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Validity and reliability of selected runs as measures of cardiovascular endurance

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THE VALIDITY AND RELIABILITY OF SELECTED RUNS AS MEASURES OF CARDIOVASCULAR ENDURANCE

by

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H.W.L.

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CHAPTER I

THE PROBLEM

Introduction

Distance runs are frequently used to measure cardiovascular endurance in physical fitness tests which are designed to test a large number of people at once. Examples of tests which are frequently used are runs of 300 yards, 600 yards, one mile, and a drop off index between the 60 yard dash and the 300 yard run.[1] The true validity of these tests as measures of cardiovascular endurance, or the advantage of one test over another, has not been precisely determined. Consequently, it would be of value to have a better knowledge of the relationship between scores subjects make on these tests and a more precise measure of cardiovascular endurance.

The Problem

The purpose of this study was to evaluate the validity of the times attained in selected running tests as measures of cardiovascular endurance in college men. This was done by finding the correlation of these times with the maximum oxygen intake which was established while walking on a treadmill. The reliability of the tests was also evaluated as a subproblem of this study.

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[1] H. Harrison Clarke, Application of Measurement to Health and Physical Education (Engle Wood Cliffs: Prentice Hall Company, 1959), p. 117.

Basic Assumptions

Validity of the Criterion. It was assumed that the maximum oxygen intake is a valid measure of cariovascular endurance. Maximum oxygen intake is believed to be the best single indicator of capacity, and a direct relationship between oxygen intake and physical fitness levels has been shown.[2,3]

Point of Maximum Oxygen Intake. It was assumed that a heart rate of 180 beats per minute was indicative of the limit of a subject's circulatory adjustment for adequate oxygen transport. Balke,[4] Bedecki,[5] and Taylor[6] have shown that this is an acceptable point at which to take air samples when testing for maximum oxygen intake.

Motivation of the Subjects. It was assumed that because of the motivational techniques used in the study, each

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[2]Walter L. Russell, "A Study of the Relationships of Performance in Certain Generally Accepted Tests of Physical Fitness," (microcarded Doctor's Thesis, Louisiana State University, Baton Rouge, 1952).

[3]S. Robinson, "Metabolic Adaption to Exhausting Work as Reflected by Training," American Journal of Physiology, 135:428-434, 1941.

[4]Bruno Balke, "Correlation of Static and Physical Endurance," USAF School of Aviation Medicine, Project Number 21-32-004, Report 1, (Randolf Field, Texas, 1952), pp. 5.

[5]Thomas Bedecki and Francis Nagle, "Use of the 180 Beat Heart Rate Response as a Measure of Circulatory Respiratory Capacity," Research Quarterly, October, 1963, pp. 361.

[6]Craig Taylor, "Some Properties of Maximal and Submaximal Exercise with Reference to Physiological Variation and the Measurement of Exercise Tolerance," Journal of Applied Physiology, 142: 200-212, 1944.

individual ran close to his best time in each of the runs. These techniques are discussed in Chapter III.

Definitions of Terms

Cardiovascular Endurance. During exercise there must be an increased supply of oxygen to the muscles, or muscular activity cannot be maintained.[7] The amount of cardiovascular endurance is shown by the ability of the body to make this provision during severe exercise. Cardiovascular endurance is primarily a function of the cardiovascular and respiratory systems and is sometimes referred to as cardiovascular-respiratory endurance.

Maximum Heart Rate. For the purposes of this study, the maximum heart rate was considered to be 180 beats per minute. This was used as an indication of the point at which the subject had reached his aerobic capacity.

Aerobic Capacity. With increases in work rate, the heart and lungs must work faster to keep up with the demands of the working muscles. When the oxygen requirement for a given work level is beyond the capacity of the heart and lungs to supply all the oxygen needed, these organs must work at their maximum and can no longer adapt to higher levels of work.[8] When this occurs, the aerobic capacity of the individual has

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[7]Henry Longstreet Taylor, "Exercise and Metabolism," Science and Medicine of Exercise and Sports, Ed. by Warren Johnson, (Harper and Bros. publishers: New York, 1960), pp. 124.

[8]Taylor, op. cit., pp. 125.

been reached. The amount of oxygen consumed at this point is known as the maximum oxygen intake.

Maximum Oxygen Intake. The maximum oxygen intake was the oxygen intake measured in liters per minute at the work load where a subject's heart rate reached 180 beats per minute.

Drop Off Index. A drop off index is the difference between the time required to complete a relatively long run and the time that would have been attained had the runner been able to maintain his maximum speed over the entire distance. His maximum speed is taken as the speed he attains in a run of a shorter distance.[9] The drop off index was computed according to the following formula:

$$D.O. = \frac{Tlr}{\frac{Dlr}{Dsr} \times Tsr} \times 100$$

D.O. = Drop off index.

Dlr = Distance of the long run.

Dsr = Distance of the shorter run.

Tlr = Time of the longer run.

Tsr = Time of the shorter run.

Validity. For the purposes of this study, validity was the degree which running times were related to the criterion of maximum oxygen intake for the subjects participating in the study. The degree of validity was shown by the correlation between the running times for a given test and the maximum oxygen intakes.

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[9]Clarke, op. cit., pp. 117.

Reliability. Reliability was defined as the extent to which the running tests gave a constant score for a constant degree of what they were to measure.[10] The degree of reliability was shown by the correlation between running times on repeated tests and the validity of the tests.

Predictive Index. Predictive indices show the percent of prediction value better than pure chance for a prediction based on a given coefficient of correlation.[11] This is also referred to as forecasting efficiency.[12]

Physical Conditioning Class. The subjects in this study were enrolled in a required physical education service class at Montana State University. The course content was designed to improve the general physical condition of each member.

Limitations of the Study

In applying the results of this study, the following limitations must be taken into consideration.

Population. Only twenty-two male students who were enrolled in a required physical education class were used as subjects. Since these students were participating in a

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[10]John F. Bovard, Fredrick W. Cozens and Patricia Hagman, *Tests and Measurements in Physical Education*, (Philadelphia, London: W.B. Saunders Book Company, 1950), pp. 329.

[11]Harrison Clarke, *Application of Measurement to Health and Physical Education*, (Engle Wood Cliff: Prentice Hall Book Company, 1959), pp. 455.

[12]Henry E. Garrett, *Statistics in Psychology and Education*, (New York, London, and Toronto: Longmans, Green Book Company, 1958), pp. 178.

physical conditioning class, they were in better physical condition than one would expect of the average student. The findings of this study might not be applicable to a similar population at a low fitness level.

Fitness Tests. The running tests used to measure cardiovascular endurance were limited to distance of 60 yards, 300 yards, 600 yards, a mile, a drop off index between the 60 and 300 yard runs, and a drop off index between the 300 and 600 yard runs.

Criteria of Validity. Maximum oxygen intake was the only criterion measure with which run times were correlated.

CHAPTER II

RELATED LITERATURE

Pasch,[1] in an evaluation of the Bruce Physical Capacity Test, used football players, cross country runners and office workers as subjects. A correlation of .54 was found between the Bruce Physical Capacity Test and the subjects' maximum oxygen intake. In a sub-problem of this study, a correlation of -.36 was shown between running times attained by the cross country runners and their maximum oxygen intakes. During the testing, some subjects participating in the study became ill with the flu. After recovery, there was a decrease in their oxygen intake scores but not in their scores on the Bruce Physical Capacity Test. Pasch felt that this showed that the maximum oxygen intake was more sensitive to physiological change than was the Bruce test.

Hettinger and co-workers[2] found a direct relationship between maximum oxygen intake and fitness test scores in an experimental group of 96 male subjects. Their maximum oxygen intakes were compared to their scores on different tests of physical work capacity. Significant correlations were found between the maximum oxygen intake and the Harvard Step Test

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[1] Philip J. Pasch, "Evaluation of a Submaximal Test for Estimating Physical Working Capacity," Ergonomics, 3, 1960, pp. 9-17.

[2] Theodor Hettinger, Newton Birkhead, Steve Horvath, Bela Issekutze, and Kaare Rodahl, "Assessment of Physical Work Capacity," Journal of Applied Physiology, 16: 153-156, 1961.

(.001 level), the Masters Step Test (.05 level) and a German test called the Puls-Frequenz Test (.001 level).

Hodgson and co-workers[3] used college women as subjects when they compared maximum oxygen intake and endurance measures. The endurance measures used were the 50-200 yard drop off index and a step test using a 12 inch step. The maximum oxygen intake had a correlation of -.73 with the 200 yard run and a correlation of -.43 with the drop off index between the 50 and 200 yard runs.

Walter Russell[4] selected twenty-three men at random to serve as subjects when he studied the relationships between five fitness tests. In his study, the maximum oxygen intake capacity was correlated with the times made in the 300 yard and mile runs. There was a correlation of -.69 between maximum intake and the 300 yard run and a correlation of -.49 with the mile run. Russell felt that the reason for this difference was that in the mile run skill and judgment of pace were important factors affecting the times. It was suggested that if running tests were to be used as fitness tests, runs shorter than a mile should be used.

Falls[5] collected data from 89 Purdue staff and faculty

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[3]Pauline Hodgson, Alice Lopez, Mary Pilliard, and Ann Newman, "A Study of Some Relationships Between Performance Tests and Certain Physiological Measures Associated with Maximal and Sub-maximal Work," Research Quarterly, 17: 3: 208, October, 1946.

[4]Walter L. Russell, "A Study of the Relationships of Performance in Certain Generally Accepted Tests of Physical Fitness, (Microcarded Doctor's Thesis, Louisiana State University, Baton Rouge, 1952).

[5]H.B. Falls, "A Criterion for Fitness Tests," (Doctor's Thesis, Purdue University, Lafayette, 1964).

members on 53 physical fitness variables and analyzed them by the factor analysis technique. The 53 fitness variables were separated into nine distinct factors. Maximum oxygen intake was included in three of these factors. These were named "Athletic Fitness," "Aerobic Working Capacity," and "Heart Response to Exertion." Maximum oxygen intake had correlations of .51, .91, and .59 respectively with these factors. The 600 yard run correlated -.61 with the factor of "Athletic Fitness" and -.64 with the factor of "Aerobic Working Capacity."

Irma Åstrand[6] tested the physical working capacity of 81 subjects who were between the ages of 50 and 64 years. It was shown that maximum oxygen intake increases in a linear relationship with physical working capacity. The subjects were exposed to increasing work loads on a bicycle ergometer while measurements of heart rate and oxygen consumption were being taken. A mean heart rate of 160 beats per minute was found at the maximum physical working capacity for this age group. When the data from these subjects were compared to those taken from young athletes, it was found that the maximum oxygen intake decreased with age. It was concluded that the physical work capacities of different age groups cannot be estimated from submaximal loads, but a maximum must be used since the rate of attaining a steady state was not significantly different for the two age groups.

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[6]Irma Åstrand, "The Physical Work Capacity of Workers 50 to 64 Years Old," Acta Physiological Scandinavica, 42: 73-86, 1958.

Peter-Olaf Åstrand[7] defined physical fitness as the capacity of an individual to continue long heavy work. He has also found that physical fitness varies considerably with age. The highest oxygen intake he found was from 53 milliliters per kilogram body weight per minute for subjects 25 years of age. The lowest he found was 30 milliliters per kilogram body weight per minute for 70 year old men. There was a steady decline from the higher intakes of the younger groups to the lower intakes of the older groups. It was felt that sex differences in aerobic capacity might be related to different amounts of adipose tissue and active tissue. The mean maximum oxygen intake of females was 17 percent lower than that of males. Elite athletes showed a much higher maximum oxygen intake than did normal (non-athletic) individuals. The athletes showed a mean maximum oxygen intake of 67.0 milliliters per kilogram per minute compared to a mean of 58.6 for a group of students the same age.

Taylor[8] compared the responses of a group of 31 subjects to submaximum and maximum work in repeat experiments on a treadmill. It was found that in submaximum work, oxygen consumption was chiefly a function of body weight and

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[7]Peter-Olaf Astrand, "Human Physical Fitness with Special Reference to Sex and Age," <u>Physiological Reviews</u>, 1956, pp. 309.

[8]Craig Taylor, "Some Properties of Maximal and Submaximal Exercise with Reference to Physiological Variation and the Measurement of Exercise Tolerance," <u>American Journal of Physiology</u>, 1944, pp. 200-212.

only slightly related to fitness. In maximum work, however, the correlation between oxygen requirements and fitness increased considerably. During maximum work, oxygen consumption correlated .70 with the maximum run time on a treadmill. The Behnke Muscle Endurance Test, which consists of mounting an 18 inch stool until the initial pace can no longer be maintained, correlated a .78 with the treadmill run.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Data was collected on 22 subjects who were enrolled in a non-professional physical education class at Montana State University. Physical characteristics are shown in Table I.

TABLE I

PHYSICAL CHARACTERISTICS

Subjects	height centimeters	weight kilograms	surface area square meters	age yrs.
RDP	172	77.1	1.90	22
JAY	170	59.0	1.70	20
TBB	184	70.3	2.00	19
RCG	183	65.7	1.96	19
JLJ	176	69.4	1.86	18
RFC	183	66.2	1.86	20
ELN	186	78.9	2.05	19
RWJ	183	84.3	2.09	22
FSJr	177	84.3	2.04	23
PJJ	178	72.3	1.90	18
WJP	178	70.3	1.89	22
RAS	183	81.6	2.09	18
DAC	174	66.2	1.80	19
JWH	173	83.0	1.98	21
REF	173	64.4	1.78	18
WPR	180	81.6	2.01	18
VJC	189	84.0	2.16	18
GDS	183	73.5	1.99	18
RLG	170	69.3	1.86	21
FMB	172	75.7	1.84	25
DWH	180	74.3	1.86	21
NLS	173	79.8	1.91	19

Equipment Used

Description of the Treadmill

The treadmill had a walking surface three feet wide and eight feet long. The belt was made of Goodyear wedge grip rubber and revolved around two 8.5 inch end rollers with forty-two 1.9 inch bed rollers between them.

The inclination of the treadmill was set by manipulating a hand winch located at one end of the treadmill. Any grade between zero percent and 51 percent could be set while the treadmill was running. The speed of the treadmill was recorded on a speedometer which was calibrated in yards per minute. The speed of the treadmill was adjusted by varying the drive belt tension. In this study the speed was held constant at 3.5 miles per hour.

The Cardiotachometer and its Use

A Waters model C-225 cardiotachometer was used to measure the subjects' heart rates during treadmill walking. This instrument consists of an amplifier, a timing circuit, a meter, and a timing device. The tachometer is activated by either the cardiac action potential or by a peripheral pressure pulse. In this study the peripheral pressure pulse was used. This instrument is accurate within 2% of scale and could be adjusted so every artifact or extrasystole could be indicated with an instantaneous signal. An external damping circuit provided for moderate and heavy damping of the signal.[1]

Air Collection and Sampling Equipment

Circuits for Collection.

The open circuit method for the collection of expired air was used because of its accuracy and availability. The subject breathed through a Collins Triple J High Velocity Valve fitted to a gas mask, (Figure 1). The expired air traveled through a system of metal pipes and rubber tubing to a pair of Douglas Bags. Two bags were used to provide an adequate collection volume and limit the air resistance of air passing through the relatively small openings into the bags. After the expired air had been collected, it was directed into a 600 liter Collins Chain Compensated Gasometer for measurement.

Collection of Sample.

The expired air was channeled to the Douglas Bags by manipulation of a Collins Three Way Valve. Five valves were used to control the passage of expired air through the circuits. These valves and circuits are shown in Figure 2. The operation of the valves was as follows:

1. During the first part of the test, Valve 1 was adjusted to allow the expired air to flow into the Douglas Bag circuit, (Figure 3). Valves 2

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[1]Waters electro-medical instruments, (The Waters Corporation: Rochester, Minnesota), C-225B Cardiotachometer.

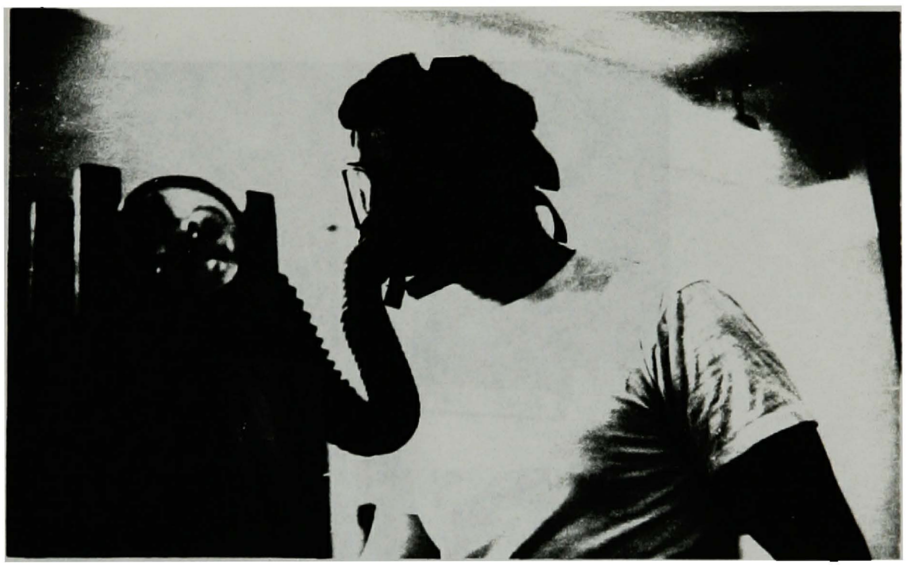


Figure 1. The Collins Triple J High Velocity Valve. A subject is shown wearing the gas mask which was connected to the air collection circuit. The Collins Triple J High Velocity Valve is to the left of the picture.

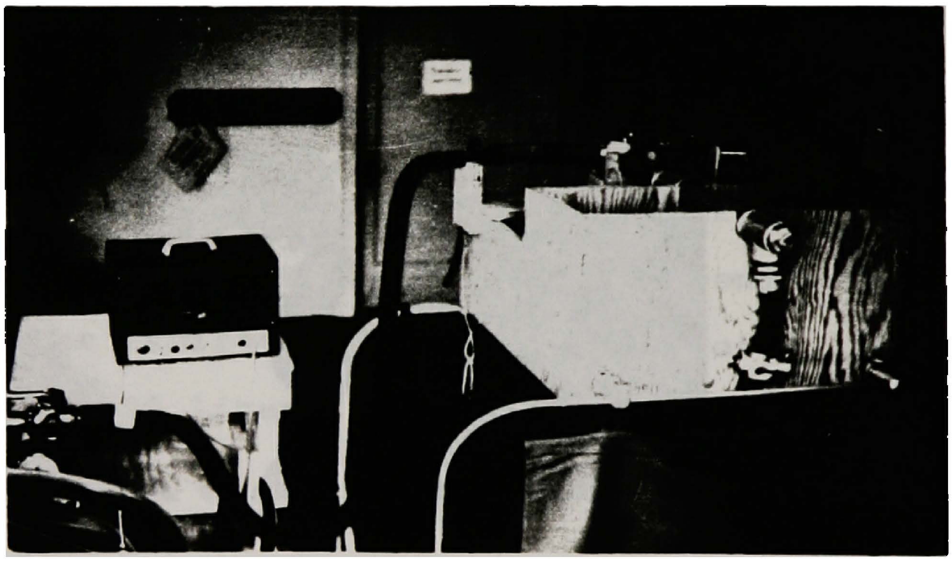
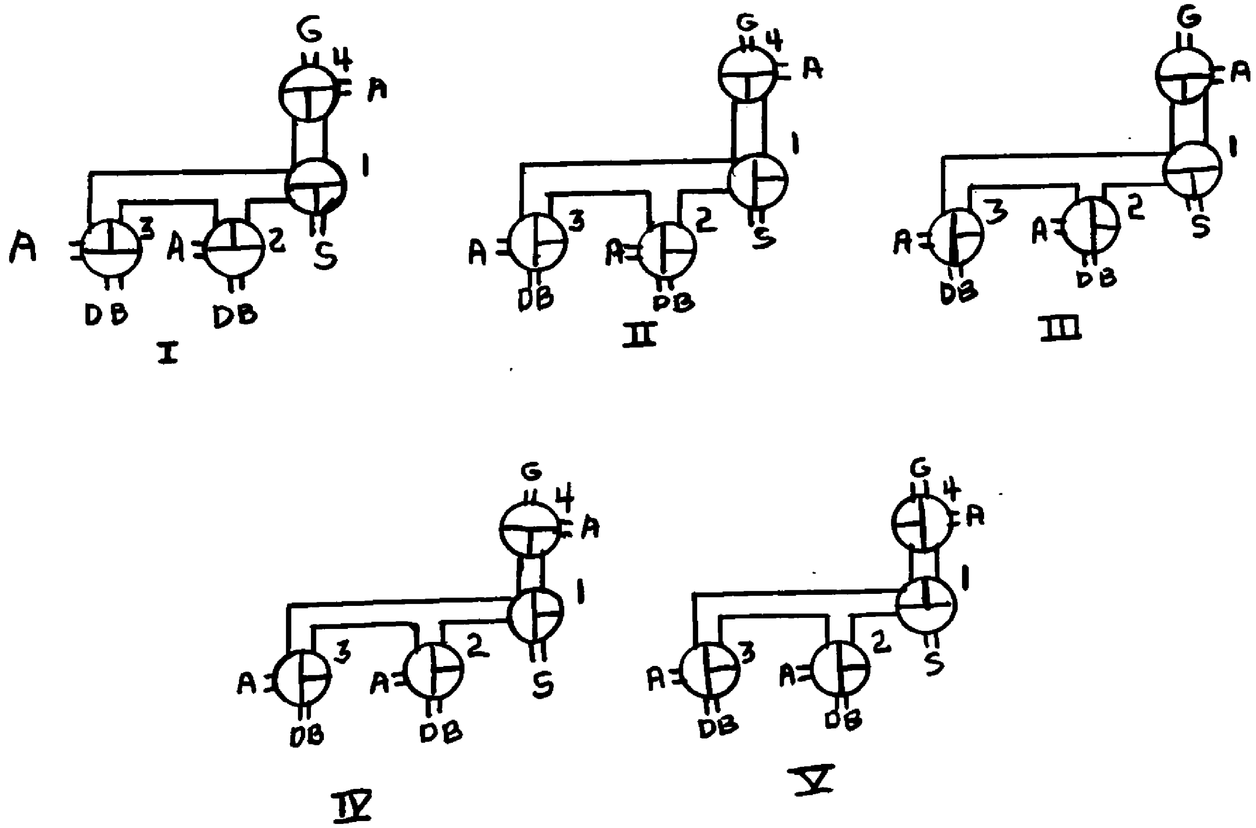


Figure 2. The valves and circuits for the air collection apparatus.



A = Atmosphere
S = Subject
G = Gasometer
DB = Douglas Bags
1,2,3,4 = Valves

Figure 3. When the valves are in the position shown in I, the expired air traveled through the Douglas Bags circuit without going into the Douglas Bags. When a heart rate of 165 to 170 beats per minute was reached, valve 1 was first turned so that the expired air would pass to the atmosphere during this period. Then valves 2 and 3 were turned to connect the Douglas Bags to the expired air circuit (II). After a heart rate of 180 beats per minute was reached, valve 1 was turned to allow air into the Douglas Bags (III). After the completion of the two minute collection period, valve 1 was again turned to allow expired air to flow to the outside (IV). Then valve 1 was turned to allow air to go to the Gasometer for volume determination (V).

and 3 were adjusted so that the expired air passed through the Douglas Bag system without going into the Douglas Bags. This flushed out all the dead air space up to the Douglas Bags.

2. When the subject's heart rate reached a point between 165 and 170 beats per minute, an assistant turned Valve 1 to direct the air toward the outside without going through the Douglas Bag circuit. Valves 2 and 3 were then immediately turned to connect the bags to the expired air circuit. At this point no air was entering the Douglas Bags.
3. When the heart rate reached the maximum point of 180 beats per minute, Valve 1 was turned back to the starting position, and the expired air was directed into the Douglas Bags for a two minute period.
4. Upon completion of the two minute collection period, Valve 1 was turned to allow the expired air to again pass to the outside. At this point, the air expired during the collection period was sealed in the Douglas Bags.
5. The air in the Douglas Bags was next mixed and then directed to the Gasometer by turning Valve 1. A valve located on the Gasometer was turned to direct air into the Gasometer Bell.

<u>Measurement of Sample</u>.

After the air had been collected in the Douglas Bags, it was thoroughly mixed and then transferred into the Gasometer for measurement. Extra weight was hung on the counter weights of the Gasometer creating a vacuum into which the air from the Douglas Bags flowed. During the transfer of the air from the bags to the gasometer, a sample for analysis was drawn into a gas collection tube by displacement of mercury.

A meter stick attached to the gasometer indicated the height that the gasometer bell rose due to the volume of the expired air. The volume of the air was obtained by multiplying the number of centimeters the bell rose times a constant factor for the conversion of the height to volume. The temperature of the expired air was obtained from a thermometer which was located within the gasometer bell.

Gas Analysis Equipment and its Use

<u>Scholander Gas Analyzer</u>.

The Scholander method of gas analysis was used to determine the percentages of oxygen and carbon dioxide in the expired air.[2] In this technique, a .5 cubic centimeter gas sample is introduced into a reaction chamber and is

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[2]P.F. Scholander, "An Analyzer for Accurate Estimation of Respiratory Gases in One-Half Cubic Centimeter Samples," <u>Journal of Biological Chemistry</u>, 167, January, 1947, 167: 1-15.

balanced by means of an indicator drop. Oxygen and carbon dioxide absorbing fluids can then be introduced to absorb the gas without changing the liquid content of the system. Mercury is admitted into the reaction chamber to compensate for the loss of volume due to the absorption of gases. The volumes of carbon dioxide and oxygen are read in terms of micrometer divisions. The accuracy of the Scholander method has been found to be adequate for all ordinary respiratory work.

The percents of carbon dioxide and oxygen were computed by using formulae prescribed by Scholander.[3] These are shown below:

$$\frac{V_1 - V_2}{V_1} = \text{percent of carbon dioxide.}$$

$$\frac{V_2 - V_3}{V_1} = \text{percent of oxygen.}$$

V_1 = Volume of air sample.

V_2 = Volume of air sample less carbon dioxide.

V_3 = Volume of air sample less oxygen and carbon dioxide.

<u>Transfer of the Gas Sample</u>.

The technique used to transfer expired air from the sampling tube to the Scholander analyzer was the one described by Nusbaum.[4] The gas sampling tube which contained

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[3] *Ibid*.

[4] Galen Nusbaum, "A Study to Investigate the Energy Expenditure of Subjects while They were Operating Mechanical Trenchers of Different Design," (Master of Science Thesis, Montana State University, Missoula), 1963, pp. 13.

the sample was attached to a 50 milliliter syringe by means of plastic tubing. The air to be analyzed was forced into the syringe by admitting mercury into the sampling tube to displace the air. The apparatus was first flushed three times with the sample air to assure that a pure sample was admitted into the reaction chamber for analysis.

Standard for Acceptance.

Each analysis had to meet certain standards before it could be considered acceptable. At the end of each analysis the micrometer had to come within a plus or minus .005 millimeters of the machine zero. The level was set by Scholander to allow for the elasticity of the rubber stoppers in the side arms of the analyzer. Also, the percents of carbon dioxide and oxygen on two consecutive analyses had to be within a plus or minus .05 percent of each other for the analysis to be accepted.

Computation of Maximum Oxygen Intake.

After the expired air had been analyzed, the maximum oxygen intake was computed in the following manner.[5]

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[5]Frank C. Consolazio, Robert E. Johnson and Louis J. Pecora, Physiological Measurements of Metabolic Functions in Man. (McGraw Hill Company publishers: New York, Toronto, London, 1963), pp. 9.

1. The volume of the oxygen consumed was found by the formula:

$$VO_2 = \frac{V\ \text{air expired (STPD)}}{100} \times (\%N_2 \times .265 - \%O_2 \text{ of analyzed sample}).$$

VO_2 = Volume of oxygen consumed.

(STPD) = Corrected to Standard Temperature and Pressure Dry.

2. The oxygen intake in liters per minute was found by dividing the volume of the oxygen consumed by the number of minutes it took to collect the sample.
3. The oxygen intake in liters per minute per kilogram of body weight was found by dividing the oxygen consumed by the body weight in kilograms.

Preparation of the Subjects

Training Period

Every subject who participated in this study was required to time races. Since none were acquainted with the correct method of timing, a short training period on how to time was held at the beginning of the quarter. This period was also used to inform the subjects of the purpose and scope of this study.

Equating of Groups

Each rach was run by each subject at least once during the training period to familiarize him with the distances. The groups were equated on the basis of the times in the practice 600 yard run. The method of equating is shown in Table II.

TABLE II

THE METHOD OF EQUATING GROUPS[1]

Group	Place finished in the practice run				
A	1	2	3	4	5
B	6	7	8	9	10
C	11	12	13	14	15
D	16	17	18	19	20
E	21	22	23	24	25

[1]Only 22 of the original 25 students were used in the final data because three subjects dropped out of school.

Motivational Procedures.

The subjects were motivated for maximum performance in three ways:

1. They were tested twice on each run and encouraged to "beat their own scores" the second time.
2. The groups were equated so that the subjects were of near equal ability. Each subject was encouraged to win his own race. This provided a great deal of competition in each of the runs.
3. Subjects were also assigned to one of five teams. The placement of the subjects on teams is shown in Table III. Each team was made up of one member from each group, giving each team competitors who averaged near equal ability. Points were

then set up for place winners. The number of points each subject received corresponded to the finish place in each run. In this way each team member contributed points to the team score. The team scores were used as a factor when computing course grades.

TABLE III

METHOD OF TEAM CONSTRUCTION[1]

Teams	Groups A	B	C	D	E
Red	1	10	11	20	21
Blue	2	9	12	19	22
Yellow	3	8	13	18	23
Green	4	7	14	17	24
Black	5	6	15	16	25

[1]The number refers to the rank order of the subjects equated in Table II.

The Fitness Tests

The fitness tests used were the 60 yard, 300 yard, 600 yard and mile runs. These tests were rotated so that each week each group ran a different test item. This rotational procedure is shown in Table IV. Each group ran each test twice during one week and then progressed to the next test the following week. The 60 yard test was given twice during each testing period for the two periods in the week. The

The 300 yard, 600 yard and mile runs were given only once each testing period.

TABLE IV

GROUP ROTATIONAL PROCEDURES[1]

Experimental Test	Week 1	2	3	4	5
60 Yards	A	B	C	D	E
300 Yards	B	C	D	E	A
600 Yards	C	D	E	A	B
Mile Run	D	E	A	B	C

[1]The treadmill test was originally scheduled into this table. However, the laboratory facilities were being used for another study at the beginning of the quarter. Therefore, the subjects scheduled for the treadmill test during that week helped time and assisted in the running tests outside. The treadmill tests were given by appointment at a later time.

The 60 yard test was run on a 60 yard straightaway. The 300 and 600 yard runs were run in part out of a 220 yard chute. The remainders of these races were completed on turns of the track. The 300 was finished on the first turn while the 600 was finished after running around two turns. The mile was run as four complete laps on a 440 yard track.

With the exception of the 60 yard dash, each race was started from a standing position. The 60 was started in a sprinter's position, with the back foot braced against a plank.

Drop Off Index.

Two separate drop off indices were computed for each subject. The first index was formed on the basis of the 60 yard dash and the 300 yard run, while the second was formed on the basis of the 300 and the 600 yard runs. The indices were computed by the formula shown on page 4 in Chapter I.

Maximum Capacity Test

The maximum capacity test was a modification of the Balke[6] test. The work load increase was that suggested by Åstrand and Saltin.[7] This work load was recommended by these authors after the completion of studies in which they imposed maximum work on men and women by means of a bicycle ergometer. They suggest the use of two or more submaximal loads before going on to a "super-maximal" load. Their recommendation that the subject should work at this level for at least two minutes before the collection of expired air was also followed.

The treadmill test time intervals are shown in Table V. As the subject progressed through each of the steps his body had to adjust to the demands of the working muscles. The work load was increased every five minutes by increasing the grade of the treadmill. After the maximum work load had been reached and maintained for two minutes, the expired air

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[6]Bruno Balke, "Correlation of Static and Physical Endurance," USAF School of Aviation Medicine, Project Number 21-32-004, report 1, Randolf Field, Texas, 1952, pp. 5.

[7]Peter-Olaf Åstrand and Bength Saltin, "Oxygen Uptake During the First Five Minutes of Exercise," <u>Journal of Applied Physiology</u>, 1961, p. 976.

was collected for two minutes and the test terminated. The subject was then allowed to step off the treadmill. The speed of the treadmill was held constant at 3.5 miles per hour throughout the test. A picture of a subject taking the treadmill test is shown in Figure 4.

TABLE V

TREADMILL TEST PROGRESSIONS

Steps	Percent Grade	Time Progression in Minutes
First five minutes	0	0 - 5
Second five minutes	5	5 - 10
Third five minutes	10	10 - 15
Fourth five minutes	15	15 - 20
Fifth five minutes	20	20 - 25

Experimental Procedures

The running tests were given during an 8:00 A.M. physical education class that met on Tuesday and Thursday of each week. The subjects were clothed in gym attire. The same testing procedures were followed each day.

Starting Stimulus

Each race was started with a starting gun. It was felt that this was the easiest way to give a uniform starting stimulus and increase the accuracy of the timing. All of the starts were given by the class instructor or his assistant.

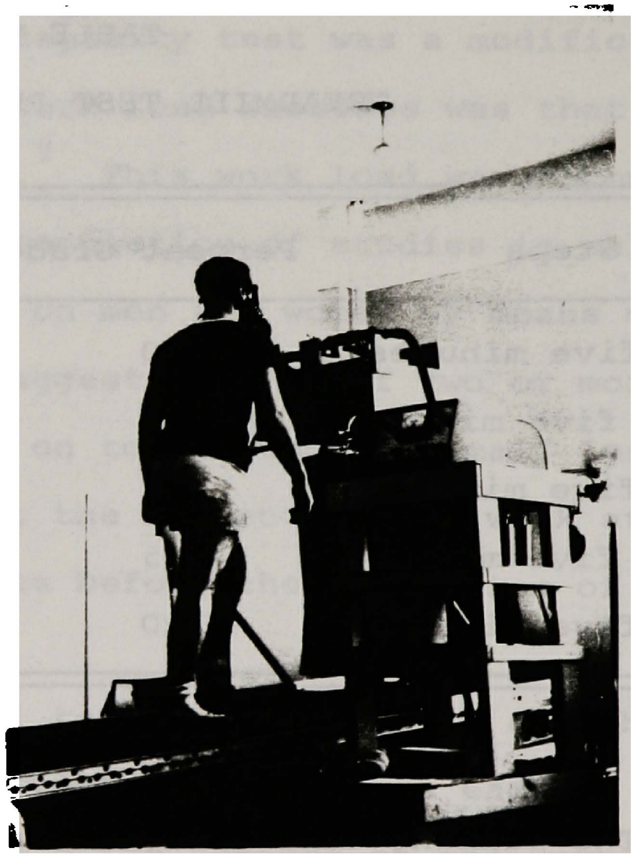

Figure 4. A subject walking at a 5 percent grade in the maximum capacity test.

Timing

Students who were not running acted as timers. Prior to the beginning of each race, the timers were assigned a finish place which they were to time. To insure accuracy, two watches were used to time each subject in each race. The watches were checked for accuracy by a jeweler prior to the time the study began.

Daily Test Procedure

Each subject was allowed to warm up on his own for approximately 15 minutes prior to the time the testing began. An example of a daily test procedure is as follows:

1. Group A ran the 60 yard run while groups B,C,D and E timed and recorded finish places.
2. Upon completion of the 60 yard run, group B reported to the starting area for the 300 yard run. Groups A,C,D and E reported to the finish line of the 300 yard run to time and record place winners.
3. After the 300 yard run was over, group C reported to the starting area of the 600 yard run, and the remaining groups timed and recorded finish places at the finish line.
4. After the 600 yard run, group D ran the mile around four laps of the track. Groups A,B,C and E timed and recorded finish places.

5. This concluded one days testing procedure. This procedure was followed each week. Groups were rotated week by week as shown in Table IV, page 25.

Testing Procedure for the Maximum Capacity Test

Treadmill Procedure

The treadmill test was given to each subject only once during the quarter. The tests were given when the subject could make an appointment. The procedure followed is outlined below.

1. The subject's body weight and height were taken when he arrived at the laboratory.
2. The gas mask was next put on the subject and he then reported to the treadmill for his instructions about walking on it.
3. The gas mask was attached to the Collins Valve by means of rubber hosing, and the finger pickup of the cardiotachometer was attached to the index finger.
4. The treadmill was then started. The speed was checked, and adjusted if necessary to 3.5 miles per hour. The heart rate was recorded at the end of each minute. This rate was taken at the radial pulse at frequent intervals to check the cardiotachometer's accuracy. As the individual approached his maximum capacity near the termination of the test, two spotters were employed at the sides of

the treadmill in case the subject could no longer maintain the treadmill pace.

5. The air collection period was started two minutes after the subject's heart rate reached 180 beats per minute. The expired air was collected into Douglas Bags for later volume measurement and composition analysis. After the expired air had been collected, the treadmill was turned off and the subject was permitted to leave the laboratory.

6. Upon completion of the test the expired air was mixed, its volume determined, and its composition analyzed as described on pages 19 to 21.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Analysis of Results

The statistic used to analyze the data was the Product Moment Correlation Coefficient. This technique permits the study of the extent to which a linear relationship exists between two variables. It was applied in two ways: (1) to determine the validity of the running tests as shown by their relationship to the criterion of maximum oxygen intake, and (2) to determine the reliability of the running tests as shown by the relationship between scores obtained on repeated tests. The statistical significance of each of the coefficients was determined by reference to a table presented by Garrett.[1]

The Predictive Index for each correlation coefficient was computed by the method described by Clarke.[2] This index, like the standard error of estimate, gives the probability of predicting scores made in one variable from scores on another on the basis of their coefficient of correlation.[3]

Validity Measures

The correlation between times in the running tests and

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[1]Henry E. Garrett, Statistics in Psychology and Education, (New York: Longmans Green Book Company, 1958), pp. 201.

[2]H. Harrison Clarke, Application of Measurement to Health and Physical Education, (Engle Wood Cliffs: McGraw Hill Book Company, 1959), pp. 455.

[3]Garrett, op. cit. pp. 164

maximum oxygen intake are shown in Table VI. With the exception of the one for the second mile, these correlations were all significant beyond the .01 level of confidence. For the second mile run, the correlation with maximum oxygen intake was significant at the .05 level. This would indicate that the times attained in the running tests had a high degree of relationship with the subjects' maximum oxygen intakes.

TABLE VI

THE RELATIONSHIP BETWEEN RUNNING TIMES AND MAXIMUM OXYGEN INTAKE

Run	Test No.	Mean	Standard Deviation	Correlation	Significance	Predictive Index
60	1	8.0	.39	-.58	.01	.185
	2	8.1	.47	-.67	.01	.258
300	1	40.7	2.6	-.59	.01	.193
	2	40.3	2.2	-.68	.01	.267
600	1	1:37.7	7.5	-.63	.01	.223
	2	1:38.3	6.9	-.64	.01	.232
Mile	1	6:23.1	36.8	-.64	.01	.232
	2	6:17.9	37.3	-.47	.05	.118
Drop off 60x300	1	101.4	4.09	-.41	not	.088
	2	99.2	2.7	-.11	not	.006
Drop off 300x600	1	119.5	5.23	-.29	not	.043
	2	120.7	5.59	-.32	not	.053

None of the correlations between the drop off indices and the maximum oxygen intakes showed a correlation that was significant at or beyond the .05 level of confidence. The low Predictive Indices (.006 to .088) would indicate that the scores on these tests had very little or no predictive value. Hodgson[4] and co-workers found similar results in a drop off index established on the basis of 50 and 200 yard runs.

The 600 yard run had the most consistent correlations with the oxygen intake (-.63 and -.64). Neither of these correlations were as high as those between the second running times of the 60 and 300 yard runs and the oxygen intake. However, both of the correlations for the 600 yard run were higher than those for the first running of the other two tests. The Predictive Index for all three of these tests ranged from .185 to .267 showing only a small variation (.08) in their relative effectiveness as predictors of the criterion. Russell[5] and Falls[6] found comparable correlations between run times and factors of erobic capacity when using techniques similar to those used in this study.

In both the 60 yard and 300 yard runs the correlations with maximum oxygen intake were higher for the times in the second test than for the times in the first test. In both cases, the Predictive Indices were improved slightly more than

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[4]Pauline Hodgson, Alice Lopez, Mary Pilliard, and Ann Newman, "A Study of Some Relationships between Performance Tests and Certain Physiological Measures Associated with Maximal and Sub-Maximal Work," <u>Research Quarterly</u>, 1947, 17: 3: 208.

[5]Walter L. Russell, "A Study of the Relationship of Performance in Certain Generally Accepted Tests of Physical Fitness," (Microcarded Doctor's Thesis, Louisiana State University, Baton Rouge, 1952).

[6]H.B. Falls, "A Criterion for Fitness Testing," (Doctor's Thesis, Purdue University, Lafayette, 1964).

.08. The differences between these two tests in terms of their efficiency for the prediction of the oxygen intake were negligible. It would be very difficult to draw any final conclusions as to the true differences between them on the basis of these correlations.

The greatest difference between correlations with maximum oxygen intake on successive tests was shown by the mile run (-.64 and -.47). The second correlation (-.47) agrees with that found by Russell[7] (-.49) in his study of generally accepted tests of physical fitness. He felt that a correlation which was this low was due to the role skill and judgment of pace played in running a race of this length.

Test Reliabilities

The Product Moment Correlation Coefficients between scores on the first and second trials of each running test and each drop off index are shown in Table VII. These correlation coefficients are indicative of the reliability of these tests in that they show the degree to which the results of the first trial have been duplicated in the second trial.

For the runs, all of the reliability coefficients were quite high. The lowest coefficient was the one for the 60 yard run (.88). All of the other coefficients were higher ranging from .91 to .94. In all cases, the coefficients were significant beyond the .01 level of confidence.

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[7]Russell, loc. cit.

The reliability coefficients for the drop off indices were not as good as those for the runs. The coefficient for the index between the 60 and 300 yard runs was -.002, showing that no relationship existed. The index between the 300 and 600 yard runs was significant at the .01 level, but it did not approach the size of the test-retest coefficients for the running tests.

TABLE VII

TEST-RETEST RELIABILITIES

Test	Correlation between test 1 and test 2	Sig.
60 yard run	.88	.01
300 yard run	.94	.01
600 yard run	.91	.01
Mile run	.93	.01
Drop off (60x300)	-.002	not
Drop off (300x600)	.60	.01

Discussion of Results

Apparently there were very few differences among the 60, 300, and 600 yard tests as measures of cardiovascular endurance when maximum oxygen intake was used as the criterion of validity. However, with the 60 and 300 yard runs, the maximum effectiveness was apparently with the second administration of the test. In the 600 yard run, the results were quite consistent for both tests. On the basis of the Predictive

Indices, the 600 yard run was the best of the three on the first test, but the 300 yard run was the best on the second test.

There is actually a negligible difference between the correlation coefficients of the 60 and 300 yard runs on both of the tests. On the first test this difference is .008 and on the second .009. The same is true for the Predictive Indices.

The mile run presented a special problem. In the first test there was a correlation of -.64, but in the second this dropped to -.47. This incongruity becomes more apparent when one refers to the reliability coefficient for this test which was .93, the second highest in the study. The case of such a situation was discussed by McCloy[8] in reference to test reliability.

> This correlation, however, may be high without the test's really being reliable. This might be illustrated in such a case as that in which the average score of a group in the first test might be fifty, and the average score in the same test given subsequently be ninety. Hence, the difference in the mean score between the two tests, as well as the correlations between the two administrations of the test, must be taken into account.

Apparently, the subjects in this study finished the second test in approximately the same order as the first, which would contribute to the high test-retest correlation. But the mean time for the second test was lower and the

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[8]Charles Edward McCloy, Tests and Measurements in Health and Physical Education, (New York: Appleton Century Crofts Co. 1939), pp. 8.

variability as measured by the standard deviation was greater. This could cause the lower correlation between the second test and the maximum oxygen intake.

All of the running tests had relatively high reliability coefficients. The evaluation of these is subjective, but guide lines have been presented by various authors.[9,10,11,12] These authors agree that reliability coefficients should reach a .90 level or above. On this basis, the coefficients for the 60 yard run and the two drop off indices would be too low. The drop off indices were considerably below the criterion level, but the coefficient for the 60 yard run (.88) approached the minimum. It would probably not be advisable to exclude this test on the basis of this correlation without repeating the experiment with larger groups.

The mile run had the second highest reliability in the test. However, this test was nevertheless shown to be unreliable since the second test had such a low correlation with the criterion of validity. The reason for this difference merits further study. The differences between the correlations of the first and second running times of the 60

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[9] Garrett, _op. cit._, pp. 351.

[10] Clarke, _op. cit._, p. 8.

[11] Carl E. Willgoose, _Evaluation in Health Education and Physical Education_, (New York: McGraw Hill Cook Co. 1961), p. 24.

[12] Francis Stroup, _Measurement in Physical Education, an Introduction to Its Use_, (New York: The Ronald Press Co. 1957), p. 90.

and 300 yard runs and the maximum intake would detract from the reliability of these tests on the same basis.

On the basis of the findings from this study, the 600 yard run would probably be the best single test to use for giving a group a one-trial cardiovascular endurance test. On the first trial, its correlation with the criterion was higher than that for any other test, and it showed acceptable reliability coefficients. The 300 yard run would apparently be better if subjects were to be given two attempts, but the second trial would give more accurate results. The second 60 yard run had the second highest correlation with the validity criterion, but its reliability coefficient was slightly below the minimum of .90. The mile run would not be acceptable due to its inconsistency of measurement as shown by a low validity coefficient for the second test. Neither of the drop off indices was shown to be acceptable.

None of the tests measured cardiovascular endurance as accurately as one would like. It would be preferable to have correlations with the criterion that would more nearly approach 1.00.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Twenty-two students who were enrolled in a physical education class at Montana State University were used as subjects in an attempt to evaluate the validity of selected running tests as measures of cardiovascular endurance. A sub-problem of this study was to determine the test-retest reliabilities of each of these runs. The running tests used in this study were the 60 yard run, the 300 yard run, the 600 yard run, the mile run, a drop off index between the 60 and 300 yard runs, and a drop off index between the 300 and 600 yard runs. The criterion measure of cardiovascular endurance was maximum oxygen intake.

The maximum oxygen intake was measured while subjects walked on a motor-driven treadmill. The treadmill test consisted of walking at a constant speed of 3.5 miles per hour. The grade of the treadmill was increased 5 percent every five minutes. When the subject's heart rate reached 180 beats per minute, he was considered to be at his maximum limit of cardiorespiratory adjustments. After the subject had walked at this level for two minutes, his expired air was collected for two minutes. This air was then analyzed for content by the Scholander Method.

Three motivational techniques were used to encourage each subject to run his beat in each test. These motivational techniques were:

1. Each subject ran each test twice and was encouraged to better his time on the second run.
2. The subjects were divided into five testing groups such that each group contained members of near equal ability. This provided close competition between men in the groups.
3. Teams were formed which contained members from each of the different test groups. Team scores were used as an aid in computing course grades.

The maximum capacity test was run only once during the quarter. The maximum oxygen intake found with this test was used as the criterion with which the running times were correlated.

Each of the running tests had correlations with the maximum oxygen intake that were beyond the .01 level of significance. The 60 and 300 yard runs had the highest of these correlations (-.67 and -.68 respectively), but these were not consistent in that the second correlation was higher than the first. The second trial in the mile test had a correlation (-.47) with the oxygen intake which was below that of the first trial (-.64). Because of this inconsistency the mile was not considered to be as good an indicator of cardiovascular endurance as were the other runs. The correlations between the drop off indices and maximum oxygen intake were not significant at the .05 level of confidence.

The test-retest reliability coefficients, which ranged from .88 to .94, were high in all the running tests. The 300 mile runs had the highest correlations (.93 and .94) while the 60 yard run had the lowest (.88). The reliability coefficients for the drop off indices were not as high as those for the running tests. In one case no relationship was shown.

Conclusions

Within the limitations of this study, it was concluded that the 600 yard run would probably be the best test to use for giving a one trial cardiovascular endurance test. The 300 yard run would apparently be better if subjects were given two trials. The 60 yard run had the second highest correlation with the validity criterion, but its reliability coefficient was below the minimum of .90. The mile would not be acceptable due to its inconsistency of relationship with the criterion of validity. Neither of the drop off indices was shown to be acceptable. None of the tests measured cardiovascular endurance as well as might be desired since the highest correlation coefficient of a test with the validity criterion was only -.68.

Recommendations

In view of the findings of this study and the problems encountered during its completion, it would be profitable to pursue further research. A repeat study for all running tests with more subjects should be made, possibly using known low and high fitness groups to determine how well these tests actually discriminate between these various fitness levels.

In future studies, maximum oxygen intake should also be measured twice. This would increase the precision of the criterion measurement.

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APPENDIX

APPENDIX A

SUBJECTS' TIMES IN THE RUNNING TESTS

Subject	Run No.	60	300	600	Mile
RDP	1	7.3	36.4	1:26.9	5:45.4
	2	7.2	36.4	1:26.2	5:34.0
JAY	1	8.0	38.1	1:27.7	5:40.3
	2	8.0	38.7	1:26.6	5:12.8
TBB	1	7.6	37.0	1:27.7	5:40.8
	2	7.7	37.1	1:26.4	5:42.0
RCG	1	8.3	39.1	1:27.7	5:27.6
	2	8.2	39.6	1:28.2	5:21.4
JLJ	1	7.6	39.0	1:29.0	5:37.5
	2	7.2	39.0	1:39.0	5:46.2
RFC	1	8.0	39.0	1:31.1	5:42.5
	2	8.0	39.2	1:33.4	5:47.9
ELN	1	8.1	40.2	1:31.2	5:32.0
	2	8.1	38.5	1:31.2	5:34.8
RWJ	1	8.0	40.4	1:32.4	5:57.8
	2	8.1	40.2	1:35.1	5:54.0
FSJr	1	7.5	37.5	1:33.8	6:47.5
	2	7.7	37.3	1:33.1	6:11.7
PJJ	1	7.7	38.6	1:37.5	6:17.5
	2	8.0	39.4	1:38.2	6:14.0
WJP	1	7.8	40.2	1:38.0	6:23.8
	2	7.9	39.5	1:37.2	6:22.8
RAS	1	7.9	39.6	1:39.0	7:25.7
	2	8.1	39.7	1:39.0	7:02.0
DHC	1	7.9	40.3	1:39.4	6:05.1
	2	8.2	40.5	1:38.5	6:06.1

APPENDIX A (continued)

SUBJECTS' TIMES IN THE RUNNING TESTS

Subject	Run No.	60	300	600	Mile
JWH	1	8.0	41.5	1:43.0	7:07.8
	2	8.6	40.8	1:43.8	7:00.2
REF	1	8.2	44.0	1:44.5	6:47.0
	2	8.6	42.2	1:43.7	6:23.0
WPR	1	9.0	44.3	1:45.0	6:56.0
	2	8.8	44.1	1:44.9	6:59.5
VJC	1	8.8	45.3	1:45.1	6:47.8
	2	9.2	45.0	1:45.7	6:48.8
GDS	1	8.3	46.2	1:45.4	6:35.7
	2	8.8	44.3	1:44.7	6:53.5
RLG	1	8.5	43.4	1:49.0	6:53.5
	2	8.4	43.0	1:45.9	6:46.6
FMB	1	8.0	42.0	1:51.1	7:34.0
	2	8.3	42.1	1:50.5	7:31.5
MLS	1	7.8	42.2	1:43.4	6:34.5
	2	7.8	39.9	1:39.7	6:38.2
DWH	1	8.5	41.4	1:43.4	6:38.5
	2	8.4	41.0	1:44.0	6:33.6

APPENDIX B

PHYSIOLOGICAL MEASURES

Name	oxygen intake cc/kg/min	oxygen intake liters/min.	venti- lation	RG	highest heart rate
RDP	550	4.25	119.08	.98	195
JAY	441	2.56	77.4	1.04	192
TBB	452	3.18	94.0	.97	195
RCG	460	3.073	93.7	.96	186
JLT	452	3.147	98.05	.98	200
RFC	449	2.974	81.5	.89	200
ELN	460	3.65	98.88	1.00	186
RWJ	450	3.80	114.08	1.02	190
FSJr	440	3.66	114.15	1.03	182
PJJ	440	3.17	75.18	.95	190
WJP	440	3.093	122.25	1.03	205
RAS	390	3.185	110.9	1.02	215
DHC	450	3.04	93.45	1.05	200
JWH	338	2.64	106.5	1.16	194
REF	430	2.78	83.33	.90	190
WPR	430	2.78	83.33	.90	190
VJC	420	3.60	96.44	.90	190
GDS	410	3.60	96.4	.90	185
RLG	400	3.05	86.3	1.01	190
DWH	440	3.30	100.8	1.02	196
MLS	438	3.51	111.6	1.08	200
FMB	430	3.18	94.0	.97	205

APPENDIX C

TREADMILL TEST DATA CARD

Name:______________________ Date___________ Age______ Ht.______ Wt.______

Heart Rates: 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_______
11_____ 12_____ 13_____ 14_____ 15_____ 16_____ 17_____ 18_____ 19_____ 20_____ 21_______

Gasom. Reading I:________ Gasom. Reading II_________ Vol.(uncorrected)_________

Temperature __________ C Pressure: __________mmHg STPD Factor _________

Volume Corrected: __________L

$\%CO_2$ I __________ $\%O_2$ I__________ $\%N_2$ __________
$\%CO_2$ II __________ $\%O_2$ II__________

$\%CO_2$ __________ $\%O_2$ __________

True O_2 = $\%N_2$ in Exp. air x 0.265 - $\%O_2$ in exp. air = _____x 0.265 - ____ = ____

Vol. O_2 (L/min.) = $\frac{\text{Vol gas (L/min.)}}{100}$ x true oxygen = $\frac{\_\_\_}{100}$ x ____ = ____

RQ ______ Wt. in Kg______ O_2 Consumption

APPENDIX D

RUN TIMES RECORD CARD

Name: ______________________________

Run	time I	date	weather	time II	date	weather
60	______	____	______	______	____	______
300	______	____	______	______	____	______
600	______	____	______	______	____	______
mile	______	____	______	______	____	______

REMARKS:

60

300

600

mile