Hg.	PRE-	68-120	96	80-104	95	68-120	96
	POST-	90-122	106	89-132	104	89-132	105
Sitting Diastolic Blood Pressure Sphygmo-manometer mm. Hg.	PRE-	50-75	61	40-74	60	46-74	61
	POST-	68-90	78	58-108	79	58-108	78
Energy Index	PRE-	84-149	117	89-134	116	84-149	117
	POST-	108-150	130	120-165	144	108-150	137

[a]Boys - Pre-Test (N=15)
Post-Test (N=10)

[b]Girls - Pre-Test (N=15)
Post-Test (N=10)

[c]Team - Pre-Test (N=30)
Post-Test (N=20)

TABLE IV

ANALYSIS OF SIGNIFICANCE OF THE CRAMPTON BLOOD PTOSIS TEST BETWEEN PRE- AND POST-TEST TAKEN WITH THE SPHYGMOMANOMETER

		BOYS[a]		GIRLS[b]		TEAM[c]	
		R̄	Mx	R	Mx	R	Mx
Sitting Pulse Beats/Sec.	PRE-	68-98	77	66-108	79	60-108	78
	POST-	60-80	72	72-108	86	60-108	79
Standing Pulse Beats/Sec.	PRE-	76-120	89	84-120	93	76-120	91
	POST-	72-96	82	92-128	99	12-128	90
Difference mm. Hg.	PRE-	0-32	10	0-30	14	0-32	12
	POST-	6-18	11	4-20	13	4-20	12
Sitting Manual mm. Hg.	PRE-	74-120	94	80-116	97	68-116	95
	POST-	90-122	106	89-130	105	89-130	105
Standing Systolic mm. Hg.	PRE-	68-118	100	84-130	104	68-130	101
	POST-	97-130	114	112-132	119	97-132	116
Difference mm. Hg.	PRE-	-22+42	5.4	-6+36	8.5	0-42	9
	POST-	1-14	7	2-24	12	1-24	11
Index Percent	PRE-	30-100	81	35-100	76	30-100	74
	POST-	70-90	82	60-90	80	60-95	81

[a]Boys - Pre-Test (N=15)
Post-Test (N=10)

[b]Girls - Pre-Test (N=15)
Post-Test (N=10)

[c]Team - Pre-Test (N=30)
Post-Test (N=20)

TABLE V

ANALYSIS OF SIGNIFICANCE OF TEST FOR ENDURANCE IN SPEED SWIMMING BY CURETON, INDICATING DROP-OFF INDEX BETWEEN PRE- and POST-TEST (In Seconds)

		BOYS[a]		GIRLS[b]		TEAM[c]	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
100 Yd. Sprint	PRE-	60.4-107.6	80.7	71.2-116.8	82.4	60.4-116.8	81.5
	POST-	56.6- 86.0	69.8	66.0- 92.0	80.8	56.6- 92.0	74.8
Time First Lap	PRE-	12.5- 19.3	16.2	14.6- 20.5	17.7	12.5- 20.5	16.9
	POST-	12.0- 23.0	14.2	14.6- 23.0	16.8	12.0- 23.0	15.0
Time Last Lap	PRE-	15.9- 29.6	21.8	18.6- 29.4	23.0	15.9- 29.6	22.4
	POST-	15.4- 21.5	17.8	17.1- 28.8	19.0	13.5- 28.8	17.4
Drop-off Index	PRE-	3.4- 10.3	5.5	4.0- 8.8	5.2	3.4- 10.3	5.3
	POST-	1.5- 6.1	3.6	1.8- 5.4	4.2	1.5- 5.8	3.9
Per-cen-tile	PRE-	18 - 88	70	30 - 84	74	18 - 88	72
	POST-	64 - 95	85	72 - 84	81	66 - 95	83

[a]Boys - Pre-Test (N=15)
Post-Test (N=10)

[b]Girls - Pre-Test (N=15)
Post-Test (N=10)

[c]Team - Pre-Test (N=30)
Post-Test (N=20)

TABLE VI

ANALYSIS OF SIGNIFICANCE OF PRE- TO POST-TEST OF PULSE RATES TAKEN WITH CAMERON HEARTOMETER COMPARED WITH PULSE RATES TAKEN MANUALLY
(Beats Per Second)

		Sitting Pulse Rate Hearto-meter		Sitting Pulse Rate Manual		Standing Pulse Rate Hearto-meter		Standing Pulse Rate Manual	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
[a] Boys -	PRE-	56-96	76	68-88	75	64-114	84	80-120	89
	POST-	64-90	73	60-80	70	72-98	83	68-108	86
[b] Girls -	PRE-	72-120	88	66-108	79	88-112	100	84-120	93
	POST-	64-128	76	60- 90	82	72-144	102	84-120	100
[c] Team -	PRE-	56-120	82	66-108	77	64-114	92	80-120	91
	POST-	64-120	74	60-108	84	64-144	92	68-120	93

		BOYS		GIRLS		TEAM	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
AGE -	PRE-	8-15	11	7-16	12.6	7-16	11.8
	POST-	8-16	12.4	8-15	11.4	8-16	11.9

[a] Boys - Pre-Test (N=15)
Post-Test (N=10)

[b] Girls - Pre-Test (N=15)
Post-Test (N=10)

[c] Team - Pre-Test (N=30)
Post-Test (N=20)

TABLE VII

ANALYSIS OF SIGNIFICANCE OF PRE-TEST to POST-TEST OF BLOOD PRESSURES TAKEN WITH CAMERON HEARTOMETER COMPARED WITH BLOOD PRESSURES TAKEN WITH SPHYGMOMANOMETER (mm. Hg.)

		Sitting Systolic Blood Pressure Heartometer		Sitting Systolic Blood Pressure Sphygmomanometer	
		$\bar{R}$	Mx	R	Mx
[a]Boys -	PRE-	87-130	93	74-122	94
	POST-	92-131	113	84-120	105
[b]Girls -	PRE-	80-120	98	82-120	99
	POST-	93-156	124	102-130	116
[c]Team -	PRE-	80-130	95	74-122	96
	POST-	92-156	118	84-130	110

		BOYS		GIRLS		TEAM	
		$\bar{R}$	Mx	$\bar{R}$	Mx	$\bar{R}$	Mx
AGE -	PRE-	8-15	11	7-16	12.6	7-16	11.8
	POST-	8-16	12.4	8-15	11.4	8-16	11.9

[a]Boys - Pre-Test (N=15)
Post-Test (N=10)

[b]Girls - Pre-Test (N=15)
Post-Test (N=10)

[c]Team - Pre-Test (N=30)
Post-Test (N=20)