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CARDIOVASCULAR FITNESS TEST

DISSERTATION

Presented in Partial Fulfillment of the Requirement for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

by

Robert Leonard Kurucz, B.S., M.S.

* * * * * *

The Ohio State University
1967

Approved by

[Signature]

Adviser
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To

Donna, Jane, Jill, Joan, Jimmy, and Jennifer
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The extensive data collected in recent years have focused attention on the incidence of cardiovascular diseases particularly in the middle-aged and elderly population. For example, in the initial Framingham study the incidence of cardiovascular diseases in the sample population consisting of ages thirty to sixty-two was 24/1000 or 2.4% for males. When the sample group was divided into two age groups, the thirty to forty-four age-group had a cardiovascular disease rate of 5/1000 or 0.5%. The age-group from forty-five to sixty-two had an incidence of 46/1000 or 4.6%.

In a subsequent report four years later of the same sample population, the incidence for the male thirty to sixty-two year age-group had increased from 2.4% to 3.3%. When the sample was divided into age-groups, the male group age thirty to forty-four increased from 0.5% to 1.2%. In the age group forty-five to sixty-two, the male incidence increased from 4.6% to 5.8%.

Other studies of this nature demonstrated similar incidence of cardiovascular disease. From a preventive viewpoint, these studies also revealed similar coronary risk factors characteristic of cardiovascular disease-prone people. A composite of these major risk
factors as reported by Stamler et al.\textsuperscript{84} are (1) hypercholesterolemia, (2) hypertension, (3) obesity, (4) diabetes mellitus, (5) diet, (6) cigarette smoking, and (7) physical inactivity.

It is the concern centered around the risk factor dealing with physical inactivity which motivated this study. Research in this area on the national and international level has revealed a relationship between physical inactivity and cardiovascular disease. The study by Morris et al.\textsuperscript{68} compared relatively homogeneous socioeconomic groups engaging in different levels of physical activities, e.g. sedentary bus drivers and active conductors, and telephone operators and active postmen. The incidence of cardiovascular disease was lower in the more active groups than in the sedentary groups. Subsequent studies\textsuperscript{67, 68, 72, 78, 88} in England and the United States further verify the relationship of physical inactivity and cardiovascular disease.

In order to approach exercise and its relationship to cardiovascular disease, one needs a means of appraising fitness within safe exercise tolerance limits. The more popular methods currently in use to assess cardiovascular fitness are (1) maximum oxygen consumption,\textsuperscript{87} (2) Balke Treadmill Test,\textsuperscript{11} and (3) the Harvard Step Test.\textsuperscript{18} There are a number of problems associated with the administration of these tests. Both the Maximum oxygen consumption test and the Balke Treadmill Test require considerable fortitude on the part of the subject as they are required an all out effort. Also these tests require expensive and elaborate equipment as well as trained technicians. The Harvard Step Test has been criticized because in addition to being extremely
strenuous it causes localized fatigue and cramps in the large leg muscles. This is attributed to the high bench and immediate rapid cadence of the exercise.

Recent experimental data point out that a submaximal test might be a valid assessor of cardiovascular fitness. The findings of Harris and Porter indicate that the "heart-rate" deficit of early exercise might be developed as a possible index of performance, since it appears to parallel the oxygen debt. Balke et al. found a linear relationship between heart rate and workload up to a heart rate response of 160 beats per minute. Beyond this point, as workload and heart rate increased, the degree of relationship decreased. Billings et al. using the Balke Treadmill Test observed a very high correlation between the described score and the actual work performed (r=0.984 ± .002). Billings suggests that in future studies it may not be necessary to force test subjects to their limit of endurance in order to estimate their ability to tolerate maximal physical activity. His data indicate the time required to reach a pulse rate of 150 beats/minute is a valid indicator of the subject's capacity for more strenuous work.

Berggren and Christensen and others have also used the pulse rate as an index of metabolic rate for work periods of short duration. They found that in the range of activity from an oxygen consumption of 1 to 4 liters/minute, an increase of thirty ml of oxygen was equivalent to an approximate increase of 1 heart beat. Dill also found a linear relationship between the heart rate and oxygen consumption.
Statement of the problem

The purpose of this study was to construct a submaximal cardiovascular fitness test which will overcome some of the adverse criticisms of the more popular tests of the day. The test in its final form should meet to a significant degree the following criteria:

Scientific authenticity. To make certain that the test has been scientifically constructed and that it does an accurate job of measuring what it was designed to measure, it must be evaluated in terms of reliability, objectivity, and validity. Reliability and objectivity simply refer to the consistency of the test measurement whether it be the same examiner administering the same test twice to the same subject (reliability) or two examiners administering the test to the same subject (objectivity). A test has validity if it measures what it proports to measure. The results of the newly constructed test should demonstrate consistency in administrative results and should be significantly related to the accepted tests of cardiovascular endurance.

Administrative feasibility. In order for this test to be practical, it must be economical in terms of cost of equipment and time required for administration. Furthermore, little training should be necessary in learning to administer the test.

Application. The test must be useful in terms of application of test results. Application would include (1) determination of subjects who are below par in terms of cardiovascular fitness, (2) construction of a conditioning program based upon the subject's need, and (3) re-testing to determine if improvement has taken place.
Cardiovascular Fitness

Cardiovascular fitness refers to the functional response of the heart and blood vessels to activity. Although cardiovascular fitness, being relative, does not lend itself to a precise definition, it may be defined qualitatively by comparing the cardiovascular characteristics of a physically fit individual with those of a physically unfit individual:

<table>
<thead>
<tr>
<th>Physically fit</th>
<th>Physically unfit</th>
</tr>
</thead>
<tbody>
<tr>
<td>lower heart rate</td>
<td>higher heart rate</td>
</tr>
<tr>
<td>larger heart volume</td>
<td>smaller heart volume</td>
</tr>
<tr>
<td>larger stroke volume</td>
<td>smaller stroke volume</td>
</tr>
<tr>
<td>larger blood volume</td>
<td>smaller blood volume</td>
</tr>
<tr>
<td>lower systolic blood pressure during work</td>
<td>higher systolic blood pressure during work</td>
</tr>
<tr>
<td>less risk for coronary heart disease</td>
<td>greater risk for coronary heart disease</td>
</tr>
</tbody>
</table>

Taking into account these various factors, it is possible to determine how efficiently an individual can perform. Fitness for hard muscular work depends to a great extent on adaptations of the circulation. It has been shown that for a standard amount of moderate or submaximal work a fit subject is able to maintain a slower heart rate during work and to recover more quickly after work than a less fit individual. For maximum work, the fit and the unfit may attain the same maximum heart rate, but the fit subject is able to perform more work before he reaches that level. Such results demonstrate that heart rate measurements during and after exercise are of value in establishing distribution of normal individuals in regard to cardiovascular fitness.
Step tests to measure cardiovascular fitness have been experimented with since 1920 when C. C. Schnieder introduced the Schnieder Test. His original premise was that a cardiovascular fitness index could be determined by measuring post-exercise variables and comparing them with pre-exercise levels. Since then, many step tests have been developed utilizing similar or additional cardiovascular functions.

The Schnieder Test was devised during World War I to test whether or not aviators were functionally fit to fly. The six items comprising the test are:

1. Reclining pulse rate
2. Reclining systolic pressure
3. Standing pulse rate
4. Increase in pulse rate on standing
5. Blood pressure compared with reclining
6. Pulse rate immediately after exercise

The exercise consists of having the subject step up on a chair 18½ inches high five times in 15 seconds; count the pulse for 15 seconds immediately at the cessation of exercise; multiply this count by four. In the stepping procedure, the subject should stand with one
foot on the chair, he should continue to step up and down with the other foot; both feet should be on the floor at the end of the 15 seconds.

Continue taking the pulse in 15 second counts until the rate has returned to the normal standing rate. The time from the end of the exercise bout to the beginning of the first normal 15 second pulse count is the score. If the pulse rate has not returned to normal after two minutes, record the number of beats above normal. Compare the results to the established norms to obtain the subject's cardiovascular fitness.

The original Masters Two-Step Test consisted of ascending and descending two (2) steps nine (9) inches high twenty-two (22) inches wide a variable number of times in one and one half minutes. Blood pressure and pulse rate measured two (2) minutes after exercise are compared with pre-exercise blood pressure and pulse rate. The subject's CFI was determined by the time it took the blood pressure and pulse rate to return to normal.

In 1931, Tuttle introduced the Pulse-Ratio Test. Tuttle used the following procedures:

1. The resting pulse in sitting position is taken.
2. The male subject makes twenty (2) complete steps in one (1) minute (fifteen (15) for females) on a bench thirteen inches high.
3. Immediately after exercise, the subject sits down and the pulse is counted for two (2) minutes.
4. The total pulse for two (2) minutes is divided by the resting rate. This is called the first "pulse ratio."
5. The subject rests until the pulse returns to normal.
6. The subject again steps up and down for one (1) minute making thirty-five (35) to forty-five (45) complete steps on the bench.

7. Immediately after exercise, the subject sits down, and the pulse is counted again for two (2) minutes.

8. The pulse obtained in two (2) minutes is divided by the resting pulse. This is called the second "pulse ratio."

9. The number of steps to reach a "pulse ratio" of 2.5 is an index of fitness.

In 1943, Gallagher and Brouha and their associates developed the Harvard Step Test at the Harvard Fatigue Laboratory. This test was constructed for the purpose of measuring the ability of the body to adapt itself to and recover from strenuous exercise. Essentially, the test classifies people into three groups; least fit, fit, and most fit. The validity of the Harvard Step Test was determined by endurance running on the treadmill, maximum heart rate per minute, and blood lactate levels.

There are two (2) forms of the Harvard Step Test. They are the long and short form. In the long form, the subject steps up and down on a twenty (20) inch bench at a cadence of thirty steps per minute. He continues this work for as long as he can up to five (5) minutes. The pulse count is taken from one to one and one half, two to two and one half minutes, and three to three and one half minutes after the cessation of the exercise. The physical efficiency is computed from the following formula:

\[
\text{Index} = \frac{\text{duration of exercise in seconds} \times 100}{2 \times (\text{sum of the pulse counts in recovery})}
\]


The standards based on data obtained from 8,000 college students are as follows:

below 55 poor
55-64 low average
65-79 average
80-89 good
above 90 excellent

The short form of the Harvard Step Test consists of the same procedure as the long form, however, the pulse count is only taken from one to one and one half minutes after exercise. The scoring of the short form is as follows:

\[
\text{Index} = \frac{\text{duration of exercise in seconds \times 100}}{5.5 \times \text{pulse count}}
\]

Standards for the short form are:

below 50 poor
59-80 average
above 80 good

In the same year, Gallagher and Brouha also introduced the Step Test for High School Boys and the Step Test for High School Girls. These two tests are similar to the Harvard Step Test except for the following:

A. Boys

1. The surface area of each boy is calculated by the means of a momographic chart. The boys with less than 1.85 square meters are placed in group I and are tested on an 18 inch bench. The boys with a surface area of 1.85 square meters or more are placed in group II and are tested on a 20 inch bench.
2. The time limit is four minutes.
3. The score is calculated using the Harvard Step Test formula and compared to the four minute norms.

B. Girls
1. The step bench is reduced to 16 inches.
2. The time limit is four minutes.
3. The scores are calculated by the same formula as used in the Harvard Step Test and the results compared with the four minute norms.

In 1944, Taylor introduced the Maximum Pack Test of Exercise Tolerance. The Pack Test consists of an eighteen (18) inch bench with a cross bar mounted above the bench, the subject grasps the bar with the left hand and places the left foot on the bench. At the command "go" the subject comes to a vertical position on the bench, and continues the movement with his left foot at a rate of forty (40) steps a minute. Every thirty (30) seconds the subject changes legs without breaking rhythm. The subject starts with a 10-pound weight placed in a pack. Every two (2) minutes an additional 10 pounds is added, until the subject can no longer maintain the cadence.

The total exercise time is used—as the score.

In 1944, Karpovich and Associates developed the Test for Ambulatory Patients. There are two forms of the Karpovich Test. The first form or preliminary test consists of stepping up and down 12 times in thirty seconds on a twenty inch bench. If the subject passes the first form, then the progressive test is administered a day or two later. In the second form, the subject steps up and down at the rate
of 24 steps a minute for five minutes or until the subject cannot maintain the cadence, which ever comes first. The pulse is counted for thirty seconds in both tests beginning one minute after cessation of exercise. The pulse rate in recovery is the score and is compared to established norms.

In 1950, The Benke Test was developed. The test has two parts, the cardiovascular phase and the endurance phase. The cardiovascular phase consists of twenty step-ups in thirty seconds on an eighteen inch bench. The sitting pulse is counted before the exercise, and pulse rate counts are taken during the periods 5-20 seconds and 105-135 seconds after the completion of the step-ups. The cardiovascular score is computed as the total of the two post-exercise pulse rates. The endurance phase consists of the same exercise as in the cardiovascular phase, but the exercise is continued to exhaustion or to the point where the cadence can not be maintained. Scoring is based on the number of seconds a person can maintain the exercise.

Jung, in 1951, published a modification of the Harvard Step Test. In this modification, the "step-ups" are only half as fast as in the original test (fifteen per minute). The scoring is called the "cardiac recovery index" since emphasis is placed on how soon the heart rate of the subject returns to the initial heart rate.

In 1952, Welch and associates developed The Step Test. This modified step test is performed on a 9-inch step at the rate of 20 steps per minute, for a period of 10 minutes or less. The data needed for calculation of the PFI include (1) the duration of the exercise period, (2) the average respiratory rate during the exercise period, (3) the
total number of heartbeats for the first 3 minutes of recovery and (4) the total number of steps taken. The scoring is determined by the following formula:

$$PFI = \frac{\text{duration of exercise period} \times \text{number of step} \times 10,000}{\text{average exercise respiratory rate} \times \text{total heart rate for 3 minute recovery} \times \text{number of steps taken}}$$

In 1953, Ryhming modified the Harvard Step Test by attaching a hand bar to assist the subject in stepping up and down. All other components of the original test remain the same. They also modified the Pack Test by placing one-third of the subject's body weight for the duration of the test rather than starting with a 10 pound weight and adding 10 pounds every 2 minutes.

Again in 1955, Insull and associates published The Modified Harvard Step Test. This test is the same as the original Harvard Step Test except the duration of exercises is reduced to three minutes.

The most recent Step Test was introduced by Sloan in 1959. This test was developed for women and was also a modification of the Harvard Step Test. In this test the bench was reduced from twenty to seventeen inches but all other components of the test remained unchanged.

Summary

The majority of step tests are limited in application due to one or more of the following reasons:

1. overly strenuous
2. require extreme cooperation on the part of the subject
3. in many instances, expensive equipment and trained technicians are required
One must conclude, as a result of this related literature survey, there is a need for a submaximal, simple, and administratively feasible cardiovascular fitness test applicable to people eighteen to sixty years old in varying degrees of physical fitness.
CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to construct a submaximal test of cardiovascular fitness. In addition to developing the equipment and working out the test administration, reliability and validity were studied. Also to determine the strenuousness of the test, energy expenditure was measured on seven subjects using open circuit spirometry.

Description of the subjects

The sample group consisted of seventy-five subjects who were volunteers from among students (graduate and undergraduate), faculty, administration, custodians, and military personnel of The Ohio State University ranging in age from nineteen to fifty-six. The subjects had a mean (1) age of thirty-four, (2) height of 180 cm, and (3) weight of 83.1 Kgs. A breakdown of the age grouping and test scores appears in Table 1.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Number of Subjects</th>
<th>Mean Age</th>
<th>SD</th>
<th>Mean Innings</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-29</td>
<td>28</td>
<td>24.0</td>
<td>2.9</td>
<td>12.4</td>
<td>4.7</td>
</tr>
<tr>
<td>30-40</td>
<td>30</td>
<td>34.7</td>
<td>2.6</td>
<td>13.0</td>
<td>4.0</td>
</tr>
<tr>
<td>41-56</td>
<td>17</td>
<td>47.6</td>
<td>4.2</td>
<td>11.8</td>
<td>3.4</td>
</tr>
</tbody>
</table>

TABLE 1

NUMBER OF SUBJECTS, MEAN AGE AND SD, AND MEAN INNINGS AND SD FOR AGE GROUPS IN THE OHIO STATE UNIVERSITY STEP TEST
Methods

The initial thinking regarding the test construction problem required several considerations in order to meet the afore mentioned criteria (P. 4).

Exercise on a bench was first considered because: (1) easily and economically constructed; (2) workload constant and peculiar to the individual; (3) skill is not an important factor; and (4) as suggested by Patterson et al., an adjustable hand bar (level with the subject's head) to cause more complete body movement was included.

A second consideration was to develop a testing situation whereby the subject would not exceed a heart rate of 150 beats/minute during exercise. It was felt this would overcome serious risk factors thus permitting application of the test to a wider age range—hopefully to all men between ages eighteen and sixty regardless of fitness classification.

As a consequence of these primary considerations, the first attempt incorporated a fifteen-inch bench and a twenty-four step/minute cadence. The subject exercised for thirty seconds and rested for twenty seconds. During the middle ten seconds of the rest period, the subject counted his pulse at either the carotid or radial artery. He was then given the command to commence another thirty second period of exercise. This procedure, alternating exercise and rest continued until a ten-second pulse rate of twenty-five (150 beats/min. - $T_{150}$) was reached. The score for the test was recorded as the number of innings the subject exercised until reaching $T_{150}$. An inning is equivalent to exercise (thirty seconds) plus rest (twenty seconds) or fifty seconds.
Preliminary study required this first effort to be rejected because one subject in good condition, age seventy, after eighteen innings had a T132. As a result, the cadence was increased as follows: following six innings (five minutes) the cadence was increased to thirty steps/minute; at the end of another six innings (ten minutes) the cadence was adjusted to thirty-four steps/minute. This too was rejected because the subjects could not maintain the thirty-four step/minute cadence.

The third effort resulted in constructing a split-level bench. Alongside the fifteen-inch bench and joined was built a twenty-inch bench. (Figure 1) This set-up proved successful.

Administration of the Finalized Test

The equipment consists of a split-level bench fifteen and twenty inches high with an adjustable hand bar, a metronome, and a stop watch. (The test may be pre-recorded on tape which should be timed periodically to ensure accurate replication.)

The test comprises eighteen innings of fifty seconds duration (total fifteen minutes). Each inning is divided into a thirty second work period and a twenty second rest period. During the twenty second rest period, the subject's pulse is taken for ten seconds beginning with second "five" and stopping at second "fifteen." The test is terminated when the pulse rate reaches twenty-five beats (150 beats/min.) and/or the subject completes the entire eighteen innings. Scoring is the number of innings completed. There are three different workloads as follows:

Phase I consists of six innings at twenty-four step cadence/minute on the fifteen inch bench.
FIGURE 1

THE OHIO STATE UNIVERSITY STEP TEST SPLIT-LEVEL BENCH
Phase II consists of six innings at thirty step cadence/minute on the fifteen inch bench.

Phase III consists of six innings at thirty step cadence/minute on the twenty inch bench. Phases I, Phase II, and III are continuous.

**Test instructions**

The hand bar is adjusted to the height of the subject, he is then given the following instructions: "Grasp the bar with both hands and step up and down in cadence with the metronome. You will stop at a given command and count your pulse; if you have trouble counting your pulse, I will do it for you. To acquaint you with the procedures I am going to let you first listen to a complete inning. Be aware of the cadence and instructions as to the exact moment you are to begin counting your pulse and the point which you are to stop. When your pulse count reaches twenty-five for the ten second period, the test will be terminated. The inning in which it occurs will be your score."

The subject stands in front of the fifteen-inch platform grasping the hand bar with both hands. When the commands "ready" and "up" are given by the examiner, the subject places one foot on the platform and straightens his legs and back and immediately steps down again, one foot at a time. The pace "up" "up" "down" "down" is given every two and one half seconds. At the end of thirty seconds, the commands "stop" and "find your pulse" are given.

Exactly at five seconds of the rest period the examiner commands "count" and at fifteen seconds of the rest period the examiner commands "stop" and "prepare to exercise." Record the number of beats counted during the ten second period. Continue this procedure for six innings (or until a pulse rate of 150 is reached).
After the ten second pulse count and prior to the seventh inning, inform the subject that the cadence will be increased and continue the same procedure. The thirty step cadence/minute during the seventh through the twelfth inning requires that the commands "up" "up" "down" "down" be given every two seconds.

After the ten second pulse count and prior to the thirteenth inning, inform the subject to move over to the twenty-inch bench. Continue the thirty step cadence/minute during the thirteenth through the eighteenth inning.

The endpoint of the test is the eighteenth inning or when the subject reaches a heart rate of twenty-five beats in the ten second pulse count (150 beats/minute), which ever occurs first. The minimum and maximum time for the test is fifty seconds and fifteen minutes respectively.

Usually it is easier for the subject to lead off with the same foot each time and not try to alternate the feet. However, alternating can be done during the test if one leg becomes tired. The examiner must be sure that the subject steps completely onto the platforms during the test. No crouching should be permitted.

Reliability. Twenty-four of the seventy-five subjects repeated the test on successive days so as reliability could be determined. The mean vital data of the twenty-four subjects are summarized in Table 2.
TABLE 2

MEAN, RANGE, AND SD OF VITAL DATA ON TWENTY-FOUR SUBJECTS, IN THE RELIABILITY STUDY

<table>
<thead>
<tr>
<th>Number of Subjects</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>31.54</td>
<td>180.23 cm</td>
<td>81.55 Kgs.</td>
</tr>
<tr>
<td>24 Range</td>
<td>19-56</td>
<td>165.10-190.50 cm</td>
<td>61.7-104.4</td>
</tr>
<tr>
<td>SD</td>
<td>9.26</td>
<td>7.00</td>
<td>10.55</td>
</tr>
</tbody>
</table>

Validity. Thirty of the seventy-five subjects ranging in age nineteen to fifty-six were tested on both the OSU Step Test and at another day in the Balke Treadmill Test. The mean vital data on the thirty subjects in the validity study are summarized in Table 3.

TABLE 3

MEAN, RANGE, AND SD OF VITAL DATA ON THIRTY SUBJECTS IN THE VALIDITY STUDY

<table>
<thead>
<tr>
<th>Number of Subjects</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.93</td>
<td>179.32 cm</td>
<td>81.16</td>
</tr>
<tr>
<td>30 Range</td>
<td>19-56</td>
<td>165.1-190.50 cm</td>
<td>61.7-104.4</td>
</tr>
<tr>
<td>SD</td>
<td>9.33</td>
<td>7.48</td>
<td>9.46</td>
</tr>
</tbody>
</table>

The Balke Treadmill Test was used as the criterion measure in this study for the following reasons:

1. it is a test requiring maximal effort

2. Billings et al., using the Balke Test found (a) the scores on the Balke Test accurately described the work performed and (b) the time to reach $T_{150}$ reading to be a valid indicator of the subject's capacity for more strenuous work.
3. Age-range in the Balke Test Subjects is similar to the age-range of the subjects in the OSU Test.

4. The Balke is applicable to a wide age-range of people regardless of fitness classification.

5. Validity for the Balke Test is claimed on the basis that a number of discernible physiological changes occur during a given exercise when the heart rate reaches 180 beats per minute. At this point, the RQ exceeds 1, pulse pressure and oxygen pulse become maximal, and there is a sharp rise in respiratory frequency and minute volume, together with a sudden drop in alveolar carbon dioxide tension. At about this time blood lactate levels begin to rise sharply, indicating the inability of the physiological reserves to keep pace with the increased metabolic needs resulting from exercise.

The test consists of having a subject walk at a constant speed on a treadmill, the slope of which is increased each minute, and measuring heart rate each minute. The test results are reported in terms of the duration of exercise to produce a heart rate of 180 beats/minute (T₁₈₀). The test requires a treadmill, a stop watch, and an electrocardiograph for measuring the heart rate.

**Measurement of oxygen consumption.** To lend better understanding in regard to the physiological demands of the OSU Step Test, energy cost was measured. This was done using the method of open circuit spirometry. Data were also gathered so as a comparison could be made between performing the exercise with and without the hand bar during all three phases.

Oxygen consumption was measured while each subject performed the step test during the last 3 innings of each phase. A breast plate was
strapped to each subject which held the mouth piece into which the subject breathed. A nose clamp was used to allow breathing only through the mouth. The expired air was collected in Douglas Bags. A Hanhart, Model #15, stop watch was used to time the interval for collection of expired air. Per cent of oxygen and carbon dioxide in the exhaled air was determined by analyzing samples in a Beckman Model E. 2 Oxygen Analyzer and Beckman Medical Gas Analyzer Spinco Model LB-1 respectively.

Seven subjects at random were selected for the energy cost study. The physical condition of the subjects ranged from poor to excellent as measured by the OSU Step Test and the Balke Treadmill Test. The mean vital data of the seven subjects are summarized in Table 4.

<table>
<thead>
<tr>
<th>TABLE 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN VITAL DATA OF THE SEVEN SUBJECTS IN THE ENERGY COST STUDY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Subjects</th>
<th>Mean Age</th>
<th>Mean Height</th>
<th>Mean Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>26.57</td>
<td>180.16</td>
<td>79.31</td>
</tr>
</tbody>
</table>

Samples of expired air were drawn from the Douglas Bags into a football type bladder, and analyzed for per cent oxygen and carbon dioxide. The remaining expired air in the Douglas Bags was drawn into a 120 litre Collins Chain Compensated Spirometer. The expired volume was measured by reading directly from the spirometer meter stick before and after each collection and the volume of the analyzed sample added.
The gas temperature was recorded in C° immediately after collection and barometric pressure recorded prior to sample collection. Data were corrected to STPD.

Procedure

The subjects were requested to come dressed in the following attire: (1) trunks, (2) athletic supporter, (3) wollen socks, and (4) tennis shoes. The following information was recorded for each subject: (1) name, (2) age, (3) height, (4) weight, (5) room temperature, and (6) blood pressure. Subjects were rejected for the following reasons: (1) diastolic blood pressure exceeding 95 mm of mercury, (2) those under medical treatment utilizing drugs, (3) surgical convalescents, and (4) those constituting a liability risk.

Heart rate. After the preliminary information of the subject was obtained and recorded. The hand bar was adjusted to head level. Then, a Sanborn Visc Cardette Model 51 Standard Electro-cardiograph was used to record heart rates. Four direct leads from the electro-cardiograph were attached to electrodes placed on the subject's chest and back. The electrodes were held securely in place by a flexible elastic strap designed for this purpose. The leads on the subject's back corresponded to the leads which would normally be placed on the subject's legs and the leads on the chest corresponded to leads placed on the subject's wrists. The reason for the direct leads was to establish reliability of the subject's ability to count his pulse as specified under the test directions. Also recordings were made following exercise at the following times: 30" to 1', 1' to 1'30", 2' to 2'30", and 3' to 3'30".
Test procedure. Each subject was permitted an opportunity to hear one inning on the tape recorder. Following this the test was administered as previously described (P. 16). At the conclusion of the exercise the recovery heart rates were recorded while the subject was seated.
CHAPTER IV

STATISTICAL ANALYSIS

As this was a problem in test construction studies dealing with reliability and validity were of paramount importance. To lend better understanding regarding the strenuosity (of the finalized cardiovascular test), metabolic studies were also conducted.

Reliability

Twenty-four subjects were given a test-retest sequence on different days to establish test reliability. The mean for the first test was 13.08 innings with a SD of 4.09. The mean for the retest was 13.92 innings with a SD of 3.54. The linear coefficient of correlation was 0.9452. The data are summarized in Table 5.

TABLE 5

SUMMARY OF DATA ON TEST RELIABILITY

<table>
<thead>
<tr>
<th>Test</th>
<th>Number of Subjects</th>
<th>Mean (Innings)</th>
<th>SD</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>24</td>
<td>13.08</td>
<td>4.09</td>
<td>0.9452</td>
</tr>
<tr>
<td>Retest</td>
<td>24</td>
<td>13.92</td>
<td>3.54</td>
<td></td>
</tr>
</tbody>
</table>
Validity

Using the Balke Treadmill Test, thirty subjects participated in the study to establish validity. The mean score in innings for the step test was 14.90 (circa 12.4 minutes of exercise) with a SD of 2.89. The mean score in minutes for the Balke Treadmill Test was 16.93 with a SD of 3.19. The linear coefficient of correlation between the step test and the Balke Test was 0.9460. The data on validity are summarized in Table 6.

TABLE 6

<table>
<thead>
<tr>
<th>Test</th>
<th>Number of Subjects</th>
<th>Means</th>
<th>SD</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSU Step Test</td>
<td>30</td>
<td>14.90</td>
<td>2.89</td>
<td>0.9460</td>
</tr>
<tr>
<td>Balke Test</td>
<td>30</td>
<td>16.93</td>
<td>3.19</td>
<td></td>
</tr>
</tbody>
</table>

Metabolic Study

In order to gain better insight in regard to the physiologic effects of the test on the individual a number of metabolic computations were made: (1) a comparison of energy cost of performing the test with and without the adjustable hand bar; (2) the relationship of energy cost with useful work performed; and, (3) the relationship of energy cost with heart rate.

**Energy cost with and without handbar**

Table 7 contains means and standard deviations in liters per minute for each of the two methods of performing the step test. The
use of the handbar results in a decreased cost of the exercise. Because of the small number of cases (7) one must reject the null hypothesis at the .10 level of confidence.

TABLE 7
COMPARISON OF MEANS BETWEEN THE STEP TEST WITH AND WITHOUT THE ADJUSTABLE HAND BAR

<table>
<thead>
<tr>
<th>Test</th>
<th>Number of Subjects</th>
<th>Means of Innings</th>
<th>Means of Innings</th>
<th>Means of Innings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4-5-6</td>
<td>10-11-12</td>
<td>16-17-18</td>
</tr>
<tr>
<td>W/O Bar</td>
<td>7</td>
<td>1.66 L/Min.</td>
<td>2.03 L/Min.</td>
<td>2.58 L/Min.</td>
</tr>
<tr>
<td>With Bar</td>
<td>7</td>
<td>1.55 L/Min.</td>
<td>1.90 L/Min.</td>
<td>2.44 L/Min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P = &gt; .10</td>
<td>P = &gt; .10</td>
<td>P = &gt; .10</td>
</tr>
</tbody>
</table>

Figure 2 portrays these data graphically for the respective innings. As can be observed from this graph the exercise with the hand bar results in a lower cost of energy for each of the three phases. As the exercise becomes more difficult, the difference between the two methods becomes greater. The mean differences for Phases I, II, and III respectively are as follows 111.7 ml., 128.0 ml., and 144.5 ml. of oxygen per minute.

Energy cost and useful work performed

The relationship between energy expenditure and the vertical lift (obtained by multiplying the weight of the subject times the height he lifted himself) in performing the OSU Step Test resulted in a correlation coefficient of .895; the standard error of the slope is 0.112. These data along with the regression equation are plotted in Figure 3.
FIGURE 2
MEAN AND SD OF $\dot{V}_{O_2}$ ML/KG/MIN/INNING ON 7 SUBJECTS WITH AND WITHOUT ADJUSTABLE HANDBAR

Without Handbar

With Handbar

N = 7

INNINGS
FIGURE 3
RELATIONSHIP OF $V_O_2$ ML/MIN (WITH BAR) TO VERTICAL LIFT (7 SUBJECTS, 61 PLOTS)

$Y = 1.74X + 330$

$r = 0.895$

FIGURE 4
RELATIONSHIP OF $V_O_2$ ML/MIN (WITH BAR) TO HEART RATE (7 SUBJECTS, 61 PLOTS)

$Y = 13.47X + 330$

$r = 0.731$
<table>
<thead>
<tr>
<th>Height/Cadence</th>
<th>Time</th>
<th>Useful Work</th>
<th>Pulse Rate</th>
<th>O2 Used</th>
<th>Pulse Ventilation</th>
<th>Ventilation Equivalent for O2</th>
<th>Oxygen Pulse</th>
<th>R</th>
<th>Kcal/LO₂</th>
<th>Kcal/Min</th>
<th>Kgm/Min</th>
<th>E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15&quot;/24</td>
<td>4a</td>
<td>727.7</td>
<td>98</td>
<td>1548.2</td>
<td>32.6</td>
<td>21.2</td>
<td>15.8</td>
<td>.768</td>
<td>4.761</td>
<td>7.275</td>
<td>3164.82</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>4b</td>
<td>727.7</td>
<td>106</td>
<td>1680.8</td>
<td>36.5</td>
<td>21.8</td>
<td>15.9</td>
<td>.812</td>
<td>4.814</td>
<td>7.463</td>
<td>3185.06</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>5a</td>
<td>727.7</td>
<td>99</td>
<td>1576.3</td>
<td>33.9</td>
<td>21.7</td>
<td>15.9</td>
<td>.793</td>
<td>4.792</td>
<td>7.552</td>
<td>3223.04</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>5b</td>
<td>727.7</td>
<td>108</td>
<td>1657.7</td>
<td>35.6</td>
<td>21.6</td>
<td>15.3</td>
<td>.802</td>
<td>4.803</td>
<td>7.973</td>
<td>3402.72</td>
<td>24</td>
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<tr>
<td></td>
<td>6a</td>
<td>727.7</td>
<td>106</td>
<td>1665.6</td>
<td>38.8</td>
<td>22.2</td>
<td>15.3</td>
<td>.822</td>
<td>4.828</td>
<td>7.454</td>
<td>3181.22</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>6b</td>
<td>727.7</td>
<td>108</td>
<td>1544.4</td>
<td>35.2</td>
<td>22.8</td>
<td>15.4</td>
<td>.822</td>
<td>4.828</td>
<td>8.063</td>
<td>3441.13</td>
<td>21</td>
</tr>
<tr>
<td>15&quot;/30</td>
<td>10a</td>
<td>900.5</td>
<td>117</td>
<td>1921.4</td>
<td>43.3</td>
<td>22.6</td>
<td>16.4</td>
<td>.844</td>
<td>4.855</td>
<td>9.326</td>
<td>3980.15</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>10b</td>
<td>900.5</td>
<td>124</td>
<td>2055.6</td>
<td>47.4</td>
<td>23.2</td>
<td>16.6</td>
<td>.868</td>
<td>4.884</td>
<td>10.061</td>
<td>4293.83</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>11a</td>
<td>900.5</td>
<td>123</td>
<td>1872.4</td>
<td>43.9</td>
<td>23.5</td>
<td>15.2</td>
<td>.857</td>
<td>4.871</td>
<td>9.116</td>
<td>3891.81</td>
<td>23</td>
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<tr>
<td></td>
<td>11b</td>
<td>900.5</td>
<td>124</td>
<td>2023.7</td>
<td>49.3</td>
<td>24.5</td>
<td>16.3</td>
<td>.883</td>
<td>4.903</td>
<td>9.904</td>
<td>4226.83</td>
<td>21</td>
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<tr>
<td></td>
<td>12a</td>
<td>900.5</td>
<td>124</td>
<td>1916.3</td>
<td>45.8</td>
<td>24.0</td>
<td>15.5</td>
<td>.848</td>
<td>4.860</td>
<td>9.312</td>
<td>3974.18</td>
<td>23</td>
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<tr>
<td></td>
<td>12b</td>
<td>900.5</td>
<td>126</td>
<td>2012.1</td>
<td>49.2</td>
<td>24.5</td>
<td>15.9</td>
<td>.875</td>
<td>4.893</td>
<td>9.835</td>
<td>4197.38</td>
<td>21</td>
</tr>
<tr>
<td>20&quot;/30</td>
<td>16a</td>
<td>1200.7</td>
<td>143</td>
<td>2442.3</td>
<td>57.5</td>
<td>23.6</td>
<td>17.1</td>
<td>.881</td>
<td>4.900</td>
<td>11.966</td>
<td>5106.85</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>16b</td>
<td>1200.7</td>
<td>150</td>
<td>2561.0</td>
<td>63.6</td>
<td>24.9</td>
<td>17.1</td>
<td>.926</td>
<td>4.960</td>
<td>12.698</td>
<td>5419.25</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>17a</td>
<td>1200.7</td>
<td>144</td>
<td>2422.2</td>
<td>56.9</td>
<td>23.5</td>
<td>16.8</td>
<td>.872</td>
<td>4.889</td>
<td>11.841</td>
<td>5053.50</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>17b</td>
<td>1200.7</td>
<td>154</td>
<td>2607.5</td>
<td>63.8</td>
<td>24.5</td>
<td>16.9</td>
<td>.915</td>
<td>4.942</td>
<td>12.899</td>
<td>5505.04</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>18a</td>
<td>1200.7</td>
<td>149</td>
<td>2450.5</td>
<td>58.7</td>
<td>24.0</td>
<td>16.4</td>
<td>.895</td>
<td>4.918</td>
<td>12.049</td>
<td>5142.27</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>18b</td>
<td>1200.7</td>
<td>158</td>
<td>2579.4</td>
<td>64.2</td>
<td>24.9</td>
<td>16.3</td>
<td>.936</td>
<td>4.968</td>
<td>12.817</td>
<td>5470.04</td>
<td>22</td>
</tr>
</tbody>
</table>
Energy cost and heart rate

Figure 4 contains the graphic representation for the correlation between $V_{O_2}$ L/Min. and heart rate ($r = 0.7312$). Also appearing in Figure 4 is the regression equation describing the slope of the line and the standard error.

Summary of metabolic data

Table 8 contains a summary of the metabolic data showing a comparison of the step test with and without the adjustable handbar. One might conclude from the tabled data that: (1) it is easier to work with than without the handbar; (2) the test does not over stress the individual; (3) the exercise commences gradually, so even those in poorest condition can be evaluated and it builds up to a more strenuous exercise so that even the highly fit can be measured; (4) the third phase is definitely lactate producing hence requiring the subject to draw upon his anaerobic reserves; and (5) the mechanical efficiency remains quite constant even at the more strenuous work loads.

Discussion

The need for a valid cardiovascular test which meets the aforementioned criteria is unequivocal. The finalized Ohio State University Step Test has been scientifically developed and may serve a need growing out of the increased interest relating particularly to coronary artery disease among men. The test is somewhat unique in that the subject exercises for a thirty-second period, stops for twenty seconds during which time he counts his pulse. A ten-second pulse count is taken
following each thirty seconds of exercise to insure the subject
does not exceed 150 beats per minute.

Preliminary studies have shown that a design in which the sub-
ject had time to stop exercising, find his pulse at either the Radial
or Carotid Artery, and to count his pulse for ten seconds within
fifteen seconds after exercise was most suitable. A comparison of an
EKG during the last ten seconds of exercise with (1) the subject's
counted pulse during the ten seconds after exercise and (2) an EKG of
the subject's heart rate during the ten seconds following exercise
showed that the count obtained after exercise was consistent with the
pulse rate of exercise if only the QRS complex was counted on the EKG.
These results concur with the findings of Dill, LeBlanc, and
Consolazio.

In a more careful study of the test-retest data it was ob-
served those who were tested and retested on successive days had more
identical scores than those subjects experiencing a delay of one to four
weeks. The least identical scores were observed in those who were
actively engaged in a conditioning program and had an elapsed time of
two weeks or more between tests. However, this observation does provide
some useful information in that the test is apparently sensitive to
changes in Cardiovascular fitness.

In arriving at scores for the correlation, it should be pointed
out that three of the thirty subjects who were highly conditioned com-
pleted the twenty innings of the step test without reaching a heart
rate of 150 beats per minute. These same three subjects also exceeded
the established normative times for the Balke Treadmill Test.
correlation purposes, the three were arbitrarily assigned twenty-one innings on the step test and twenty-three minutes on the Balke Test.

The idea to reduce the step test to six innings in phase three was conceived at this point for the following reasons: (1) the difference of two in the raw scores between the inning score of the step test and the minute score of the Balke Test was consistent; and (2) the 90th percentile fell at the eighteenth inning which correlates with the normative minute that describes the subjects' condition as "very good" on the Balke Test. One could readily ascertain that a subject who completes the eighteenth inning with less than a heart rate of 150 beats per minute would score excellent on the Balke Test.

The metabolic studies revealed that the step test without the adjustable handbar was more strenuous than the test with the handbar. Apparently the ability to rest the arms on the bar resulted in a lesser cost for the exercise. This is in opposition to the views held by Patterson and associates who conjectured use of the hand bar brought into play the upper shoulder girdle region to a greater extent. Even though the exercise is less strenuous than without the hand bar the cost indicates the subjects must make use of anaerobic reserves. This contributes further to the validity of the test.

Additional evaluation of the work performed in doing the step test was motivated by studies of Margaria. Figure 6 graphically portrays a plot of the cost of the exercise in Kg-M/min, against the cost in $V_{O_2}$. The two lower lines (A, B) represent the regression equations for data obtained in doing the step test with and without the hand bar. The upper line (C) is obtained by multiplying Margaria's constant times
FIGURE 5
RELATIONSHIP OF $\dot{V}_O_2$ ML/MIN (WITHOUT BAR) TO VERTICAL LIFT

$Y = 1.88X + 327$
$S_b = 0.114$
$r = 0.095$

FIGURE 6
PREDICTED AND ACTUAL COST OF STEPPING EXERCISE WITH AND WITHOUT HAND BAR

With bar
$Y = 2.73X$

Without bar
$Y = 1.74X + 330$

Predicted
$Y = 1.88X + 327$
the actual work (vertical lift) to obtain a predicted $\dot{V}_{O_2}$. It should be observed the constant 5.7 as reported by Margaria to be used in computing Kg-M/min of predicted work has been mathematically reduced to 2.73 so as predicted work might be expressed as $\dot{V}_{O_2}$.

From Figure 6 the two lower regression equations (A,B) representing actual data, posses nearly the identical intercepts (330 and 327 ml of oxygen). These intercepts represent quite accurately the resting values for $O_2$ consumption. The data (gross cost of exercise) depicting the exercise without the bar (B) are in good agreement with those of Norris and Shock.

It is apparent Margaria's predictive value of 2.73, even assuming it is based upon gross cost is much too high. Further evidence of this exaggerated prediction is manifested in the fact the computed data and efficiency of the exercise for this study are in agreement with other authors. Also when comparing data obtained from riding a bicycle ergometer which is predominately a leg exercise the predictive values from slope B is in excellent agreement with the obtained data. For example, one subject who participated in the OSU Step Test obtained a work output in terms of vertical lift of 845.8 Kg-M/minute, his actual $V_{O_2}$ was 1916.2 ml (Figure 5) and his predicted value from line B was 1919.3 ml. While riding the bicycle ergometer at 1162.4 Kg-M/min (190W) his actual cost was 2,590 ml. From line B his predicted cost would be 2,512 ml. It seems the regression equation of $Y = 1.88X + 327$ may be employed quite satisfactorily in predicting gross $V_{O_2}$ either on a step test or while riding a bicycle ergometer.
The use of recovery heart rates in reflecting cardiovascular condition during submaximal work proved to be of little value. Heart rates were recorded at the following times: (1) 30" to 1', (2) 1' to 1'30", (3) 2' to 2'30", and (4) 3' to 3'30". Heart rates recorded during these times as well as the total of the four recovery measurements were correlated with the Balke Treadmill Test results. The significant but low correlations using thirty subjects ranged between .4295 to .5051. As a consequence one might consider the additional time required to take recovery heart rates does not add significantly to the value of the finalized test.
CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to construct a submaximal test of cardiovascular fitness. In addition to developing the equipment and working out the test administration, reliability and validity were studied. Also to determine the strenuosity of the test, energy expenditure was measured on seven subjects using open circuit spirometry.

Description of the subjects

The sample group consisted of seventy-five subjects who were volunteers from among students (graduate and undergraduate), faculty, administration, custodians, and military personnel of Ohio State University ranging in age from nineteen to fifty-six. Average age, height and weight of the subjects was as follows: (1) thirty-four years, (2) 180 cm, and (3) 83.1 kgs. respectively.

Reliability and validity

Twenty-four of the seventy-five subjects repeated the test on successive days so as reliability could be determined (.9452). Thirty of the seventy-five subjects ranging in age nineteen to fifty-six were tested on both the Ohio State University Step Test and at another day in the Balke Treadmill Test to establish validity (r = .9460).
Measurement of oxygen consumption

To lend better understanding in regard to the metabolic demands of the Ohio State University Step Test, energy cost was measured. This was done using the method of open circuit spirometry. Data were also gathered so as a comparison could be made between performing the exercise with and without the hand bar during all three phases.

Oxygen consumption was measured while seven subjects, ranging in physical condition from poor to excellent as measured by the Balke and Ohio State University Step Test, performed the step test during the last three innings of each phase. A breast plate was strapped to each subject which held the mouth piece into which he breathed. A nose clamp was used to allow breathing only through the mouth. The expired air was collected in Douglas Bags and quantitated by forcing the gas into a 120 Liter Tissot type spirometer. A Hanhart, Model #15, stop watch was used to time the interval for collection of expired air. Percent of oxygen and carbon dioxide in the exhaled air was determined by analyzing samples in a Beckman Model E 2 Oxygen Analyzer and Beckman Medical Gas Analyzer Spinco Model L B-1 respectively.

Procedure

The subjects were required to come dressed in the following attire: (1) trunks, (2) athletic supporter, (3) woolen socks, and (4) tennis shoes. The following information was recorded for each subject: (1) name, (2) age, (3) height, (4) weight, (5) room temperature, and (6) blood pressure. Subjects were rejected for the following reasons: (1) diastolic blood pressure exceeding 95 mm of mercury, (2) those under
medical treatment utilizing drugs, (3) surgical convalescents, and (4) those constituting a liability risk.

Heart rate. After the preliminary information of the subject was obtained and recorded, the hand bar was adjusted to head level. Then a Sanborn Visco Cardiette Model 51 Standard Electrocardiograph was used to record heart rates. Four direct leads from the electrocardiograph were attached to electrodes placed on the subject's chest and back. The electrodes were held in place by a flexible elastic strap designed for this purpose. The leads on the subject's back corresponded to the leads which would normally be placed on the subject's legs and—the leads on the chest corresponded to leads placed on the subject's wrists. The reason for the direct leads was to establish reliability of the subject's ability to count his pulse as specified under the test directions. Also recordings were made at 30" to 1'; 1' to 1'30"; 2' to 2'30"; and 3' to 3'30" while the subject was seated following the exercise.

The Ohio State University
Step Test

The Ohio State University Step Test is a submaximal cardiovascular test devised to estimate the fitness of men eighteen years and up. The test is based on the findings that the time to reach a heart-rate of 150 beats/minute is a valid indicator of a subject's cardiovascular capacity for exhaustive work.

Test administration. The equipment consists of a split-level bench 15 and 20 inches high with an adjustable hand bar, a metronome, and a stopwatch (Figure 1). The test may be pre-recorded on a tape recorder or dictaphone. The tape should be timed periodically to ensure accurate replication.
The test comprises 18 innings of 50 seconds duration (total, 15 minutes). Each inning is divided into a 30-second work period and a 20-second rest period. During the 20-second rest period, a pulse count is taken for 10 seconds beginning with second 5 and stops at second 15. The test is terminated when the pulse rate reaches 25 beats (150/beats minute) or when the subject completes the entire 18 innings. Scoring is number of innings completed. There are three different work loads as follows:

1. Phase I consists of 6 innings at 24 step cadence/minute on the 15-inch bench.

2. Phase II consists of 6 innings at 30 step cadence/minute on the 15-inch bench.

3. Phase III consists of 6 innings at 30 step cadence/minute on the 20-inch bench. Phase I, II and III are continuous.

Adjust the hand bar to the height of the subject.

The subject is given the following instructions: "Grasp the bar with both hands and step up and down in cadence with metronome. You will stop at a given command and count your pulse; if you have trouble counting your pulse, I will do it for you. To acquaint you with the procedures, I am going to let you first listen to a complete inning. Be aware of the cadence and instructions as to the exact moment you are to begin counting your pulse and the point which you are to stop. When your pulse count reaches 25 for the 10-second period, the test will be terminated. The inning in which it occurs will be your score."

The subject stands in front of the 15-inch platform, grasping the bar with both hands. When the commands "ready" and "up" are given by the
examiner, the subject places one foot on the platform and straightens his leg and back and immediately steps down again, one foot at a time. The pace "up" "up" "down" "down" is given every 2½ seconds. At the end of 30 seconds, the commands "stop" and "find your pulse" are given.

Exactly at 5 seconds of the rest period the examiner commands "count" and at fifteen seconds into the rest period the examiner again commands "stop" and "prepare to exercise." Record the number of beats counted during the 10-second period. Continue this procedure for 6 innings (or until a pulse rate of 150 is reached).

After the 10-second pulse count and prior to the 7th inning, inform the subject that the cadence will be increased and continue the same procedure. The 30-step cadence/minute during the 7th through 12th inning requires that the commands "up" "up" "down" "down" be given every 2 seconds.

After the 10-second pulse count and prior to the 13th inning, inform the subject to move over to the 20-inch platform. Continue the 30-step cadence/minute during the 13th through the 18th inning.

The endpoint of the test is the 18th inning or when the subject reaches a heartrate of 25 beats in the 10-second pulse count (150 beats/minute), whichever occurs first. The minimum and maximum time for the test is 50 seconds and 15 minutes respectively.

Usually it is easier for the subject to lead off with the same foot each time and not try to alternate the feet. However, alternating can be done during the test if one leg becomes tired. The examiner must be sure that the subject steps completely onto the platform during the test. No crouching should be permitted.
Scoring. The subject's score is the inning in which his heart rate reaches 150 beats/minute (25 beats during the 10-second pulse count).

Conclusions

Within the limitations of this study, the following conclusions are justified:

1. The finalized Ohio State University Step Test meets the requirements of being reliable and valid. Furthermore, the test is easy to administer, does not require elaborate equipment, or considerable technical skill.

2. It does not overstress the individual and at the same time reflects to a significant degree a person's cardiovascular capacity for exhaustive work.

3. The exercise commences gradually, so even those in poor condition can be evaluated; and it builds up to a more strenuous exercise so that even the highly fit can be measured.

4. Scoring is simple.

5. The test has an unique feature in that it has a built-in safety factor by terminating when the subject's heart rate reaches 150 beats per minute.

6. The 16th, 17th, and 18th innings are lactate producing requiring the subject to employ his anaerobic reserves.

7. The efficiency remains constant throughout the eighteen innings.
8. The regression equation \( Y = 1.88X + 327 \) is useful in predicting energy expenditure or gross energy expenditure from work done (vertical lift). It appears to be equally accurate in predicting energy expenditure on riding a bicycle ergometer.

9. Post exercise heart rates appear to contribute little towards validity of the test.

10. The test appears useful not only in measuring the least fit and highly fit but subjects between the ages of nineteen to fifty-six.
APPENDIXES
TABLE 9
INDIVIDUAL $V_{O2}$ ML/MIN. DURING INNINGS 4, 5, 6, 10, 11, 12, 16, 17, and 18

<table>
<thead>
<tr>
<th>Weight in Kgs.</th>
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<th>5</th>
<th>6</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>16</th>
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<td>2030.5</td>
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WITH BAR

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</table>

a = collection aborted because of mechanical failure
b = subject's mouthpiece fell out
BIBLIOGRAPHY
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