The Validity of a Submaximal Cardiovascular Step Test for Women.

Eva Jean Lee

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THE VALIDITY OF A SUBMAXIMAL CARDIOVASCULAR
STEP TEST FOR WOMEN

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Education
in
The Department of Health, Physical
and Recreation Education

by
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B.S., North Texas State University, 1962
M.Ed., Sam Houston State University, 1967
December, 1974
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# TABLE OF CONTENTS

**LIST OF TABLES**  

**LIST OF FIGURES**  

**Chapter**  

**I. INTRODUCTION**  

- STATEMENT OF THE PROBLEM  
- PURPOSE OF THE STUDY  
- SIGNIFICANCE OF THE STUDY  
- DELIMITATIONS OF THE STUDY  
- LIMITATIONS OF THE STUDY  
- DEFINITION OF TERMS  

**II. REVIEW OF RELATED LITERATURE**  

- DIRECT MEASURES OF OXYGEN CONSUMPTION  
- SUBMAXIMAL CARDIOVASCULAR FITNESS TESTS  
- SUMMARY  

**III. PROCEDURE OF THE STUDY**  

- OVERVIEW  
- SELECTION OF SUBJECTS  
- ADMINISTRATION OF THE SUBMAXIMAL STEP TEST  
  - Selection of Cadence  
  - Selection of Heart Rate Criteria  
  - Step Test Equipment  
  - Step Test Administration
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQUIPMENT FOR THE BALKE TREADMILL TEST AND MAXIMUM OXYGEN UPTAKE</td>
<td>44</td>
</tr>
<tr>
<td>Equipment</td>
<td>44</td>
</tr>
<tr>
<td>PROCEDURES FOR ADMINISTRATION OF THE BALKE TREADMILL TEST AND SIMULTANEOUS MAXIMUM OXYGEN UPTAKE</td>
<td>54</td>
</tr>
<tr>
<td>Administration of the Balke Treadmill Test</td>
<td>56</td>
</tr>
<tr>
<td>Procedure for Determining Maximum Oxygen Uptake</td>
<td>57</td>
</tr>
<tr>
<td>ANALYSIS OF DATA</td>
<td>63</td>
</tr>
<tr>
<td>IV. PRESENTATION AND ANALYSIS OF DATA</td>
<td>64</td>
</tr>
<tr>
<td>ANALYSIS OF TARGET HEART RATES AND THE VALIDITY CRITERIA</td>
<td>64</td>
</tr>
<tr>
<td>RELATIONSHIP OF OTHER HEART RATES WITH THE VALIDITY CRITERIA</td>
<td>66</td>
</tr>
<tr>
<td>Relationship Between Selected Heart Rates and the Balke Treadmill Test</td>
<td>67</td>
</tr>
<tr>
<td>Relationship Between Selected Heart Rates and Maximal Oxygen Consumption</td>
<td>67</td>
</tr>
<tr>
<td>INTERCORRELATIONS OF ALL VARIABLES</td>
<td>68</td>
</tr>
<tr>
<td>GRAPHICAL ANALYSIS OF MEAN HEART RATES FOR EACH INNING OF EXERCISE ON THE LSU STEP TEST</td>
<td>70</td>
</tr>
<tr>
<td>Analysis of Mean Heart Rates per Inning of Exercise for Phase I at a Cadence of Sixteen Steps per Minute</td>
<td>70</td>
</tr>
<tr>
<td>Analysis of Mean Heart Rates per Inning of Exercise for Phase II at a Cadence of Twenty Steps per Minute</td>
<td>72</td>
</tr>
<tr>
<td>Analysis of Mean Heart Rates per Inning of Exercise for Phase III at a Cadence of Twenty-four Steps per Minute</td>
<td>74</td>
</tr>
<tr>
<td>Analysis of Mean Heart Rates per Inning of Exercise for Phase IV and Phase V at a Cadence of Twenty-four Steps per Minute</td>
<td>74</td>
</tr>
</tbody>
</table>
Chapter Page

V. SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS ........ 79

SUMMARY ...................................... 79

FINDINGS ..................................... 81

Discussion of the Findings ............... 82

CONCLUSIONS ................................. 85

RECOMMENDATIONS ............................. 86

BIBLIOGRAPHY .................................. 87

APPENDIXES ................................... 92

A. Subject Score Card ....................... 93

B. Test Instructions ........................... 94

C. Formula for Maximal Oxygen Consumption Values . 95

D. Raw Data ................................. 96
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Correlations of Target Heart Rates of 150 and 168 Beats per Minute with the Validity Criteria</td>
<td>65</td>
</tr>
<tr>
<td>2. Correlation of Selected Target Heart Rates on the LSU Step Test with the Validity Criteria</td>
<td>66</td>
</tr>
<tr>
<td>3. Intercorrelations of Maximal Oxygen Consumption, Balke Treadmill Test and Heart Rates on the LSU Step Test (N=30)</td>
<td>68</td>
</tr>
<tr>
<td>4. Table of Means and Standard Deviations for all Variables</td>
<td>69</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Performance on the LSU Step Test</td>
<td>45</td>
</tr>
<tr>
<td>2. Otis-McKarrow Respiratory Valve, Rubber Mouthpiece, Screw Type Nose Clip</td>
<td>47</td>
</tr>
<tr>
<td>3. Dry Gas Meter, Vacuum Pump</td>
<td>48</td>
</tr>
<tr>
<td>4. Motor Driven Treadmill</td>
<td>49</td>
</tr>
<tr>
<td>5. Douglas Bag</td>
<td>50</td>
</tr>
<tr>
<td>6. Three-Way Residual Air Valve</td>
<td>51</td>
</tr>
<tr>
<td>7. BT-1200 Biotachometer</td>
<td>52</td>
</tr>
<tr>
<td>8. Two Lead Silver Electrodes and Shielded Input Cable</td>
<td>53</td>
</tr>
<tr>
<td>9. Douglas Bags Connected to Three-Way Residual Air Valve</td>
<td>55</td>
</tr>
<tr>
<td>10. Positioning of Respiratory Valve and Nose Clip for Collection of Expired Air</td>
<td>58</td>
</tr>
<tr>
<td>11. Laboratory Arrangement for Collection of Expired Air Samples</td>
<td>59</td>
</tr>
<tr>
<td>12. Expired Air Sample Taken from Douglas Bag in 50 cc. Syringe</td>
<td>60</td>
</tr>
<tr>
<td>13. Vacuuming Expired Air from the Douglas Bag Through the Dry Gas Meter</td>
<td>62</td>
</tr>
<tr>
<td>14. Mean Heart Rates per Inning for Phase I—16 Steps/Min. on the LSU Step Test</td>
<td>71</td>
</tr>
<tr>
<td>15. Mean Heart Rates per Inning for Phase II—20 Steps/Min. on the LSU Step Test</td>
<td>73</td>
</tr>
<tr>
<td>16. Mean Heart Rates per Inning for Phase III—24 Steps/Min. on the LSU Step Test</td>
<td>75</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>17.</td>
<td>Mean Heart Rates per Inning for Phase IV--</td>
</tr>
<tr>
<td></td>
<td>24 Steps/Min. on the LSU Step Test</td>
</tr>
<tr>
<td>18.</td>
<td>Mean Heart Rates per Inning for Phase V--</td>
</tr>
<tr>
<td></td>
<td>24 Steps/Min. on the LSU Step Test</td>
</tr>
</tbody>
</table>
ABSTRACT

The primary purpose of this study was to establish the validity of a submaximal cardiovascular step test for females that could be used in a mass testing situation, required little equipment, and could be scored objectively. The Balke Treadmill Test and maximal oxygen consumption were the validity criteria.

A secondary purpose of the study was to compare target heart rates of 150 and 168 obtained on the step test to determine which was the more valid indicator of the subject's capacity to perform maximal work.

Thirty female subjects, ages seventeen to twenty-six years, served as subjects. Subjects were volunteers from the University of Houston Women's Basketball Team, the Modern Dance Club, and the Women's Olympic Development Volleyball Team. Subjects were considered conditioned and not representative of the normal population.

Subjects were tested on the step test which consisted of stepping up and down on a seventeen inch bench. The test originally contained three phases with cadences of sixteen, twenty, and twenty-four steps per minute for Phases I, II, and III, respectively. The test was extended to a fourth and fifth phase at twenty-four steps per minute to assure that nearly all subjects attain a heart rate of 168. Each test inning involved thirty seconds of stepping and twenty seconds of rest. During the rest period, subjects took a ten second pulse count, starting with second six and ending
on second fifteen. Expired air samples for determining max VO$_2$ were collected during the same testing session as the Balke Treadmill Test.

Target heart rates of 150 and 168 were correlated with the Balke Treadmill Test and max VO$_2$ values to establish validity on the step test. Coefficients of correlation were computed to determine the relationship between several heart rates, from 120 to 168, and the validity criteria. Graphical analyses of heart rates per inning of exercise were prepared for each of the five step test phases.

The findings of the study were:

1. A significant validity coefficient of .50 was obtained for the amount of exercise required to reach a heart rate of 150 beats per minute and the Balke Treadmill Test.

2. The relationship between target heart rate of 150 beats per minute and maximal oxygen consumption was significant (r = .36).

3. A significant correlation was found between the number of innings on the step test required to reach a heart rate of 168 beats per minute and the Balke Treadmill Test (r = .55).

4. There was no significant relationship between maximal oxygen consumption and the amount of exercise on the step test required to elicit a heart rate of 168 beats per minute.
5. The Balke Treadmill Test correlated highest with amounts of exercise necessary to elevate the heart rate above 160 beats per minute.

6. Maximal oxygen consumption correlated highest with amounts of exercise that produced moderate heart rates of approximately 135 to 155.

7. The Balke Treadmill Test correlated higher with scores on the submaximal step test than did maximal oxygen consumption.

Based upon the findings of this study the following conclusions were drawn:

1. The submaximal cardiovascular step test with target heart rates of 150 or 168 beats per minute is a valid test of cardiovascular fitness when considering the Balke Treadmill Test as the validity criterion.

2. The Balke Treadmill Test and maximal oxygen consumption are not comparable criteria of cardiovascular fitness.

3. With conditioned subjects, the capacity for maximal work as measured by max VO$_2$ is more effectively predicted by light to moderate work loads, whereas prediction of maximal work as measured by the Balke Treadmill Test requires more strenuous exercise.
CHAPTER I

INTRODUCTION

If one subscribes to the philosophy that the physical educator utilizes physical activity to contribute to the enrichment of man then it follows that the knowledgeable physical educator understands the relationship between physical activity and the sociological, psychological and physiological nature of man.¹

Standard subdisciplines of physiology deal with the function of the entire organism, however the development of subdisciplines in which concentrated investigation focuses upon conditions which alter the "normal function" of the organism are becoming increasingly prominent.

In this era of accountability educators must define as well as measure and evaluate the objectives alluded to in the schematic of their disciplines.

The primary work of the physical educator concerned with the effects of exercise and sport on various systems of the body is to identify changes that occur within the

Concentrated research in the physiological domain has extended the knowledge and understanding of the role of physical activity on the various systems of the human body.

One of the most complex and controversial problems in exercise physiology is the assessment and measurement of physical fitness. While physical fitness has defied absolute definition agreed upon by researchers, it is generally agreed that cardiovascular fitness is a major component of physical fitness. Cardiovascular fitness—often referred to as cardiac efficiency—is generally improved by imposing properly regulated exercise sessions that induce a certain amount of exercise overload. The basic physiological response to exercise overload is an increase in total body oxygen consumption attainable as a result of increased pulmonary ventilation, cardiac output and oxygen utilization by the working tissues of the muscles. Performance of high levels of exercise intensity is best determined by the maximal amount of oxygen transported to the working muscles by the lungs. The measurement of an individual's maximal oxygen uptake (max VO₂) during intense physical effort is considered the best available criterion measure of cardiovascular fitness.²

²Ibid., p. 16.

For decades cardiovascular tests have been developed and utilized by researchers in physical education, physiology and medicine whose primary concern has focused on exercise and work physiology and rehabilitative medicine. Since many of these tests present administrative difficulties in the educational setting where their use is paramount in the evaluation of physical fitness programs, they have undergone modification and minimization often resulting in decreased reliability and validity.

Sophisticated means of evaluating cardiovascular fitness usually requires maximal physical exertion and must be conducted on an individual basis in a well equipped laboratory with highly trained personnel, thus making such tests unfeasible for schools and colleges.

The measurement of cardiovascular endurance has long been a concern to physical educators. Major adjustments of the respiratory and circulatory systems are necessary in this form of endurance if the entire organism is to function efficiently during continuous activity.

Cardiovascular endurance is not only dependent upon the functional capacity of the muscular system involved but must also rely upon the respiratory and circulatory systems of the performing organism. Based upon the interaction of these systems during continued endurance activity, many tests have been developed to measure the various aspects of the cardiovascular system's response to exercise. While many of these tests have proven very effective in the
measurement of cardiovascular endurance in males, researchers have taken a "laissez-faire" approach to the evaluation of the female within the framework of sports involvement.

The physiological aspects of exercise and sport have received acute visibility, and as the focal point of research has provided a wealth of physiological information on the male performer. While this research has both enlarged the field of exercise physiology and provided specialized knowledge regarding the effects of exercise stress, training methodology and particularly prescribed exercise regimens for improved cardiovascular efficiency, researchers are still operating within an atmosphere of genuine neglect with regard to the female performer. Available data have little relevancy for the sportswoman due to the specialized physiological sex differences.

Research dealing with sex differences in exercise physiology, sparse as it may be, has successfully identified the most obvious and important differences both structurally and organically. Acceptable higher level athletic competition is a fairly recent development, consequently there has been little interest in the reaction of the female to various stressors in athletic competition based upon these differences.4

STATEMENT OF THE PROBLEM

Physiological differences between the sexes are repeatedly reported in the literature. Astrand reported that sex differences in cardiac output can be observed at a given oxygen uptake. According to this report the most pronounced difference exists in the smaller stroke volume and higher heart rate during exercise of a given intensity for women when compared with men. For some females a pulse rate of 180 beats per minute (bpm) represents an oxygen uptake of 2.0 liters per minute and as much as 5.0 liters per minute for some males. Also in the case of men the pulse rate was on the average of 128 beats per minute at an oxygen uptake representing fifty percent of the maximum oxygen consumption and 154 beats per minute at an oxygen uptake representing seventy percent of maximum oxygen uptake. Corresponding values for females were 138 beats per minute at fifty percent of maximum oxygen uptake and 168 beats per minute at seventy percent maximum oxygen consumption. The standard deviation was nine beats per minute. On the basis of these data Astrand and Rhyming developed a nomogram for predicting maximum oxygen consumption from submaximal pulse rate, weight, age and exercise work loads.


Williams studied the reliability of the Astrand-Rhyming test with female subjects and concluded that the nomogram was not sufficiently reliable when administered only once but a testing schedule of at least three days was necessary to produce acceptable reliability.

Billings and others determined that the time required to reach a heart rate of 150 beats per minute is a valid indicator of cardiac capacity for more strenuous work in males.

Based upon general knowledge that the female's heart rate is higher than that of the male, Witten studied various submaximal heart rates of college females to determine the best assessment of cardiovascular fitness. The findings of this study revealed that a heart rate of 168 beats per minute for college women on the F-EMU Step Test correlated highest with the Balke Treadmill Test. Witten's work agrees with Astrand's findings and both conclude that the female heart rate at submaximal work loads is higher than that of the male. There is also agreement that the time to reach a heart rate of 168

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beats per minute is a good predictor of a female's capacity to do maximal work.

Cotten\textsuperscript{10} modified the Ohio State Step Test and established reliability and validity of the submaximal test for college men and high school boys. Cotten concluded that the modified Ohio State Step Test is a satisfactory instrument for testing cardiovascular fitness but recommended that the test be further modified for female subjects due to findings on preliminary research that the workload on the modified test was too great for discrimination among female subjects.

Astrand and Rodahl reported that motivation is an important factor determining endurance during heavy exercise and that highly motivated subjects will continue on endurance tasks while most individuals feel compelled to stop when the prescribed work load begins to tax the oxygen transporting system. The literature suggests that the involvement of psychological factors, of which motivation plays a major role, contributes to spurious reliabilities in endurance runs commonly used to determine levels of physical fitness, particularly in girls and women. It is further implied that cardiovascular endurance tests requiring long periods of time to administer or requiring the subject to perform at work loads that elicit symptoms

of physical discomfort will not present a true analysis of a subject's endurance capacity, but will measure motivational level. In support of this thesis, Buskirk and Taylor reported that the Harvard Treadmill Test, a maximum endurance test, actually measures "motivational climate" rather than true performance capacity due to the difficulty experienced in keeping the motivational level constant throughout the test.11

Cotten's recommendations, and statements by Astrand and Rodahl and Buskirk and Taylor, strongly support the obvious need to develop a practical submaximal cardiovascular test that has motivational and educational value and can be used in mass testing situations with female subjects.

PURPOSE OF THE STUDY

The primary purpose of the study was to establish the validity of a submaximal cardiovascular step test designed specifically for females. The investigation utilized the Balke Treadmill Test and maximal oxygen consumption as validity criteria.

A secondary purpose of the study was to compare the validity of criterion heart rates of 150 and 168 beats per

minute obtained on the submaximal step test as an indication of the subject's capacity to perform maximal work, as measured by the Balke Treadmill Test and maximal oxygen consumption.

SIGNIFICANCE OF THE STUDY

A review of the literature revealed a wealth of research dealing with maximal oxygen consumption yet there appeared to be an obvious gap in the use of direct measures of oxygen consumption as validity criterion for submaximal cardiovascular fitness tests. More specifically, research dealing with the assessment of aerobic capacity in the female performer has only recently become an area of concern. While acceptable submaximal cardiovascular fitness tests have been developed over the past few years, few of them have used direct measures of oxygen consumption as validity criteria.

Recent relaxation of cultural mores which were imbued with sociological and physiological condemnation of the female's role in sports participation has now prompted girls and women to pursue higher levels of exercise and sport. It was felt that there was a need for further knowledge regarding the physiological limitations of the female. Such knowledge would contribute to enriched physical education programs.

It was believed that the development of a valid submaximal cardiovascular fitness test would not only
extend the knowledge of the female's capacity to do maximal work, but would enhance physical education programs that are designed to tax female students in keeping with their ability and desire for expanded participation.

This study was undertaken to produce an instrument to measure submaximal cardiovascular fitness in females valid enough to warrant its use in mass testing situations.

DELIMITATIONS OF THE STUDY

The number of subjects for the study was limited to thirty college women enrolled at the University of Houston and members of the 1976 Women's Olympic Development Volleyball Team. Subject selection was based upon a predetermined level of conditioning due to the severity of the maximal oxygen consumption test.

The study was limited to a submaximal cardiovascular fitness test that could be used in a mass testing situation, required little equipment and could be scored easily and objectively. The primary criterion heart rate for the submaximal step test was 168 beats per minute based upon Witten's findings. However, scores were also recorded at a heart rate of 150 beats per minute to determine which of the two heart rates was a more valid indicator of the subject's ability to perform maximal work.

\[12\] Witten, loc. cit.
LIMITATIONS OF THE STUDY

Due to the severity of the maximal oxygen consumption test subjects were not selected at random from the total population. A sample of conditioned subjects was used. It was recognized that this may have some influence on the relationships among the different variables. No attempt was made to control subject activities on the test day which might affect heart rate. Rather, subjects were required to rest for a period of fifteen minutes prior to the test to establish a resting heart rate.

Motivation and fatigue are variables which were impossible to control but may have had some effect on maximal oxygen consumption values.

Although subjects were instructed in the palpation technique of pulse counting, there were perhaps some limitations in the use of this technique by relatively untrained subjects.

DEFINITION OF TERMS

**Cardiovascular fitness.** Often used synonymously with cardiorespiratory fitness, cardiovascular endurance and aerobic fitness, this term referred to the ability of the circulatory and respiratory systems to maximally employ oxygen to adjust to and recover from exercise.

**Submaximal Cardiovascular Test.** This term was defined as a test in which the subject does not obtain top
performance or reach maximal aerobic capacity but stops at some predetermined target heart rate.\(^\text{13}\)

**Maximal Oxygen Consumption** (\(\text{max VO}_2\)). This term represents the highest achievable level of exercise intensity determined by maximal amounts of oxygen that can be transported from the lungs and utilized by the working muscles.

**Heart Rate Criterion.** This term represents the predetermined end point for submaximal exercise determined by a ten second pulse count during a twenty second rest period between each thirty second bench stepping exercise bout.

**Validity Criterion.** This term was defined as the comparison of a test of the same factor in which the results are already known.\(^\text{14}\)

**ml/kg/min.** This term refers to the amount of oxygen in milliliters used by 1 kilogram of body weight per minute.

**LSU Step Test.** The submaximal cardiovascular step test used in this study was referred to as the LSU Step Test.

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\(^\text{13}\) American Heart Association, loc. cit.

CHAPTER II

REVIEW OF RELATED LITERATURE

Submaximal cardiovascular testing is preferred by many authorities because it is safer than maximal testing, requires less equipment and encourages greater subject cooperation. Recently there has been considerable concern expressed by physicians and physiologists regarding the dangers involved in maximal cardiovascular testing which requires the highest level of exercise intensity to determine the maximal amount of oxygen that can be transported to the working muscles. Conversely, submaximal testing does not require that the subject attain his top level of functional aerobic capacity, but is discontinued at some predetermined endpoint usually based on a target heart rate.

Despite the possible dangers to subjects, maximal endurance testing is an acceptable and frequently used technique to determine the statistical validity of proposed submaximal tests. The submaximal test then can be utilized to estimate an individual's capacity to do maximal work.

Measurement of one's ability to maximally utilize oxygen during exhaustive work is considered the most valid means of appraising cardiovascular fitness; therefore various measures of maximal oxygen utilization
have been used to validate measures of cardiovascular
fitness.\textsuperscript{15}

The review of literature pertinent to the study was
concerned with (1) direct measures of oxygen consumption,
and (2) the construction of submaximal cardiovascular tests
which utilize maximal endurance measures as validity
criteria.

**DIRECT MEASURES OF OXYGEN CONSUMPTION**

While direct measures of oxygen consumption are
generally divided into two types, those requiring the use
of a motor driven treadmill and those requiring the use of
a bicycle ergometer, there are nearly as many procedures
and modifications in the measurement of maximal oxygen
consumption as there are studies reported in the literature
on the subject.

The Astrand Test\textsuperscript{16} utilized the bicycle ergometer
with a pedaling frequency of fifty complete pedal turns per
minute. The subject pedaled at a work load of 600 kilopond-
meters (kpm) and continued for six minutes. After a five
minute rest period a second six minute ride was performed
at an increased work load of 900 kpm. An expired air sample

\textsuperscript{15}Donald K. Mathews, *Measurement in Physical Education*

\textsuperscript{16}Per-Olof Astrand, *Experimental Studies of Physical
Working Capacity in Relation to Sex and Age* (Copenhagen:
Enjar Munksgaard, 1952).
was collected between the fifth and sixth minute of each exercise bout. Following a rest interval of five minutes, a third six minute ride was performed at an increased work load of 1200 kpm. This procedure continued through 1500, 1800, and 1950 kpm or until the oxygen consumption leveled off or declined. An increased consumption of eighty milliliters (ml) or less was the leveling off criterion.

The Balke Treadmill Test\textsuperscript{17} has been one of the most widely known tests of direct measurement and is frequently used as a validity criterion in submaximal testing. The Balke Test, reported in this study, maintained a constant speed of 3.5 miles per hour (mph) on a motor driven treadmill and the slope was increased by one half percent of belt travel per minute at the end of each minute. The test was terminated on reaching a heart rate of 184-188 beats per minute (bpm). By following this procedure it was possible to cover the essential criteria of optimal work capacity without leading to the exhaustion of the subject. It was further concluded that when a heart rate of 180 bpm was compared with gas analysis, the respiratory gas exchange reached unity and the oxygen pulse rate reached maximum value.

A treadmill test credited to Taylor, Buskirk and Henschel\textsuperscript{18} required a ten minute warm-up performed on a motor driven treadmill at 3.5 mph at a ten percent grade, followed by a five minute rest interval. Subjects then ran at seven miles per hour at a grade selected on the basis of a fitness test. The subject ran continuously for three minutes with expired air being collected between one minute and forty-five seconds and two minutes and forty-five seconds. Oxygen consumption was calculated for this period. The following day the procedure was repeated at an increased grade of 2.5 percent. If the oxygen consumption values differed by less than 150 cc per minute for the two days the higher value was taken as the maximum oxygen consumption value. A difference of 150 cc per minute or more resulted in a continuation of the test on subsequent days until two values were obtained which did not differ by more than 150 cc per minute.

Mitchell, Sproule and Chapman\textsuperscript{19} designed a test to be administered on a single testing day. The subjects performed on a motor driven treadmill at three miles per hour and at a ten percent grade. Following a ten minute


rest interval, the subject began running at six miles per hour at a zero percent grade for a period of two minutes and thirty seconds. Expired air was collected during the last minute of a two minute and thirty second run. After ten minutes of rest the grade was increased to 2.5 percent. This procedure was continued increasing the grade by 2.5 percent after each rest interval until the oxygen consumption on two consecutive runs leveled off or declined. The criterion for leveling off was an increase of less than fifty-four milliliters.

SUBMAXIMAL CARDIOVASCULAR FITNESS TESTS

The Astrand-Rhyming nomogram has been one of the most widely used methods of predicting maximum oxygen consumption. The test uses the extrapolation principle which is dependent upon the subject's weight, age and heart rate response to submaximal work loads. The test consists of fifty pedal turns per minute on a bicycle ergometer set at a work load that would elicit a steady state somewhere between a heart rate of 125 beats per minute and 175 beats per minute. In the Astrand study maximum oxygen intake and heart rate were determined on twenty-seven male and thirty-one female subjects between ages twenty and thirty years. The

resultant measures were used to develop the nomogram. Astrand reported that the difference between the actual measured and the calculated maximum oxygen consumption was 6.7 percent for men and 9.4 percent for women.

Wyndham and Ward\textsuperscript{21} reported that the extrapolation method can be used to predict the maximum value of oxygen consumption based upon the assumption that the heart rate and oxygen consumption are linearly related over a wide range of values.

A nomogram for prediction of maximum oxygen consumption values per kilogram of body weight based on heart rate values obtained at two different submaximal work loads was developed by Margaria, Aghemo and Rovelli.\textsuperscript{22} Forty-seven subjects between the ages of nine and eighty were tested on two stepping work loads on a thirty and forty centimeter bench with stepping frequencies maintained by a metronome. The two submaximal work loads were designed to yield a heart rate of 100 and 150 beats per minute. The investigators reported that results more reliable than those of the Astrand-Rhyming nomogram could be obtained by determining heart rate and corresponding maximum oxygen consumption.


consumption values at two submaximal work loads using the following equations:

\[
V_{O_2}^{\text{max}} = \frac{f_{\text{max}} (V_{O_2}'' - V_{O_2}''') + f''V_{O_2}'' - f V_{O_2}''')}{f'' - f'}
\]

and

\[
f' = \frac{f'' (V_{O_2}^{\text{max}} - V_{O_2}'') - f_{\text{max}} (V_{O_2}'' - V_{O_2}'')}{V_{O_2}^{\text{max}} - V_{O_2}''}
\]

where:

- \(f_{\text{max}}\) = the individual's maximum heart rate
- \(f'\) = heart rate at the first work load
- \(f''\) = heart rate at the second work load
- \(V_{O_2}'\) = the predicted \(O_2\) intake at the first work load
- \(V_{O_2}''\) = the predicted \(O_2\) intake at the second work load
- \(V_{O_2}^{\text{max}}\) = the individual's predicted maximum \(O_2\) intake

The nomogram presented in the study is read similarly to that reported by Astrand and Rhyming. The investigators reported a 5.7 percent difference between the predicted and the determined maximum oxygen uptake values.

The Astrand-Rhyming nomogram has been found to satisfactorily predict direct measures of maximum oxygen intake in several studies. Glassford and others,\(^{23}\) using

maximum oxygen consumption as the validity criterion, tested the nomogram and reported a validity coefficient of .80. Teraslinna, Ismail and MacLeod\textsuperscript{24} reported a coefficient of .69 between maximum oxygen consumption and the predicted maximum oxygen consumption value on the nomogram which was comparable to the validity coefficient of .71 reported by Astrand and Rhyming. de Vries and Kalfs\textsuperscript{25} tested twenty-four male subjects and reported a validity figure of .736 for the Astrand-Rhyming nomogram using maximum oxygen consumption as the validity criterion.

Davies\textsuperscript{26} compared the Astrand-Rhyming nomogram with the one developed by Margaria, Aghemo and Rovelli. Twenty-five males and nineteen females ages twenty to twenty-eight years served as subjects. The study tested the premises inferred by both tests which were (1) that the relationship between cardiac frequency and oxygen uptake is linear up to and including maximum levels of work, and (2) that all subjects within a particular age group are able to reach similar maximum cardiac frequency values. Davies reported that neither premise is strictly valid because the


relationship between cardiac frequency and oxygen uptake becomes asymptotic at near maximum effort and maximum cardiac frequency shows a small but significant negative correlation with maximum oxygen intake. Also the variability of cardiac frequency in response to a given work load precludes accurate estimation of maximum oxygen uptake from either nomogram. From the results of the study, Davies concluded that single or double measures of cardiac frequency and oxygen uptake yield a crude estimation of maximum oxygen uptake.

The de Vries and Kalfs study tested six submaximal tests for validity using a maximum oxygen intake procedure similar to that described by Mitchell, Sproule and Chapman as the validity criterion. The submaximal tests were:

1. Sjostrand-Wahlund test of physical working capacity,
2. a modification of the Sjostrand-Wahlund test using bench stepping instead of a bicycle ergometer, 
3. the Harvard Step Test, 
4. the Progressive Pulse Ratio Test, 
5. a three minute modification of the Delta Respiratory Quotient Test, 
6. the Astrand-Rhyming nomogram. The subjects were sixteen male physical education majors ranging in age from twenty to twenty-six years. All of the tests showed significant correlations with measured maximum oxygen intake at the .01 level with the exception of the Delta Respiratory

\[^{27}\text{de Vries and Kalfs, loc. cit.}\]

\[^{28}\text{Mitchell, Sproule and Chapman, loc. cit.}\]
Quotient which was significant at the .05 level and the modification of the Sjostrand-Wahlund which was not significant.

Billings and others\(^2\) studied the Balke Treadmill Test and reported that the time required to reach a heart rate of 150 beats per minute was a valid indication of a subject's capacity for more strenuous work. Using twenty-six college males as subjects it was reported that rises in heart rate were directly proportional to time after the heart rate became linear with respect to test time; also, nearly all subjects' heart rates achieved linearity prior to attaining a heart rate of 150 beats per minute.

Nagle and Bedecki\(^3\) tested forty-four subjects on an all out run to exhaustion on a motor driven treadmill for the purpose of determining the acceptability and the conditions for use of the Balke Test. The times for attaining heart rates of 150, 160, 170 and 180 beats per minute were recorded along with maximum oxygen uptake and gas analysis data. The correlations of .69 at 150 beats per minute; .76 at 160 beats per minute; .77 at 170 beats per minute and .85 at 180 beats per minute concurred that a heart rate of 180 beats per

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minute, using criteria established by Balke, serves as a valid cut-off point in measuring circulatory-respiratory capacity.

In an investigation to determine the correlation between time to reach a heart rate of 180 beats per minute and time to reach heart rates below 180 beats per minute, Truett, Benson and Balke\textsuperscript{31} used a treadmill test similar to that described by Balke and Ware. The test terminated when the subject reached a criterion heart rate of 180 beats per minute. Based on a correlation of .95 between time to reach a heart rate of 160 beats per minute and 180 beats per minute, the investigators concluded that submaximal and maximal data were comparable and that submaximal work is a good estimate of maximal work.

Falls and Humphrey\textsuperscript{32} reported that the main advantage of the Balke test was that the small increments in work load resulted in gradual attainment of maximum or near maximum oxygen uptake in a single testing session. However, the investigators pointed out that a disadvantage of the test is the length of time required for trained subjects to reach maximum. In an attempt to establish a shorter method of


obtaining maximum oxygen uptake three alternative shorter methods were compared with the conventional Balke test. Subjects for the study were fourteen healthy female physical education majors. All of the subjects completed: (1) the conventional Balke test; (2) the short Balke test in which the subject walked the first two minutes at a ten percent treadmill grade, the grade was then increased one percent per minute; (3) light work followed by a maximum load test in which the subject exercised two minutes at light work on a motor driven treadmill, the work was then increased to the level of maximum previously achieved on the conventional Balke; (4) a step increment test (modified Balke) in which the subject started out as in a conventional Balke but after two minutes the treadmill grade was raised three percent, instead of the established one percent per minute, for the next four to six minutes. When the grade neared the maximum level attained by the subject in a previous Balke test, one percent per minute increments were continued to exhaustion. The findings of this study revealed that any of the four test procedures yielded reasonably good results in estimating maximum oxygen uptake in fit college women. The three short tests, the short Balke, the modified Balke and the maximum load test resulted in savings of eight to ten minutes per test when compared with the conventional Balke. However, if the time element is not a factor of importance the longer conventional Balke should be used as most subjects favored this procedure.
The Harvard Step Test developed by Brouha in the Harvard Fatigue Laboratories during World War II has been widely used and studied since it was first reported in the literature in 1943. The test consists of stepping up and down on a twenty inch bench thirty times per minute for five minutes or until the subject stops due to exhaustion. The score is derived from the duration of the exercise in seconds divided by pulse counts in recovery. In the original study treadmill running, maximum heart rate per minute and blood lactate level were used as validity criteria.

In 1944, Brouha, Fradd and Savage reported the use of the Harvard Step Test to determine the fitness of 2,167 students at Harvard College. The investigators reported that the achieved fitness index gives a suitable indication of the physical efficiency of young men because "it improved under regular training and declined when training was insufficient or wanting."

Taddonio and Karpovich utilized the Harvard Step Test with five groups of marathon and cross country runners.

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35 Dominik A. Taddonio and Peter V. Karpovich, "The Harvard Step Test as a Measure of Endurance Running," Research Quarterly, XXII (October, 1951), 381-84.
to determine the relationship of running to the step test and to compare the step test scores with the order in which subjects finished the marathon and cross country races. The findings of this study resulted in the conclusion that the Harvard Step Test produced a lack of statistically significant correlation between the test scores and the order of finish in all groups but one and suggested that the test may reflect the order of finish with greater accuracy in inexperienced runners.

Skubic and Hodgkins[^36] modified the Harvard Step Test in an effort to find a suitable cardiovascular fitness test for girls and women. Based on the hypothesis that a test of shorter duration could be shown to be valid and reliable for women, Skubic and Hodgkins shortened the original Harvard Step Test from five minutes to three minutes duration. Both the five minute and the three minute tests were given to ninety-six females between the ages of twelve and twenty-five years in a preliminary study. The stepping cadence in both the three minute and the five minute test was twenty-four steps per minute on an eighteen inch bench. After one minute of rest following exercise the pulse was taken for thirty seconds. The obtained correlation of .79 was considered sufficiently high to warrant further investigation of the three minute test.

Assuming that heart rates should differentiate between various levels of fitness, Skubic and Hodgkins\textsuperscript{37} then tested four groups of females: trained girls, untrained girls, active women, and sedentary women. The results revealed that the three minute test did differentiate between the four groups with the trained group eliciting a significantly lower heart rate than the untrained group. Based upon these findings the investigators concluded that the test was a valid instrument for determining the cardiovascular fitness of girls and women.

The Skubic Hodgkins Test was used as the validity criterion in a study conducted by Harvey and Scott\textsuperscript{38} for the purpose of validating a one minute step test for women used at Kent State University. The test consisted of stepping on an eighteen inch bench at a cadence of thirty steps per minute. Subjects for the study were thirty-two female college freshmen and fourteen female athletes. Using recovery heart rates as scores similar to the procedure described by Skubic and Hodgkins the Kent State Test differentiated between athletes and non-athletes significantly.

\textsuperscript{37}Ibid.

In March of 1969 a study by Kurucz, Fox and Mathews\(^{39}\) was reported in the literature revealing the reliability and validity of a step test to be used with men between the ages of eighteen and sixty years. The test, known as the Ohio State University Step Test, was eighteen innings of fifty second duration and each inning was divided into a thirty second work period with a twenty second rest period. During the rest period a ten second pulse count was taken beginning with second five and ending with second fifteen. The three test work loads were as follows: Phase I consisted of six innings at twenty-four steps per minute on a fifteen inch bench; Phase II consisted of six innings at thirty steps per minute on a fifteen inch bench; and Phase III consisted of six innings at thirty steps per minute on a twenty inch bench. The test terminated when the subject's pulse rate reached 150 beats per minute or when the subject completed the entire eighteen innings. The score was the inning in which the subject reached the criterion heart rate. Subjects completing all eighteen innings were assigned a score of nineteen. The stepping bench for the test was equipped with an adjustable hand bar which was adjusted to the level closest to the subject's head. A test-retest reliability coefficient of .94 was reported. The validity coefficient was .94 using the Balke Treadmill

Test as the validity criterion. Expired air samples were taken during the step test to determine energy costs with the use of the hand bar and without the hand bar. It was determined that exercise with the hand bar resulted in lower energy cost and therefore the hand bar should be included in the test to permit a wider range of subjects to be tested.

Cotten modified the Ohio State University Step Test for the purpose of establishing a cardiovascular fitness test that could be used for mass testing in class situations. Cotten used one seventeen inch bench for all three phases of the test, did away with the use of the hand bar and changed the stepping cadence in Phase III to thirty-six steps per minute. The commands and test instructions were prerecorded on tape to insure correct timing throughout the test.

Data were collected on thirty-four male subjects between the ages of twenty and thirty years to determine the reliability and validity of the test using the Balke Treadmill Test as the validity criterion. Subjects were assigned a partner to allow one partner to exercise and the other to count the pulse rate at the carotid artery. The "buddy system" allowed one half of the class to be tested simultaneously. The test-retest reliability of the modified step test was .95. The test correlated .84 with the Balke

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Treadmill Test. The investigator concluded that the modified test was a satisfactory instrument for testing cardiovascular fitness and that it is practical for mass testing in high school situations. It was further concluded that the test workload proved too great to discriminate among female subjects.\textsuperscript{41}

McCardle and others\textsuperscript{42} sought to relate maximum oxygen consumption to measures of physical work capacity and scores on the Skubic-Hodgkins Step Test. Test-retest reliability of maximum oxygen uptake and work capacity scores were also determined. In addition, reliability and validity of heart rate recovery from a step test, the Queens College Test which the authors had used successfully with college women, was obtained. Forty-one female subjects were given the Balke Treadmill Test for determining maximum oxygen consumption. Physical work capacity was the length of time the subject walked before the heart rate reached 150 beats per minute, PWC 150; 170 beats per minute, PWC 170 and the point at which the subject could no longer continue, PWC max. Expired air samples were collected each minute following PWC 170 to PWC max. The Queens College Test (QC test) involved stepping on a bleacher 16\textsuperscript{1/4} inches in

\textsuperscript{41}Ibid.

height for three minutes at a cadence of twenty-two steps per minute. Pulse rate was taken for fifteen seconds of recovery starting with second five and ending with second twenty and for another fifteen second period after one minute of recovery. The Skubic-Hodgkins Test was also administered. The highest validity coefficient \( r = -0.76 \) was found when obtained maximum oxygen consumption was correlated to the first fifteen second recovery heart rate scores from the three minute Queens College Step Test. Validity coefficients for the Skubic-Hodgkins Test were \( r = -0.64; \) PWC 150, \( r = 0.623; \) PWC 170, \( r = 0.68; \) and PWC max, \( r = 0.75 \). From the data presented it was concluded that the aerobic capacity of women can be obtained from recovery heart rate following a three minute step test as well as from various measures of physical work capacity on the Balke Treadmill Test.

In a study to determine the validity of Cooper's Twelve Minute Endurance Run Test, Katch\(^43\) and others tested thirty-six college women using maximum oxygen consumption as the validity criterion. The Balke Treadmill Test was used to measure maximum oxygen consumption. Percent body fat and lean body weight were also determined in seventeen women from body density measures (underwater weighing). A significant correlation of 0.67 was obtained between the

endurance run and maximum oxygen consumption which increased to .71 when corrected for attenuation from test unreliability in maximum oxygen uptake \( r = .95 \) and the run \( r = .78 \). Because lean body weight correlated .49 with the run scores and .76 with maximum oxygen consumption, use of partial correlation technique to statistically control for heterogeneity in lean body weight resulted in lower correlations between maximum oxygen consumption and the run. It was concluded that Cooper's Twelve Minute Run Test for Women was not an effective predictor of individual differences in maximum oxygen consumption.

Witten\textsuperscript{44} constructed a submaximal step test for females and made comparisons between six criterion heart rates on the test and the Balke Treadmill Test. Comparisons were made between the step test (F-EMU Step Test) at heart rates of 150, 156, 162, 168, 174, and 180 beats per minute. The test described by Witten was twenty innings divided into four different work loads as follows: (1) Innings 1-5 consisted of a stepping cadence of twenty-four steps per minute on a fourteen inch bench; (2) Innings 6-10 consisted of a stepping cadence of thirty steps per minute on a fourteen inch bench; (3) Innings 11-15 consisted of a stepping cadence of thirty steps per

\textsuperscript{44}Chet Witten, "Construction of a Submaximal Cardiovascular Step Test for College Females," \textit{Research Quarterly}, XXXIV (March, 1973), 46-50.
minute on a seventeen inch bench; and (4) Innings 16-20 consisted of a stepping cadence of thirty steps per minute on a twenty inch bench. The number of innings required to attain a heart rate of 150, 156, 162, 168, 174, and 180 beats per minute were individually correlated with the Balke test. The highest correlation \( r = .85 \) was found between the number of innings to reach a heart rate of 168 beats per minute and the Balke Treadmill Test.

Having established the validity of 168 heart rate response on the F-EMU Step Test, Witten\(^{45} \) then tested a second group of fifty-one freshman females to establish a test-retest reliability of .90 and concluded that a submaximal heart rate of 168 beats per minute is probably sufficient for cardiovascular testing with college females. It was further concluded that since a heart rate response of 168 beats per minute correlated higher than 174 or 180 beats per minute there was no need to have subjects work beyond a heart rate of 168 beats per minute.

\(^{45}\)Ibid.
SUMMARY

Tests of cardiovascular fitness have been predominantly of two types: those that attempt to assess maximal exercise performance, and tests of submaximal exertion which purport to predict the capacity for maximal performance. Tests reported in the review of literature, both maximal and submaximal, appear to be those most commonly utilized in the physical education laboratories and in the gymnasium.

Maximal oxygen consumption tests utilize either the treadmill or the bicycle ergometer and require that the subject exercise to exhaustion. Maximum tests developed by Astrand; Balke; Taylor, Buskirk, and Henschel; and Mitchell, Sproule, and Chapman are those more commonly used as validity criteria for establishing the validity of submaximal tests. The Balke test appeared often in the literature as a highly accepted validity criterion.

Numerous submaximal cardiovascular fitness tests are reported in the literature, however to include all of them is beyond the scope of this review. An attempt was made to review studies utilizing the more reliable and valid tests and to include as many different kinds of tests as possible.

One of the most widely used methods of predicting maximal oxygen consumption is the Astrand-Rhyming nomogram which uses the extrapolation method. Glassford and others studied the nomogram using maximal oxygen uptake as the
validity criterion and reported a validity coefficient of .80. Teraslinna, Ismail and MacLeod reported a coefficient of .69 between the nomogram and maximal oxygen uptake and de Vries and Klafs found a validity figure of .736. Wyndham and Ward found that the extrapolation method could be used as a predictor of maximal oxygen consumption provided that the heart rate and oxygen consumption are linearly related over a wide range of values. Margaria, Aghemo and Rovelli developed a nomogram using two different submaximal work loads and found the results more reliable than those of the Astrand-Rhyming nomogram. Davies compared the Astrand-Rhyming nomogram with that of Margaria, Aghemo and Rovelli and reported that neither is strictly valid because they assumed linearity between cardiac frequency and oxygen uptake and the relationship between the two becomes asymptotic at near maximal levels.

de Vries and Kalfs studied the validity of the Sjostrand-Wahlund Test of Physical Capacity, a modification of the Sjostrand-Wahlund, the Harvard Step Test, the Progressive Pulse Ratio, a three minute modification of the Delta R.Q. Test and the Astrand-Rhyming nomogram. All of the submaximal tests showed significant validity coefficients except the modification of the Sjostrand.

Billings and others used college males to investigate the Balke Treadmill Test and reported that a heart rate of 150 beats per minute was a valid indicator of a subject's capacity to do more strenuous work.
Nagle and Bedecki concluded from their investigation that time to reach a heart rate of 180 serves as a valid cut-off point in measuring circulatory-respiratory capacity. Truett, Benson and Balke studied time to reach a heart rate of 180 beats per minute and time to reach heart rates below 180 beats per minute and concluded that submaximal and maximal work are comparable and submaximal exercise is a good estimate of maximal work. Falls and Humphrey modified the Balke in an effort to shorten the length of time required to administer the test. Using three shorter modifications it was concluded that the three shorter methods were valid. However, the original Balke was preferred by the subjects because it was less strenuous than the shorter method.

The Harvard Step Test, one of the first and most widely known step tests, was developed by Brouha. Treadmill running, maximum heart rate and blood lactate level served as validity criteria. In a follow-up study Brouha, Fradd and Savage used the test to determine the fitness level of 2,167 students at Harvard College. Taddonio and Karpovich found little success when they used the test in a comparison with the order of finish in marathon and cross country races. Skubic and Hodgkins modified the Harvard Step Test in an effort to develop a suitable test for women. It was reported that a correlation of .79 with the original test was high enough to warrant further investigation. Harvey and Scott used the Skubic-Hodgkins Test as the validity criterion in a study to validate a one minute step test for women.
Kurucz, Fox and Mathews developed the Ohio State Step Test and correlated it with the Balke Treadmill Test to determine a validity coefficient of .92 using college men as subjects. Cotten modified the Ohio State Test and using the same validity criterion reported a validity coefficient of .84 but concluded that the test was not suitable for use with female subjects.

Based on Cotten's conclusions several investigations have been conducted to develop a valid submaximal cardiovascular test for women. McCordle and others tested college women in an effort to compare scores on the Skubic-Hodgkins Test, and scores on the Queens College Test with maximal oxygen consumption. Katch and others tested the validity of Cooper's Twelve Minute Run Test on college women. Witten developed a step test for women and investigated six different heart rates in an effort to find a valid criterion heart rate on the test.

The review of literature shows quite clearly that there are numerous valid submaximal cardiovascular fitness tests. The more recent concern of researchers appears to be the need for the development of a suitable submaximal test for women with a statistically valid submaximal criterion heart rate. While there are a limited number of tests for women reported in the literature it is obvious that research in this area is lacking and warrants far more extensive investigation.
CHAPTER III

PROCEDURE OF THE STUDY

OVERVIEW

Thirty female volunteers ranging in age from 17 to 26 years served as subjects to determine the validity of a submaximal cardiovascular step test using the Balke Treadmill Test and maximal oxygen consumption values as criteria. The study was conducted at the University of Houston, Houston, Texas in the summer of 1974.

Each subject performed on the step test and the Balke Treadmill Test. Expired air samples were collected during the Balke Treadmill Test beginning with the subject's first physical signs of exercise stress. Each test was administered no less than four days apart under controlled environmental laboratory conditions.

Subjects were female volunteers from the University of Houston Modern Dance Club and Basketball Team and members of the Women's Olympic Development Volleyball Team training in Houston, Texas for the 1976 Olympic Games.

Target heart rates of 150 and 168 were correlated with the two criteria. A graphical analysis of heart rate per inning of exercise was prepared and relationships of other heart rates and the criteria measures were determined.
SELECTION OF SUBJECTS

Dr. Suzanna Garrison, Director of Undergraduate Programs in Physical Education at the University of Houston, granted the request for female volunteers to act as subjects. Subjects were selected on a volunteer basis from the University of Houston Modern Dance Club and the University of Houston Women's basketball team. In an attempt to avoid negatively skewed data, highly conditioned subjects were selected from the Olympic Development Volleyball Team presently training for the 1976 Olympic Games. Subjects were asked to take pulse counts immediately after the conditioning drills conducted during workouts in basketball, volleyball and modern dance. Those subjects reporting a heart rate of 168 beats per minute or higher were considered conditioned and acceptable for maximal stress testing. All subjects were required to have a current medical examination.

ADMINISTRATION OF THE SUBMAXIMAL STEP TEST

Selection of Cadence

Cotten\textsuperscript{46} reported a reliability coefficient of .95 for the modified Ohio State Step Test. The modified test

\begin{flushright}
\end{flushright}
was also found to correlate highly ($r = .84$) with the Balke Treadmill Test. Cotten reported that although the test was reliable for men, the workloads of twenty-four steps per minute in Phase I, thirty steps per minute in Phase II and thirty-six steps per minute in Phase III were too great to provide discrimination among female subjects.

Based upon Cotten's findings Compton conducted a study with high school girls and tested two forms of a step test similar to that described by Cotten with the exception that the stepping cadence was lowered in each form. The test investigated in Compton's research included:

Form I  
<table>
<thead>
<tr>
<th>Phase</th>
<th>Innings</th>
<th>Workload (steps/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1-6</td>
<td>16</td>
</tr>
<tr>
<td>II</td>
<td>7-12</td>
<td>20</td>
</tr>
<tr>
<td>III</td>
<td>13-18</td>
<td>24</td>
</tr>
</tbody>
</table>

Form II  
<table>
<thead>
<tr>
<th>Phase</th>
<th>Innings</th>
<th>Workload (steps/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1-6</td>
<td>18</td>
</tr>
<tr>
<td>II</td>
<td>7-12</td>
<td>24</td>
</tr>
<tr>
<td>III</td>
<td>13-18</td>
<td>30</td>
</tr>
</tbody>
</table>

Compton reported a test-retest reliability of .91 on Form I and found that Form II, the progressively higher workload, yielded a considerably lower reliability of .61. While it was concluded that Form I was a reliable test of cardiovascular fitness in high school girls, it was recommended that a similar study be conducted to investigate stepping cadences of 18, 18 and 24 steps per minute to allow for a greater spread of scores among subjects.

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48 Ibid., pp. 24-25.
In an unpublished study using college women Pittillo\(^{49}\) tested the following cadences:

**Form I**
- Phase I Innings 1-6 = 18 steps/minute
- Phase II Innings 7-12 = 18 steps/minute
- Phase III Innings 13-18 = 24 steps/minute

**Form II**
- Phase I Innings 1-6 = 16 steps/minute
- Phase II Innings 7-12 = 20 steps/minute
- Phase III Innings 13-18 = 24 steps/minute

Based upon Astrand's\(^{51}\) findings that a heart rate of 150 beats per minute is a good predictor of cardiovascular fitness in males and that the female's heart rate is ten to fifteen beats per minute higher than the male's, Pittillo studied criterion heart rates of 150(A) and 162(B) beats per minute to determine which would elicit the most reliable submaximal heart rate response. The investigator reported that Form IA, heart rate 150 beats per minute and stepping cadence 18-18-24, elicited a .79 reliability coefficient. Form IB, criterion heart rate 162, was .74. For Form IIA, stepping cadence 16-20-24 and criterion heart rate 150 beats per minute the reliability was .82. A reliability coefficient of .67 was found for Form IIB, heart rate 162 beats

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\(^{49}\) Nila Pittillo, "Influence of Cadence and Cardiovascular Response Criteria on Reliability and Variability of a Submaximal Step Test for Women" (unpublished Master's study, Louisiana State University, 1973).

\(^{50}\) Ibid., p. 23.

per minute. It was concluded that in light of reliability, range and spread of scores, the stepping cadence of 16-20-24 with a criterion heart rate of 150 beats per minute appeared the most satisfactory test.

The stepping cadence of 16-20-24 was the stepping cadence investigated in this study. Such procedure was used to determine the validity of the submaximal cardiovascular step test for women using the Balke Treadmill Test and maximum oxygen consumption as the validity criteria.

Selection of Heart Rate Criteria

Although Pittillo reported that the time to reach a heart rate of 150 beats per minute proved most reliable with the proposed stepping cadence, a recent study by Witten reported that a heart rate response of 168 beats per minute yielded the most significant correlation coefficient for college females when correlated with the Balke Treadmill Test. Witten's test, known as the F-EMU Step Test, consisted of four phases with stepping cadences of 24-30-30-30 at varying bench heights. It was the opinion of this investigator that Witten's findings provided substantial support for selecting the heart rate response

52Pittillo, op.cit., p.24.

of 168 beats per minute as a criterion heart rate. Subjects' scores were also recorded at a heart rate of 150 beats per minute to determine which of the two heart rates correlated higher with the validity criteria.

**Step Test Equipment**

The following equipment was utilized for the administration of the step test: a standard reel to reel tape recorder; a prerecorded tape with instruction and cadence rhythm for test administration; a seventeen inch stepping bench; an electric metronome; and individual score cards for each subject. (Appendix A)

**Step Test Administration**

Subjects reported to the laboratory in groups of two and were assigned a partner for the test period. An eight foot long bench measuring seventeen inches in height was used for the step test in order that three subjects could be tested at one time. All subjects were tested in the laboratory to assure regulation of temperature and humidity for the step test and the Balke Treadmill Test. A fifteen minute rest period preceded the test. During the rest period subjects were instructed in pulse counting using the carotid artery method and were given an opportunity to practice counting their own pulse. Subjects then listened to the instructions and cadence prerecorded on a tape (Appendix B) and viewed a demonstration of one inning of the step test. An electric metronome was used
to set the stepping rhythm. Following instructions and the demonstration subjects were asked to stand and face the bench. On the command "prepare to exercise" the tape was started and the subject began to exercise (Figure 1).

The test consisted of three phases of work with an increased workload in each phase. Six innings constituted one phase resulting in a total of eighteen innings for the three phases of work. An inning was a thirty second exercise period followed by a twenty second rest period. During the twenty second rest period the exercising partner counted the pulse rate for ten seconds beginning on second five and ending on second fifteen. The test terminated when a predetermined pulse count (25 for 150 HR, and 28 for 168 HR) was attained. The inning in which the exercising partner reached the predetermined pulse count was recorded on the score card by the scoring partner. Subjects that had not reached a pulse count of 168 beats per minute after eighteen innings continued the last phase of the test until 168 beats per minute was attained or thirty innings were completed. Subjects that completed thirty innings of the test were assigned a score of thirty-one.

EQUIPMENT FOR THE BALKE TREADMILL TEST AND MAXIMUM OXYGEN UPTAKE

Equipment

The following equipment was required for the Balke Treadmill Test and collection of expired gases for
Figure 1

Performance on the LSU Step Test
determination of maximum oxygen uptake: one plastic Otis-McKarrow respiratory valve (Figure 2); two rubber mouthpieces (Figure 2); two screw type nose clips (Figure 2); one barometer; one dry gas meter, model number DTM-115, American Meter Company (Figure 3); one Warren E. Collins vacuum pump (Figure 3); one motor driven treadmill (Figure 4); two stopwatches, one bag rack to hold two Douglas bags; eight Douglas bags with 125-200 liter capacity (Figure 5); fifteen 50 cc. syringes per subject; one tube heavy parafin oil, UXP IX; one bottle of 80 percent alcohol; nine aluminum three-way residual air valves (Figure 6); one Narco-Bio BT-1200 Biotachometer (courtesy Narco-Bio Systems)(Figure 7); one mass spectrometer (courtesy Lyndon B. Johnson Space Center Cardio-Pulmonary Laboratory); one standard clock; and two sets of two lead silver electrodes and two shielded input cables (Figure 8).

Some of the equipment described is far more sophisticated than that found in the average physical education laboratory. However, through the cooperative efforts of the Lyndon B. Johnson Space Center Cardio-Pulmonary Laboratory, Houston, Texas and Narco-Bio Systems Instrument Company, Houston, Texas the equipment used in this study allowed for more accurate testing procedures and data collection. The study could be replicated with less sophisticated equipment.
Figure 2
Otis-McKarrow Respiratory Valve
Rubber Mouthpiece
Screw Type Nose Clip
Figure 3

Dry Gas Meter, Vacuum Pump
Figure 4

Motor Driven Treadmill
Figure 5
Douglas Bag
Figure 6

Three-Way Residual Air Valve
Figure 7

BT-1200 Biotachometer
Figure 8

Two Lead Silver Electrodes
and Shielded Input Cable
The Balke Treadmill Test and determination of maximum oxygen uptake were conducted simultaneously for each subject in one test session within a four to seven day period of administration of the step test. A counterbalanced testing order was used.

Preliminary procedures similar to those described by Consolazio, Johnson and Pecora were conducted prior to the subjects' arrival. All Douglas bags were checked for leaks by transferring a measured quantity of air into each bag. The bag was then sealed off at the neck and a twenty pound weight was placed on it for approximately one hour. The contents of the bag were passed through the dry gas meter and measured to assure that the volume of gas was approximately the same as the original quantity. Each bag was evacuated completely by the vacuum pump and clamped off at the exit tube to prevent air from entering the bag. Douglas bags were numbered one through eight and bags number one and two were hung on the bag assembly. The exit tube of bags number one and two were connected to the three-way tap (Figure 9). The corrugated tube from the mouthpiece to the three-way tap was also connected. The three-way tap was adjusted to permit expired air to pass to the outside.

---

Figure 9
Douglas Bags Connected to Three-Way Residual Air Valve
until minute air sample collection began at which time the tap was turned to bag number one.

Upon arrival at the testing station a two lead silver electrode to allow for continuous heart monitoring through a Narco-Bio Systems Model BT-1200 Biotachometer was connected to the subject. Room temperature and barometric pressure were recorded on the subject's data card and a sample of ambient air was taken in a well oiled syringe to determine the amount of gas concentration in the laboratory.

A screw type nose clip was placed firmly on the subject's nose. To test for leaks the subject was asked to attempt to blow air past the nose clip.

Administration of the Balke Treadmill Test

Procedures for the Balke Treadmill Test\textsuperscript{55} consisted of walking at a speed of 3.4 miles per hour at a zero percent treadmill grade for the first minute; the grade was then raised to two percent for the second minute and increased one percent for each minute thereafter. The score was the duration of time in minutes required to reach a heart rate of 180 beats per minute.

Although the scoring on the Balke Treadmill Test was terminated when the subject's heart rate reached 180 beats per minute, the subject continued walking at a treadmill speed of 3.4 miles per hour and the grade was raised one

\textsuperscript{55}Ibid., p. 72.
percent per minute until the subject could no longer continue. Expired air samples were taken during the last five to six minutes of exercise to determine maximum oxygen consumption.

**Procedure for Determining Maximum Oxygen Uptake**

The mouthpiece for collecting expired air was placed in the subject's mouth when the subject began to show physical signs of exercise stress (Figure 10). The subject's expired air emptied to the outside until the subject indicated that the remaining exercise capability was approximately five minutes at which time the three-way valve was adjusted to begin collection in Douglas bag number one (Figure 11). Following one minute of collection the valve was turned so that the expired air emptied into bag number two. Bag number one was clamped off and removed from the bag assembly and bag number three was hung in its place. The corrugated tubing from bag number one was immediately attached to bag number three to prepare for the third minute of collection. This procedure was continued with bag number four replacing bag number two, bag number five replacing bag number three and bag number six replacing bag number four until the subject could no longer continue.

As each bag was removed from the Douglas bag assembly it was agitated to assure that the gases were well mixed. An expired air sample was taken into a well oiled 50 cc. syringe (Figure 12). The syringe was labeled to
Figure 10

Positioning of Respiratory Valve and Nose Clip for Collection of Expired Air
Figure 11

Laboratory Arrangement for Collection of Expired Air Samples
Figure 12

Expired Air Sample Taken From Douglas Bag in 50 cc. Syringe
correspond with the Douglas bag from which the sample was drawn. The Douglas bag was then taken to the dry gas meter and vacuum pump assembly where the expired air was vacuumed from the bag through the dry gas meter (Figure 13). Readings were taken on the dry gas meter before and after each sample and the difference represented the volume of air expired in liters per minute. The reading was recorded immediately on the subject's data card.

Syringe samples were stored for delivery to the Lyndon B. Johnson Space Center Cardio-Pulmonary Laboratory where the oxygen and carbon dioxide content were analyzed on a mass spectrometer which gave an immediate digital readout in percent oxygen and carbon dioxide. The syringe samples were delivered to the Space Center within six hours of sample collection as carbon dioxide diffuses more rapidly than oxygen but shows only slight loss up to six hours. 56

To determine maximal oxygen consumption values the percent values of nitrogen, oxygen and carbon dioxide for each expired air sample and the age, weight, room temperature, barometric pressure and sample collection time for each subject were calculated on an Olevetti desk computer. The formula for determining maximal oxygen consumption values (Appendix C) was prerecorded on a magnetic tape which when placed into the computer set the program for readouts of maximal oxygen consumption values in liters per minute and milliliters per kilogram per minute.

56Ibid., p. 22.
Figure 13

Vacuuming Expired Air from the Douglas Bag Through the Dry Gas Meter
ANALYSIS OF DATA

Target heart rates of 150 and 168 beats per minute were correlated with the Balke Treadmill Test and maximum oxygen uptake to determine the validity of the step test. A graphical analysis of heart rates per inning of exercise was performed and relationships of all other heart rates and the criteria measures were determined. The computer facilities of the Louisiana State University Computer Center were used for all statistical analysis.
CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The data for the study were scores of thirty female subjects' performance on a submaximal cardiovascular step test and two criterion measures, the Balke Treadmill Test and maximal oxygen consumption. Coefficients of correlation were used to determine the validity of the step test at target heart rates of 150 and 168 beats per minute. Correlations were also computed between heart rates of 120, 126, 132, 138, 144, 156 and 162 beats per minute and the validity criteria as well as intercorrelations among the variables. A graphical analysis of heart rate per inning of exercise on the step test was performed. Means and standard deviations were reported for all variables.

ANALYSIS OF TARGET HEART RATES AND THE VALIDITY CRITERIA

Coefficients of correlation were computed between the target heart rates of 150 and 168 beats per minute on the submaximal step test, the Balke Treadmill Test and maximal oxygen consumption. Variation percentages were computed for all correlations. The data are presented in Table 1.
Table 1
Correlations of Target Heart Rates of 150 and 168 Beats per Minute with the Validity Criteria

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>r</th>
<th>r²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR 150 - Balke</td>
<td>30</td>
<td>.50</td>
<td>25</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>HR 150 - VO₂</td>
<td>30</td>
<td>.36</td>
<td>12</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>HR 168 - Balke</td>
<td>30</td>
<td>.55</td>
<td>30</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>HR 168 - VO₂</td>
<td>30</td>
<td>.24</td>
<td>05</td>
<td>NS</td>
</tr>
</tbody>
</table>

r required for significance with 28 (N-2) df, .36.

As shown in Table 1 the target heart rate of 150 beats per minute correlated higher with the Balke Treadmill Test \( (r = .50) \) than with the maximal oxygen consumption \( (r = .36) \). The target heart rate of 168 beats per minute also correlated higher with the Balke Treadmill Test \( (r = .55) \) than with maximal oxygen consumption \( (r = .24) \).

In terms of percent of variation, the heart rate of 168 was shown to have 30 percent common variance with the Balke Treadmill Test performance; whereas, only 5 percent of the maximal oxygen consumption scores were associated with submaximal step test performance as measured by the amount of work required to reach a heart rate of 168. The heart rate of 150 exhibited higher common variance with maximal oxygen consumption than the heart rate of 168.
RELATIONSHIP OF OTHER HEART RATES WITH THE VALIDITY CRITERIA

Heart rates were recorded during ten seconds of a twenty second rest period for each inning of the LSU Step Test. Heart rates were then multiplied by six to convert to beats per minute. The number of innings it required for the subject to elicit a heart rate response of 120, 126, 132, 138, 144, 150, 156, 162 and 168 beats per minute were individually correlated with the Balke Treadmill Test and maximal oxygen consumption. The percent of variation ($r^2$) was also calculated for each correlation. The results of these computations are shown in Table 2.

Table 2

<table>
<thead>
<tr>
<th>HR</th>
<th>$r$ with Balke</th>
<th>$r^2$</th>
<th>$r$ with VO$_2$</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>.42*</td>
<td>17</td>
<td>.30</td>
<td>09</td>
</tr>
<tr>
<td>126</td>
<td>.47*</td>
<td>22</td>
<td>.22</td>
<td>04</td>
</tr>
<tr>
<td>132</td>
<td>.42*</td>
<td>17</td>
<td>.38*</td>
<td>14</td>
</tr>
<tr>
<td>138</td>
<td>.48*</td>
<td>23</td>
<td>.44*</td>
<td>19</td>
</tr>
<tr>
<td>144</td>
<td>.41*</td>
<td>16</td>
<td>.36*</td>
<td>12</td>
</tr>
<tr>
<td>156</td>
<td>.52*</td>
<td>27</td>
<td>.34</td>
<td>11</td>
</tr>
<tr>
<td>162</td>
<td>.56*</td>
<td>31</td>
<td>.26</td>
<td>06</td>
</tr>
</tbody>
</table>

* $p$ = less than .05
Relationship Between Selected Heart Rates and the Balke Treadmill Test

The highest correlation coefficient \( r = .56 \) was found between the number of innings required by the subject to reach a heart rate of 162 beats per minute and the Balke Treadmill Test (refer to Table 2). A percent of variance of 31 was determined for this relationship. It should be noted that the relationship between heart rate 162 and the Balke Treadmill Test was essentially the same as between heart rate 168 and the Balke Treadmill Test \( (r = .55) \) (see Table 1).

The correlations between heart rates 120 to 144 ranged from .41 to .48, with percentages of variation ranging from 16 to 23.

A heart rate of 156 beats per minute had a slightly higher \( r = .52 \) correlation with the Balke Treadmill Test than the target heart rate of 150.

Relationship Between Selected Heart Rates and Maximal Oxygen Consumption

The correlations between maximal oxygen consumption and selected heart rates on the step test appear in Table 2. Heart rates in the middle range, between 132 and 146, showed the highest correlations with maximal oxygen consumption. The highest relationship between maximal oxygen consumption and heart rate on the submaximal step test was found for the heart rate of 138 beats per minute \( r = .44 \). A percent of common variance of 19 was
found between step test performance until a heart rate of 138 was reached and maximal oxygen consumption.

INTERCORRELATIONS OF ALL VARIABLES

The intercorrelations between maximal oxygen consumption, the Balke Treadmill Test and heart rates on the LSU Step Test appear in Table 3.

<table>
<thead>
<tr>
<th>Variable</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Max VO₂</td>
<td>.085</td>
<td>.36</td>
<td>.24</td>
<td>.30</td>
<td>.22</td>
<td>.38</td>
<td>.44</td>
<td>.36</td>
<td>.34</td>
<td>.26</td>
</tr>
<tr>
<td>2. Balke</td>
<td>.50</td>
<td>.55</td>
<td>.42</td>
<td>.47</td>
<td>.42</td>
<td>.48</td>
<td>.41</td>
<td>.51</td>
<td>.56</td>
<td></td>
</tr>
<tr>
<td>3. HR 150</td>
<td>.80</td>
<td>.61</td>
<td>.72</td>
<td>.78</td>
<td>.84</td>
<td>.95</td>
<td>.98</td>
<td>.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. HR 168</td>
<td>.51</td>
<td>.59</td>
<td>.58</td>
<td>.64</td>
<td>.77</td>
<td>.86</td>
<td>.96</td>
<td></td>
<td></td>
<td></td>
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<td>5. HR 120</td>
<td>.95</td>
<td>.89</td>
<td>.79</td>
<td>.71</td>
<td>.64</td>
<td>.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. HR 126</td>
<td>.94</td>
<td>.88</td>
<td>.82</td>
<td>.74</td>
<td>.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. HR 132</td>
<td>.93</td>
<td>.85</td>
<td>.77</td>
<td>.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. HR 138</td>
<td>.90</td>
<td>.82</td>
<td>.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. HR 144</td>
<td>.94</td>
<td>.81</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>10. HR 156</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>11. HR 162</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The highest relationship found between maximal oxygen consumption and heart rates on the step test was $r = .44$ obtained when Max VO₂ was correlated with a heart rate of
Maximal oxygen consumption showed the lowest relationship \((r = .22)\) with heart rate 126. The Balke Treadmill Test had the highest intercorrelations with heart rates of 162 \((r = .56)\) and 168 \((r = .55)\). The lowest relationships for the Balke were at heart rates 144 \((r = .41)\), 132 \((r = .42)\) and 120 \((r = .42)\). The correlation coefficient between heart rate 150 and 168 was \(r = .80\ (p < .05)\). The low correlation between Max \(\text{VO}_2\) and the Balke Treadmill Test of \(r = .085\) was not a significant relationship.

The table of means and standard deviations for all of the variables in question are shown in Table 4.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balke</td>
<td>30</td>
<td>15.6(^a)</td>
<td>4.34</td>
</tr>
<tr>
<td>(\text{VO}_2)</td>
<td>30</td>
<td>47.88(^b)</td>
<td>6.80</td>
</tr>
<tr>
<td>120</td>
<td>30</td>
<td>3.96(^c)</td>
<td>3.07</td>
</tr>
<tr>
<td>126</td>
<td>30</td>
<td>5.53</td>
<td>4.36</td>
</tr>
<tr>
<td>132</td>
<td>30</td>
<td>7.16</td>
<td>4.75</td>
</tr>
<tr>
<td>138</td>
<td>30</td>
<td>9.40</td>
<td>6.47</td>
</tr>
<tr>
<td>144</td>
<td>30</td>
<td>11.86</td>
<td>7.35</td>
</tr>
<tr>
<td>150</td>
<td>30</td>
<td>14.56</td>
<td>7.55</td>
</tr>
<tr>
<td>156</td>
<td>30</td>
<td>15.93</td>
<td>7.39</td>
</tr>
<tr>
<td>162</td>
<td>30</td>
<td>18.96</td>
<td>8.21</td>
</tr>
<tr>
<td>168</td>
<td>30</td>
<td>21.30</td>
<td>7.58</td>
</tr>
</tbody>
</table>

\(^a\)measured in minutes

\(^b\)measured in ml/kg/min

\(^c\)measured in innings
The mean heart rates for each inning of exercise on the LSU Step Test are presented graphically in Figures 14 through 18. Figure 14 represents the mean heart rates for Phase I innings one through six at stepping cadence sixteen steps per minute. Mean heart rates for Phase II innings seven through twelve at a cadence of twenty steps per minute are shown in Figure 15. Figure 16 presents the mean heart rates for Phase III innings thirteen through eighteen at a stepping cadence of twenty-four steps per minute. The mean heart rates for Phase IV innings nineteen through twenty-four and Phase V innings twenty-five through thirty are plotted in Figure 17 and Figure 18, respectively. Innings nineteen through thirty were scored at a stepping cadence of twenty-four steps per minute.

**Analysis of Mean Heart Rates per Inning of Exercise for Phase I at a Cadence of Sixteen Steps per Minute**

The mean heart rates for Phase I innings one through six are presented in Figure 14. Since this was the first phase of the test and was the least taxing stepping cadence, all subjects were able to complete the phase. The individual plots for each inning display a gradual increase in mean heart rates throughout the phase. The graphical presentation of mean heart rates for Phase I shows three
Figure 14

Mean Heart Rates per Inning for Phase I—16 Steps/Min. on the LSU Step Test

Key:

<table>
<thead>
<tr>
<th>Inning</th>
<th>N</th>
<th>Mean Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>108</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>114</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>114</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>120</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>126</td>
</tr>
</tbody>
</table>
distinct increases in heart rate with a leveling off or a plateau effect between the second and third and the fourth and fifth innings of exercise. Each sharp rise in mean heart rate showed a uniform increment of six beats per minute.

Analysis of Mean Heart Rates per Inning of Exercise for Phase II at a Cadence of Twenty Steps per Minute

Figure 15 is a graph of the mean heart rates for innings seven through twelve (Phase II) at a cadence of twenty steps per minute. Twenty-eight subjects completed the second phase of the test. One subject reached the criterion heart rate of 168 beats per minute in the eighth inning and another reached the end heart rate in inning eleven. The increase in stepping cadence from inning six at sixteen steps per minute to the seventh inning at twenty steps per minute showed an increase to 132 beats per minute.

The graphical presentation for the last three innings of Phase II showed the same curve as the last three innings of Phase I (see Figure 14) with a leveling off effect between inning ten and eleven (138 beats per minute) and a sharp rise for the twelfth inning (144 beats per minute).
Figure 15

Mean Heart Rates per Inning for Phase II—20 Steps/Min. on the LSU Step Test

Key:

<table>
<thead>
<tr>
<th>Inning</th>
<th>N</th>
<th>Mean Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>30</td>
<td>132</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
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<td>9</td>
<td>29</td>
<td>132</td>
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<td>29</td>
<td>138</td>
</tr>
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<td>11</td>
<td>29</td>
<td>138</td>
</tr>
<tr>
<td>12</td>
<td>28</td>
<td>144</td>
</tr>
</tbody>
</table>
Analysis of Mean Heart Rates per Inning of Exercise for Phase III at a Cadence of Twenty-four Steps per Minute

A graphical presentation of mean heart rates for Phase III innings thirteen through eighteen at a cadence of twenty-four steps per minute is found in Figure 16. Seventeen subjects completed Phase III which was the most strenuous of the three exercise bouts. Two subjects reached the target heart rate of 168 beats per minute in the thirteenth inning and terminated the test as instructed. The target heart rate was reported in the fourteenth inning for two subjects, in the fifteenth inning for three subjects, in the seventeenth inning for four subjects, and in the eighteenth inning for two subjects.

The curve for innings thirteen through eighteen revealed a sharp rise in mean heart rate at the fifteenth and sixteenth innings. A leveling off effect occurred at inning seventeen with a decrease in mean heart rate in the eighteenth inning.

Analysis of Mean Heart Rates per Inning of Exercise for Phase IV and Phase V at a Cadence of Twenty-four Steps per Minute

A cadence of twenty-four steps per minute was extended through Phase IV and Phase V of the test to determine at which point the remaining subjects would reach the criterion heart rate of 168 beats per minute.
Figure 16

Mean Heart Rates per Inning for Phase III—
24 Steps/Min. on the LSU Step Test

Key:

<table>
<thead>
<tr>
<th>Inning</th>
<th>N</th>
<th>Mean Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>28</td>
<td>144</td>
</tr>
<tr>
<td>14</td>
<td>26</td>
<td>144</td>
</tr>
<tr>
<td>15</td>
<td>24</td>
<td>150</td>
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<tr>
<td>16</td>
<td>21</td>
<td>156</td>
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<td>17</td>
<td>21</td>
<td>156</td>
</tr>
<tr>
<td>18</td>
<td>17</td>
<td>150</td>
</tr>
</tbody>
</table>
Four subjects reached the criterion heart rate in Phase IV. Two subjects reached the target heart rate in the nineteenth inning and terminated the test. One subject terminated the test in the twenty-first inning and another in the twenty-second inning. Two additional subjects reached the criterion heart rate and terminated the test in inning twenty-seven and inning twenty-eight of Phase V. Nine subjects completed all thirty innings of the test without achieving the target heart rate.

The graphical analysis for Phases IV and V present the mean heart rates per inning of exercise in Figures 17 and 18. Figures 17 and 18 reveal that the mean heart rates for innings nineteen through thirty were constant (150 beats per minute) with the exception of innings twenty and twenty-nine where a decline was evident. There were no increases in mean heart rates beyond 150 beats per minute.
Figure 17

Mean Heart Rates per Inning for Phase IV—
24 Steps/Min. on the LSU Step Test

Key:

<table>
<thead>
<tr>
<th>Inning</th>
<th>N</th>
<th>Mean Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>15</td>
<td>150</td>
</tr>
<tr>
<td>20</td>
<td>13</td>
<td>144</td>
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<td>21</td>
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<td>22</td>
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<td>23</td>
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<td>150</td>
</tr>
<tr>
<td>24</td>
<td>11</td>
<td>150</td>
</tr>
</tbody>
</table>
Figure 18

Mean Heart Rates per Inning for Phase V—24 Steps/Min. on the LSU Step Test

Key:

<table>
<thead>
<tr>
<th>Inning</th>
<th>N</th>
<th>Mean Heart Rate</th>
</tr>
</thead>
<tbody>
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<td>11</td>
<td>150</td>
</tr>
<tr>
<td>26</td>
<td>11</td>
<td>150</td>
</tr>
<tr>
<td>27</td>
<td>11</td>
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<tr>
<td>28</td>
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<td>150</td>
</tr>
<tr>
<td>29</td>
<td>9</td>
<td>144</td>
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SUMMARY

The primary purpose of this study was to attempt to establish the validity of a submaximal cardiovascular step test designed specifically for females that could be used in a mass testing situation, required little equipment and could be scored objectively. The investigation utilized the Balke Treadmill Test and maximal oxygen consumption as the validity criteria.

A secondary purpose of the study was to compare the target heart rates of 150 and 168 beats per minute obtained on the submaximal cardiovascular step test to determine which of the two heart rates was more valid as an indicator of the subject's capacity to perform maximal work.

Thirty female subjects ranging in age from seventeen to twenty-six years served as subjects for the study. Subjects were selected on a voluntary basis from the University of Houston Women's Basketball Team and Modern Dance Club and members of the Women's Olympic Development Volleyball Team. All subjects were considered conditioned,
therefore were not representative of the normal population.

The subjects were tested on the submaximal cardiovascular step test. The test consisted of stepping up and down on a seventeen inch bench. The test originally contained three phases of work with cadences of sixteen, twenty and twenty-four steps per minute for Phases I, II, and III, respectively. The test was extended to include a fourth and fifth phase at twenty-four steps per minute so as to make sure that nearly all of the subjects would attain a heart rate of 168 beats per minute. Each inning involved thirty seconds of stepping and twenty seconds of rest. During the twenty second rest period the subjects counted their pulse for ten seconds starting on second six and ending on second fifteen. The pulse counts were recorded on the subjects' score cards and were later converted to beats per minute by multiplying the ten second pulse count for each inning by six. Expired air samples for determining maximal oxygen consumption were collected during the same test period as the Balke Treadmill Test.

Target heart rates of 150 and 168 beats per minute were correlated with the Balke Treadmill Test and with maximal oxygen consumption values to establish validity of the step test. Coefficients of correlation were also computed to determine the relationships between several
heart rates, from 120 to 168, and the validity criteria. Intercorrelations among all variables were also determined. Graphical analyses of heart rates per inning of exercise were performed for each of the five phases of the step test. Means and standard deviations were reported for all variables.

FINDINGS

The findings of this study were as follows:

1. A significant validity coefficient of .50 was obtained for the amount of exercise required to reach a heart rate of 150 beats per minute and the Balke Treadmill Test.

2. The relationship between target heart rate of 150 beats per minute and maximal oxygen consumption was significant ($r = .36$).

3. A significant correlation was found between the number of innings on the step test required to reach a heart rate 168 beats per minute and the Balke Treadmill Test ($r = .55$).

4. There was no significant relationship between maximal oxygen consumption and the amount of exercise on the step test required to elicit a heart rate of 168 beats per minute.

5. The Balke Treadmill Test correlated highest with amounts of exercise necessary to elevate the heart rate above 160 beats per minute.
6. Maximal oxygen consumption correlated highest with amounts of exercise that produced moderate heart rates of approximately 135 to 155.

7. The Balke Treadmill Test correlated higher with scores on the submaximal step test than did maximal oxygen consumption.

Discussion of the Findings

The submaximal cardiovascular step test for females which was investigated in this study might prove more economical, less strenuous and easier to administer to large groups than other tests reported in the literature to date. Although not high, the significant coefficients found when heart rates were correlated with the Balke Treadmill Test tend to support the test as being valid when considering the Balke Test as a validity criterion. The highest validity coefficient was found when the Balke Treadmill Test was correlated with a heart rate of 162 beats per minute. Pittillo\textsuperscript{57} reported a reliability coefficient of .67 for the test at heart rate 162 beats per minute.

The criterion heart rates of 168 and 150 beats per minute produced significant but not the highest validity coefficients when correlated with the Balke Treadmill Test. Witten\textsuperscript{58} reported that a heart rate

\textsuperscript{57}Pittillo, loc. cit.

\textsuperscript{58}Witten, loc. cit.
response of 168 beats per minute correlated higher with the Balke Treadmill Test than did other heart rate responses on the F-EMU Step Test. The test described by Witten began with a cadence of twenty-four steps per minute which is a greater work load than that used in the first phase of the test in this investigation and would tend to elicit higher heart rates earlier in the test. Witten's test also utilized increased bench heights in each phase which further increased the exercise workload.

The Balke Treadmill Test tended to correlate higher with all heart rate responses than did maximal oxygen consumption values. This can be explained by the similarities in the parameters of measurement since both the Balke and the step test involve the amount of work necessary to reach certain heart rate criteria.

It was unexpected that the correlation of between the Balke Treadmill Test and maximal oxygen consumption would be so small (.085). However, since the Balke Treadmill Test terminated at a heart rate response of 160 and maximal oxygen consumption samples were taken at near maximal heart rate levels, it was not expected that the two criteria would be highly related since they are different parameters of measurement.

Wyndham et al\(^5\) reported that maximal oxygen consumption values and heart rate responses to exercise

are linearly related up to a point near the maximum value at which time they appear to have a horizontal asymptote. Horvath and Michael stated that they found no relationship between the submaximal heart rate and maximal oxygen consumption values in young women. Falls and Humphrey further support the low relationship between submaximal heart rates and maximal oxygen consumption values. It was reported that the asymptote for maximal oxygen consumption occurs in young adult women at a heart rate between 180 and 187 beats per minute. The findings of this study in regard to the low relationship between maximal and submaximal cardiovascular measures are in agreement with those reported by Wyndham et al, Horvath and Michael, and Falls and Humphrey.

The graphical analyses of mean heart rates per inning of exercise clearly show a gradual but progressive increase in mean heart rate for innings one through sixteen. Beyond inning sixteen the mean heart rates appeared to level off at approximately 150 beats per minute. It was determined through observation of individual test scores during the testing sessions that those subjects that exhibited the higher levels of conditioning


61Falls and Humphrey, loc. cit.
appeared to reach a steady state at the seventeenth inning and continued in this state through inning thirty. These results can be accounted for due to the conditioned sample used in the study and the fact that the fourth and fifth phases of the test presented the same work load as Phase III. This would perhaps further explain the very low relationship between the two criteria measures; since nine of the subjects completed all thirty innings without achieving the heart rate of 168 beats per minute. Apparently, the test is not strenuous enough to discriminate among highly conditioned subjects, if a target heart rate of 168 is used.

CONCLUSIONS

Based upon the findings of this study the following conclusions were drawn:

1. The submaximal cardiovascular step test with target heart rates of 150 or 168 beats per minute is a valid test of cardiovascular fitness when considering the Balke Treadmill Test as the validity criterion.

2. The Balke Treadmill Test and maximal oxygen consumption are not comparable criteria of cardiovascular fitness.

3. With conditioned subjects, the capacity for maximal work as measured by max VO₂ is more effectively predicted by light to moderate
work loads, whereas prediction of maximal work as measured by the Balke Treadmill Test requires more strenuous exercise.

RECOMMENDATIONS

Based upon the findings of this study the following recommendations were made:

1. Repeat the study using subjects that more closely approximate the normal population.
2. Conduct a similar study to investigate the possibility of increasing the cadence for Phases IV and V to attempt to provide for better evaluation of the cardiovascular fitness of the more conditioned subjects.
BIBLIOGRAPHY

A. BOOKS


B. PERIODICALS


C. UNPUBLISHED


APPENDIXES
APPENDIX A

Subject Score Card

Subject ___________________________ Height __________
Date ______________________________ Weight __________
Age _______________________________ Resting HR ______
Temperature _______ Humidity _____ Barometric Pressure ______

Balke Treadmill Test

Time began _____ Time to reach 160 bpm _____ Score _____

Max. VO₂

Time to reach 168 bpm _____ Time test terminated _____

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 LSU Step Test

Phase I - 16 steps/min.

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Phase II - 18 steps/min.

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Phase III - 24 steps/min.

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Phase IV - 24 steps/min.

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Phase V - 24 steps/min.

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Side 2
APPENDIX B

Test Instructions

The following is a step test of cardiovascular function. The test consists of eighteen innings at three specific stepping rates. On the command, "Exercise," begin stepping up and down for thirty seconds at the given stepping rate. On the command, "Stop," step down and find your pulse at the carotid artery. On the command, "Count," count your pulse for ten seconds until the command "Stop" is given. Report your pulse count to your partner for recording and listen for the rhythm of the next stepping bout. On the command "Exercise" begin stepping again. When you reach a pulse count of twenty-eight beats, your test is over and you may be seated. If you have completed the eighteenth inning and have not reached a pulse count of twenty-eight beats you will continue on the last phase of the test until a pulse count of twenty-eight beats is obtained. Please observe a demonstration of one complete inning.
APPENDIX C

Formula for Maximal Oxygen Consumption Values

\[ \text{VO}_2 = \min \text{Vol} \times \text{STPD} \times \frac{(\text{N}_2 \times \text{FIO}_2 - \text{O}_2 \times \text{FIN}_2)}{\text{FIN}_2} \]

where:
- \( \text{FIO}_2 \) = Fraction of \( \text{O}_2 \) in ambient air
- \( \text{FIN}_2 \) = Fraction of \( \text{N}_2 \) in ambient air
- \( \text{FICO}_2 \) = Fraction of \( \text{CO}_2 \) in ambient air

where:
- \( \text{FIO}_2 + \text{FIN}_2 + \text{FICO}_2 = 1 \) (or 100%)

\[ \text{VCO}_2 = \min \text{Vol} \times \text{STPD} \times \frac{(\text{CO}_2 \times \text{FIN}_2 - \text{N}_2 \times \text{FICO}_2)}{\text{FIN}_2} \]

\[ \text{VE} = \min \text{Vol} \times \text{BTPS} \]

\[ \text{BTMV} = \min \text{Vol} \times \text{BTPS} \]

where:
- \( \text{STPD} = \frac{\text{(Room Pressure} - \text{C})}{760} \)
- \( \text{BTPS} = \frac{310 \times \text{(Room Pressure} - \text{C})}{(273 + \text{Room Temperature})(\text{Room Pressure} - 47)} \)
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VITA

The author was born in Galveston, Texas, on September 7, 1937. She received her elementary education at St. Mary's Cathedral in Galveston, Texas, and attended Texas City High School in Texas City, Texas. She received a B.S. degree from North Texas State University, Denton, Texas, in June, 1962 and a M.Ed. degree in August, 1967 from Sam Houston State University, Huntsville, Texas.

Her professional experience has included teaching at Sam Houston High School in Houston, Texas, in 1962-1968, Pan American University in Edinburg, Texas, in 1968-1969, Southern University in Baton Rouge, Louisiana, in the Summer of 1969, and Rice University in Houston, Texas from 1969 to the present. In her present position at Rice University she is Director of Equal Employment Opportunity Programs and devotes one-half of her time to teaching in the Department of Health and Physical Education.
EXAMINATION AND THESIS REPORT

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Major Field: Physical Education

Title of Thesis: The Validity of a Submaximal Cardiovascular Step Test for Women

Approved:

Jack K. Nelson
Major Professor and Chairman

James P. Spero
Dean of the Graduated School

EXAMINING COMMITTEE:

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Date of Examination:

November 26, 1974