KERR, FRANCES BETH. An Investigation of the Relationship Between the Cardiac Cost During a Basketball Game and the Performance of Selected Basketball Skills. (1968) Directed by Dr. Frank Pleasants. pp. 113

The purpose of this study was to investigate the relationship between the performance of selected basketball skills and the cardiac cost for the roving player during college varsity basketball games. The subjects were the five roving players on the University of North Carolina at Greensboro women's varsity basketball team. Each subject took the Leilich Push Pass test and a modified version of the Leilich Bounce and Shoot test two minutes after completing a five-minute rest in sitting position and repeated the two Leilich tests in a post-game test on another day following participation in a twenty-minute basketball game. The E & M Physiograph "Four" was used to telemeter the subjects' heart rates during the resting periods, the non-game tests, the basketball games, and the post-game tests. The cardiac cost for the game and skill tests was the difference between the exercise heart rate and the resting heart rate for an equivalent period of time.

The Wilcoxen Matched-Pairs Signed-Ranks Test revealed no significant differences between the non-game and post-game Push Pass test scores and no significant differences between the non-game and post-game Bounce and Shoot test scores. There was a significant difference at the 10 per cent level of confidence between the non-game and post-game cardiac cost for skill.

The Spearman Rank Correlation Coefficient was used to compare the cardiac cost of play during the twenty-minute game

to (1) the difference between the non-game and post-game Push Pass test scores and (2) the difference between the non-game and post-game Bounce and Shoot test scores. There was no significant relationship between the players' cardiac cost during a game and the difference between the non-game and post-game skill test scores.

Within the limitations of this study the following conclusions appear warranted for the five roving players that participated in the testing:

1. Play during a twenty-minute game did not change the rovers' normal ability to execute selected basketball skills.

2. The rovers' cardiac cost for two skill tests was higher than normal following play during a twenty-minute basketball game.

3. The rovers' cardiac cost during a twenty-minute basketball game was not related to the difference between their normal skill and their skill following the basketball game.

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN THE CARDIAC COST DURING A BASKETBALL GAME AND THE PERFORMANCE OF SELECTED BASKETBALL SKILLS

by

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Approved by

Frank Pleasants

APPROVAL SHEET

This thesis has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro, Greensboro, North Carolina.

Thesis Director

Oral Examination
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TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Within this century girls and women have gained the privilege of playing vigorous games and sports. A widespread concept of weak and fragile females fostered early American social customs limiting ladies to refined activities such as backyard croquet. With the turn of this century, however, girls began to clamour to play team sports such as basketball and hockey and to compete in individual areas such as track and field. These requests were acknowledged and controlled carefully. Early leaders took special precautions to insure that playing conditions were not so strenuous that they endangered a girl's health or detracted from her game skills. The slow modification of game rules throughout this century illustrates the gradual appreciation of women and girls' ability to withstand vigorous physical activity and to excel as athletes.

Basketball evolved slowly from a three-court passing game to a two-court running and passing game. More recent rule changes permit two roving players to cross the center line to play at both ends of the floor. The roving player's position is a strenuous assignment. The current style of play requires the rover to run quickly between the ends of the court and to adjust to constantly changing offensive and defensive patterns.

The rover must meet the ball handling, passing, dribbling, shooting, and rebounding requirements for guards and forwards. She often plays near the top of the key on defense and moves constantly to intercept passes and block attempted shots. She is responsible for bringing the ball down the court and for running down the court herself to establish her offensive or defensive position before the opponents organize their play. The rover must remain quick, alert, and agile throughout four eight-minute quarters.

The roving position in basketball and the center halfback position in hockey have been found to require a greater energy cost than positions in many other individual and team sports. The rover reaches a higher heart rate than stationary forwards and guards. Her oxygen consumption and pulmonary ventilation rise to high levels. (76) The question remains whether the rover's long periods of strenuous play influence her ability to execute the skill patterns learned for the game. Most players admit that they tire after long periods of running. A coach watches carefully for signs that the rover is slowing down. A girl that falls behind the play, fails to position and jump for rebounds, reacts slowly, and uses inaccurate passes becomes a liability to her teammates. The coach must make a subjective decision about the player's effectiveness in order to decide whether to allow her to remain in the game.

The changes in skill that appear to occur as a player tires may be related to the amount of work she has been doing during the game. The heart rate during submaximal exercise is an indirect indication of the work output and energy cost. The heart rate rises proportionately as the work output increases and energy cost increases to meet exercise demands. Changes in skill that occur during strenuous play may be a function of the exercise heart rates that the player reaches during a game.

This study investigated the relationship between the cardiac cost during a college varsity basketball game and the performance of selected basketball skills. The cardiac cost was chosen to indicate five roving players' relative levels of work output and energy consumption during basketball games and skill tests. The investigator considered the high levels of heart rate, work output, and energy cost that the roving player reaches and maintains during a game a general index of the rover's level of fatigue. (47, 76) Heart rates telemetered during game situations and skill tests provided the data necessary to compute the cardiac cost of play. The roving players took two modified items of the Leilich Basketball Battery to measure their normal skill. At a later date each subject played in a twenty-minute game and repeated the tests at the end of play. The analysis of data tested the significance of the difference between the test scores under non-game and post-game conditions. A second comparison tested the significance of the difference between the cardiac cost during the non-game and post-game test. The correlation between the cardiac cost during a game and the differences in skill performance between non-game and post-game tests provided a measure of the relationship between the cardiac cost and the performance of the skills during a basketball game.

I. STATEMENT OF THE PROBLEM

The purpose of this study was to investigate the relationship between the performance of selected basketball skills and the cardiac cost for the roving player during college varsity basketball games.

II. BASIC ASSUMPTIONS

1. The heart rate during exercise was assumed to reflect the work output during exercise and the energy cost of exercise. (47) The cardiac cost of exercise was assumed to be a valid and reliable comparison between the response of the same person to different types of exercise or different workloads and the response of different individuals to the same workload. (83)

2. The E & M Physiograph "Four" was assumed to provide a valid and reliable measure of heart rate during exercise and resting conditions. (6)

3. The Leilich Push Pass test and a modified version of the Leilich Bounce and Shoot test were assumed to be valid and reliable measures of the relative abilities of roving players to perform basketball skills. (1:280)

III. DELIMITATIONS

1. The subjects were limited to five members of the varsity basketball team at the University of North Carolina at Greensboro.

2. Basketball performance was limited to those aspects of basketball measured by two modified items of the Leilich Basketball Battery.

3. The basketball games were limited to twenty-minute games played between teams composed of members of the varsity team and graduate students at the University of North Carolina at Greensboro. The variable factors that cause discrepancies within the playing conditions during different games were not controlled.

4. The cardiac cost was the only index used to evaluate the roving players' physiological responses to the strenuous activity during basketball games and skill tests.

5. The heart rate measured during each minute of exercise was considered an indication of the cardiovascular response to the intensity of the exercise. The average heart rate recorded while a subject sat on a chair in the gymnasium for five minutes was considered the resting heart rate. The following factors that may influence the heart rate were not controlled:

A. The time of day of testing.
B. The temperature and humidity of the gymnasium.
C. The amount of food that a subject ingested prior to testing.
D. The amount of sleep that a subject received the night prior to testing.
E. The smoking habits of the subjects.
F. The subjects' participation in other physical activities prior to testing.

G. The subjects' emotional response to the testing equipment, skill tests, and games.
H. The subjects' motivation to excel during the testing and games.

IV. DEFINITIONS

Cardiac cost. The cardiac cost is the total number of heart beats above the resting level that are needed to perform work. (83)

Resting heart rate. Resting heart rate is the average number of heart beats per minute recorded during a five-minute rest in a sitting position.

Exercise heart rate. Exercise heart rate is the number of heart beats per minute recorded during a specifically designated exercise or activity.

Cardiovascular response to exercise. The cardiovascular response to exercise is the total sum of the compensatory adjustments that the cardiovascular system makes to maintain homeostasis during exercise. These adjustments include specific functional changes in cardiac output, blood pressure, blood distribution and rate of flow, and the components within the blood.

Fatigue. Fatigue is a linguistic construct describing the temporary and reversible physical state in which the body's "normal" physiological adjustments for a given physical task become inadequate. The body may utilize additional physiological mechanisms to complete the task or in extreme conditions may become unable to accommodate the demands of the task. (24)

Energy cost. Energy cost is an objective measure expressed by a metabolic index of the energy required by the body to complete and recover from a given task. (11:263)

Work output. Work output is an objective measure of the intensity of the mechanical work that a person accomplishes expressed in terms such as foot-pounds or kilogram-meters. (10:305)

Telemetry. Telemetry is the process of recording the heart rate during exercise or rest with a measuring device that converts the electrical potential of the heart to radio waves, transmits the waves to a receiver, and amplifies and converts the waves to a graphic representation of the frequency of the heart rate.

Physiograph. The physiograph is a precision measurement and recording instrument manufactured by the E & M Company. The physiograph described in this study is the Physiograph "Four" equipped with a recording channel for heart rate, a time event channel, and receiver and pre-amplifier units. (6)

Electrode. The term electrode refers to a small round surface electrode recessed within a protective rubber covering that may be attached to the surface of the body. (6)

Transmitter. The term transmitter refers to a small transistor transmitter designed to convert the electrical potential produced by the heart to radio waves. (6)

Basketball skills. Basketball skills are the specific combinations of coordinated neuromuscular movement patterns required to play the game of basketball. These patterns include game-oriented elements such as shooting and rebounding and more general elements such as the ability to change direction which may or may not be specific to the game situation.

Post-game test. A post-game test is a testing session begun two minutes after the experimental subject finishes playing in a twenty-minute basketball game.

Non-game test. A non-game test is a testing session begun two minutes after the experimental subject finishes a five-minute rest in a sitting position. The testing session neither precedes or follows a basketball game.

CHAPTER II

REVIEW OF LITERATURE

Fatigue plays an essential role in the body's response to physical exercise. The exact nature of this role, however, remains nebulous and difficult to define. As a physical and psychological syndrome fatigue has a variety of connotations ranging from subjective feelings of boredom to the panting and perspiring sensations at the end of a long run. People attribute fatigue to a variety of stressors ranging from several minutes of total physical exertion to several days, weeks, or years of repetitive working patterns. Fatigue may be described in terms of physiological changes, levels of productivity, behavioral manifestations, and personal reactions to unpleasant or long and tedious tasks. This review attempts to justify a physiological frame of reference for fatigue. The so-called "mental" and "psychological" components of fatigue fall outside the scope of this description of fatigue as a physiological phenomenon.

A person's ability to perform physical skills varies during a season, a game, or even a short practice session. Such changes may be small cyclical fluctuations, gradual or rapid improvements, or gradual or rapid declines. Long periods of submaximal activity and short periods of maximal activity appear to influence a person's ability to execute coordinated skill patterns. A period of work may be said to influence further work. This review attempts to show the changes in the ability to perform or learn motor ability and skill patterns that occur as the result of fatiguing exercise.

The cardiovascular system adjusts to the increased metabolic demands during exercise. Although changes in cardiovascular indices such as cardiac output or stroke volume are difficult to evaluate, the heart rate during exercise may be measured without impairing an individual's health or performance. This review explains the nature of the cardiovascular response to exercise and attempts to justify the heart rate as a measure of the total cardiovascular response, work output, and energy cost during exercise. The cardiac cost is described as a suitable measure of the differences between the response of the same person to different types of exercise and the response of different individuals to the same workload.

This chapter includes four subject divisions. The first section considers the description of fatigue in physiological terms. The second describes the effect of fatiguing activity on the ability to learn and the ability to perform physical skills. The third section presents the changes to the cardiovascular system during exercise and describes age, sex, environmental factors, and training as variable influences on the cardiovascular response to exercise. The fourth section reviews the relationship of the heart rate during exercise to the total cardiovascular response to exercise and defines heart rate as a measure of work output and energy cost. This section summarizes studies of the heart rates of women during exercise and studies utilizing heart rate to assess fatigue. The encompassing purpose for the entire review is to justify the tenets of the experimental rationale. This chapter reviews research evidence supporting (1) a comparison between the non-game ability to execute basketball skills and the post-game ability to execute basketball skills following the potentially fatiguing exercise during a basketball game, (2) a comparison between the non-game cardiac cost of work and the post-game cardiac cost of work following the potentially fatiguing exercise during a basketball game, and (3) the value of the cardiac cost of work as an index to compare the roving players' relative activity during a game with the differences between their non-game and post-game skill test scores.

I. DESCRIPTIONS OF FATIGUE

Fatigue is a controversial and ambiguous term. The use of the word places the reader in what Eagles and associates described as a "semantic morass." (87) The broad range of meaning that defies precise definition has led some authorities to suggest that the term is not appropriate for scientific literature. However, fatigue is a common expression that receives a considerable amount of attention from physiologists, psychologists, and educators alike. Their concern is to explain the fluctuating nature of the human ability to adjust to the demands of living. This section reviews several more conventional frames of reference for fatigue. The final paragraphs define arbitrary criteria for fatigue as a state in which normal physiological mechanisms become inadequate.

One school of thought defines fatigue as a subjective individual expression of feelings of disorganization. Bartley, a prominent spokesman for this rationale, defined fatigue as the "self-evaluation of inadequacy." (2:7) He believed that the concept of the biological fatigue manifested by reduced performance does not describe the total organism. Bartley contrasted the term fatigue, as a "sensory-cognitive syndrome" which includes tiredness, aversion to work, and ineffective performance, to the term impairment, which describes only "cellular disfunction." (2:5-6) Within this frame of reference fatigue becomes an individual's assessment of his own condition which cannot be equated with decrements in performance or functional changes within body systems.

Some authors choose to define fatigue in terms of the changes in work output that occur as the result of "tiring activity." Bartlett explained that fatigue covers the "determinable changes in the expression of an activity" associated with lower output and higher expenditure of effort. (82:1-2) Such changes are often evaluated in terms of the duration that an activity may be continued, the accuracy and precision with which an activity may be continued, or the speed at which an activity may be continued. A decrease in work output is an acknowledgment that fatigue has occurred. This frame of reference provides a convenient and precise picture of fatigue with valid and reliable measurement techniques. The authorities that criticize this hypothesis recognize the value of the study of decreased performance but disavow the underlying concept that the study of decreased performance is the same as the study of fatigue.

Psychologists often choose to define a combined form of mental and physical fatigue. Such a definition acknowledges the changes in performance resulting from insufficient motivation, boredom, and negative attitude as well as changes due to physiological disturbances. Nunney defined a "disinclination towards work" as the result of increased activity. (100:7) Schwab associated fatigue with poor judgment, omission of details, and low motivational level. (91) Shaw and associates mentioned vague feelings of inertia, a sense of heaviness, and undefinable discomfort. (72) These leaders admitted the inherent problems associated with finding objective methods to measure mental and psychological fatigue.

The description of fatigue in this experimental study relies upon a physiological basis. This concept circumscribes the layman's common understanding of the fatigue associated with symptoms such as elevated heart rate, ventilation rate, and body temperature. These visible symptoms accompany metabolic adjustments within the total organism. In a physiological sense fatigue describes a temporary and reversible state in which the body's "normal" physiological adjustments for a given task become inadequate. The body must utilize additional compensatory mechanisms to accomplish the task. Balke and associates called this type of fatigue a "decrement of functional reserves." (24) Dill described a "disturbance in balance between wear and repair." (85) Physiologists have utilized metabolic indices such as blood sugar, lactic acid, and heart rate to measure the levels of fatigue. (24, 47, 85) The third and fourth sections of this chapter describe the cardiac response to exercise and explain the rationale for selecting the heart rate as a valid indication of fatigue during physical activity.

II. CHANGES IN SKILL AS THE RESULT OF FATIGUING ACTIVITY

The analyses of the effect of a fatiguing activity on motor and skill patterns assume several distinct designs. Fatigue may be induced to a localized muscle group and body part or induced to the entire body. Investigators may determine changes in the same movement pattern repeated many times or consider the changes in a pattern after an intermittent strenuous task. The intermittent task may be a period of participation in an actual game situation, a timed bout of running or treadmill and ergometer work, or an explicit task completed without regard to length of execution. The motor task may test a specific element of skill in a given sport. In other instances, the task may be designed to measure general motor ability or specific aspects of motor fitness such as balance, strength, endurance, or kinesthetic sense. Some studies limit these motor ability elements, applying them to a given sport such as endurance in swimming or speed in throwing. One may investigate the effect of fatigue on a task already learned and performed consistently or instead consider the effect of fatigue on the ability to learn a new skill.

Several complications require caution in a review of the research conducted to study changes in skill as the result of fatiguing activity. The experimental designs for the study of fatigue effects on skill, the study of warm-up effects on skill, and the study of practice effects and learning curves parallel one another and occasionally coincide. During one testing session a person is tested in a skill without practice or warm-up; in a second test he practices before any testing begins. If the second test scores fall lower, the investigator may conclude either that warm-up is detrimental or that skill decreases as the result of fatiguing practice. If the first and second scores show no significant differences, possible conclusions are that warm-up has no effect or that the fatiguing activity fails to precipitate changes in skill. If the second test proves better than the first, one concludes either that warm-up proves beneficial or that the fatiguing activity promotes higher skill levels. If a subject practices the same task many times in a row, improved scores may indicate positive results from warm-up, learning through repetition, or insignificant changes from fatigue. At times experimental results are inconclusive. A review of the research requires close scrutiny of each author's purpose and design.

A second complication involves the use of the same activity or test for different functions within different experiments. One investigator may test the effect of intermittent activity upon the vertical jump, while a second may use the vertical jump to fatigue a subject in order to study changes in some other activity. The treadmill and the bicycle ergometer are frequently selected to induce fatigue. However, some studies investigate changes in speed or working capacity measured by the treadmill or ergometer due to the influence of some outside fatiguing factor.

The following sections examine the research conducted to determine the effects of fatiguing activity on motor performance. The review does not consider fatigue as induced by sleep deprivation, nutritional changes, drugs, anxiety, boredom, or other psychological stressors. The effect of fatigue is presented both for stablized performance standards and for learning situations. The discussions consider fatigue from repeated performance and fatigue from an intermittent activity. The effects of warm-up on skill are mentioned in those cases in which the warm-up activity can be viewed as strenuous enough to act as a possible fatiguing agent.

Effects of Fatigue From Repeated Task Performance

Strength. The majority of studies of repeated task performance deal with localized repeated muscle contraction. As the same muscle shortens again and again, the power of the contraction diminishes. (10:59) Clarke employed a spring-loaded hand ergograph to test the rate of fatigue from static and dynamic contractions. Strength decreased from an average 46.9 kilograms to a steady state 15.8 kilograms during a two-minute maximal static contraction and from an average 45.7 kilograms to a steady state 27.6 kilograms during a maximal dynamic contraction repeated every two seconds for six minutes. The two fatigue patterns followed curves defined by different exponential equations. The muscles recovered more quickly from static fatigue. (29)

Speed and reaction time. Hipple studied the effect of repeated performances of the fifty-yard dash on speed times. With no prior warm-up, eighth-grade boys ran five fifty-yard dashes within a twenty-minute period. The average speed for the first three trials was the same, but the speed fell 2 per cent lower for the fourth trial and 3.7 per cent lower for the fifth trial, reflecting possible fatigue effects. (45) Pierson tested the deviations in reaction times and movement times for men on a repeated hand-arm coordination pattern. Results showed that the decrement score of the mean of the slowest block of five trials was significantly less than the normal reaction time and movement time recorded as the mean of the sixteenth to twentieth trials. (59) Pierson and Lockhart tested women with the same apparatus and procedure. No significant differences existed for movement times. However, decrement reaction time was significantly less than normal reaction time. (60)

The Effects of Fatiguing Activity on Specific Elements of Physical Fitness and Motor Ability

Steadiness. Neuromuscular hand tremor and body sway increase as the result of fatiguing activity. Bousfield tested tremor after subjects rested and tremor after subjects used the ergograph to lift 1500 foot-pounds in three 500-pound loads with the forearm. The rate, irregularity, and amplitude of the tremor increased after the fatiguing load. (27) Tuttle and associates found that tremor varied directly with the intensity of exercise following rest and stool stepping for one minute at rates of twenty, forty, and "all out" stepping per minute. (79) Ware and Colville measured hand steadiness with the C. H. Stoelting apparatus. Colville tested subjects four times, once after rest and once following the respective performance of three, six, and ten squat thrusts. The longer exercise routines significantly increased the tremor rate. (31) Ware found significantly lower hand steadiness following an exercise bout of fifteen squat thrusts. (104) Mitchem and Tuttle reported significant differences between neuromuscular finger tremor after rest and after exercise bouts consisting of ten arm curls with a ten-pound weight, ten arm curls with a fifteen-pound weight, fifteen knee bends, twenty knee bends, or bicycle ergometer riding at 720 kilogram-meters of work per minute. (53) Ross and associates found that hand steadiness decreased and body sway increased after three rounds of heavy boxing workout with the bag or a three round bout with an opponent. (68)

Several findings contradict the above research. Scott and Mathews found no significant decreases in steadiness measured by tracing with a stylus after each item of an efficiency battery consisting of an arm dynamometer pull, the Scott Obstacle Race, a bounce from sitting position, hook sitting situps, and chair stepping. (71) Elbel measured response time after a variety of strenuous activity. A combined bout of bench stepping and pushups elicited no significant changes in finger response or hand response. In one other facet of the study, members of a college boxing class displayed improved hand response and body response scores after a thirty-minute class session. (38)

Balance. Fatiguing activity does not limit balancing ability. Ware found that fatigue from squat thrusts did not influence balance as measured by the Bass Stick test. (104) Culhane confirmed these results with a report that scores on the Balance Stick and Balance Leap tests did not change significantly following a bicycle ergometer ride. (96)

Strength. Three contradictory experimental results describe increases, insignificant changes, and decreases in strength following strenuous exercise. Scott and Mathews determined that subjects had an increase in leg strength after performance on five items of an efficiency battery. (71) Thompson found no significant differences in leg strength measured with the dynamometer between a test allowing no warm-up and a test preceded by a warm-up of calisthenics. (78) Dohrmann considered the effect of strenuous leg exercise on hand and arm strength. Right and left forearm flexion and left grip fell significantly lower after subjects pedalled the bicycle ergometer at seven thousand foot-pounds per minute until the work load could no longer be maintained. (98)

Kinesthetic sense. A variety of tests for kinesthetic acuity provide conflicting evidence of the effect of fatigue on the kinesthetic sense. Slocum administered the Arm Raising test and the Balance Stick test following the modified Carlson fatigue test, and the Floor Target test and the Weight Shifting test following a second trial of the Carlson test. Subjects registered significantly lower than normal scores on Arm Raising and significantly higher than normal scores on Balance Stick and Weight Shifting following fatigue. (102) Dial found a significant improvement in the Push test and insignificant changes in Arm Raising after an exercise requiring arm flexion and extension with a three-pound weight in the hand. (97) Ware discovered insignificant differences between normal scores on the Young test of kinesthetic positioning and exercise scores following fifteen squat thrusts. (104)

Speed. Research to date considers the value of warm-ups on speed as measured by a dash or bicycle ergometer work. Mathews and Snyder found no differences in scores for high school boys in a 440-yard dash following no warm-up or a warm-up including calisthenics, jogging, and wind sprints. (49) College women failed to improve speed scores on the bicycle ergometer after

Skubic and Hodgkins required a warm-up of twelve jumping jacks or a warm-up of eight practice revolutions on the bicycle. (74)

General motor ability tests. Jump and reach performance improves following warm-up. Pacheco found a 4.83 per cent improvement in scores for junior high girls following three minutes of running in place. (56) A group of college men improved performance after each of three types of warm-up: isometric stretching exercises, knee bends, and running in place. (57)

Effects of Fatiguing Activity on Motor Learning

Although the literature agrees that fatigue affects the performance of a pursuit type motor learning task, discrepancies exist in the influence of fatigue on learning rate and learning curves. Alderman found that a group of subjects that exercised on an arm ergograph half way through a rho motor learning task showed a 40 per cent lower performance but the same amount of learning as the group that practiced the learning task without the ergograph exercise. (16) Nunney divided subjects into five equated groups. One group rested before practice on the Snoddy Stabilometer, a mirror tracing psycho-motor instrument, while each other group received one of the following exercises: five-minute ride on the bicycle ergometer with no load, five-minute ride on the bicycle ergometer with a seven-pound load, five-minute run on the treadmill at six miles per hour at 0 per cent gradient, or five-minute run on the treadmill at six miles per hour at 25 per cent gradient. The rested control group differed significantly from the active groups on the sixth and following practice trials. Following a ten-minute recovery period there was no significant difference between groups on a second psychomotor test, the Rotary Pursuit Meter. (100)

Effects of Fatiguing Activity on Skill in A Specific Sport

Softball. Light warm-up improves distance scores for throwing. However, fatiguing activity has been shown in discrepant reports to increase, decrease, or produce no changes in throwing accuracy. Rochelle and associates recorded three distance throws for college men after no practice and after a five-minute warm-up throwing with a partner. The men threw an average of 10.2 feet farther after warm-up. (66) Thoden found no significant throwing changes in concentric accuracy, vertical deviation, or horizontal deviation after college baseball players ran on the treadmill at 50 per cent and 75 per cent of their maximum capacity. (103) Witte found that unskilled junior high girls improved throwing accuracy after light, moderate, and heavy exercise including jumping jacks and laps on the track. Skilled girls showed no change in accuracy following light and moderate exercise but a decrease in accuracy after heavy exercise. Both the learning factor for the unskilled girls and the uncontrolled time for exercise may have influenced these results. (80)

Football. After college men performed the Harvard step test, Reading found speed scores from three football stances significantly lower than speed scores recorded before the step test. (101)

Swimming. Thompson reported that a swimming warm-up rather than a calisthenics warm-up improved swimming speed and endurance scores. (78) In a later study deVries found that swimming warm-up improved the times for one hundred-yard trials and calisthenics warm-ups improved times for the breaststroke and dolphin trials and decreased times for the free style trials. (33)

Basketball. Thompson found that college freshman varsity basketball men scored a greater number of free throws after a warm-up of general floor shooting, passing, and foul shooting than after a period allowing no warm-up. (78)

III. THE EFFECTS OF EXERCISE ON THE CARDIOVASCULAR SYSTEM

During physical exercise the cardiovascular system makes special adjustments to accommodate accelerated metabolic needs. Active muscles demand increased supplies of oxygen and nutrients. The cardiovascular system carries these materials to the tissues, circulates the regulatory hormones and other metabolites needed in exercise, dissipates heat, and removes carbon dioxide and cellular wastes. This section presents the changes in cardiac output, blood pressure, the distribution and flow of blood, and the components in the blood that enable the cardiovascular system to meet the metabolic demands of exercise. In most instances the demanding exercise is continuous, submaximal isotonic work such as bicycle pedalling or treadmill running. Special cardiovascular responses to isometric exercises, prolonged work, and non-continuous work are included because of their importance in game situations such as basketball. The effects of cardiovascular diseases, drugs, artificial bandaging to occlude circulation, or extreme temperature and humidity variables fall beyond the scope of this paper. The purpose is to review the typical cardiovascular responses from normal subjects to normal exercise.

Special factors such as age, sex, body temperature, metabolic rate, time of day, humidity, ambient temperature, physical condition, posture, ingestion of food, and emotional stress may influence the response of the heart and circulatory system to normal exercise. Whenever possible the review mentions age, sex, physical condition, and posture as a frame of reference for the studies reported. The other variables were not controlled in the majority of research surveyed. A final subheading in this section summarizes the differentiating effects of age, sex, environmental factors, and training as they effect cardiovascular responses to exercise.

Cardiac Output

Cardiac output measures the amount of blood pumped by the heart per minute. The actual numerical value equals heart rate multiplied by stroke volume, where heart rate is the number of times that the heart beats per minute and stroke volume is the volume of blood pumped by each heart beat. The normal mean resting heart rate ranges between fifty and one hundred with an average of seventy-two for men and eighty-four for women. Average resting stroke volume is one hundred millimeters in supine position and sixty millimeters in sitting position. Average cardiac output is four to five liters per minute in sitting position and five to six liters per minute in supine position. (10: 93 and 101) Body posture must remain a constant factor in the study of change in cardiac output during exercise. Even at rest a change from lying to standing causes an increase in heart rate and a fall in cardiac output and stroke volume.

The cardiac output during exercise reflects changes in stroke volume and heart rate. These in turn rely on a number of stimuli from the endocrine system, nervous system, and cardiovascular system itself. The sensitive response to a number of outside stimuli explains Warren's reasoning for calling cardiac output the "servant" rather than the "director" of circulatory activities. (93) This subheading reviews the factors that cause changes in heart rate and stroke volume during exercise, discusses the changes in heart rate and stroke volume during exercise, and then considers the combined effect of stroke volume and heart rate as the change in cardiac output during exercise.

<u>Factors causing changes in stroke volume</u>. Venous return, effective filling pressure, distensibility of the ventricle in diastole, contractility, and systemic arterial blood pressure influence stroke volume. (5:67) The volume of venous return of blood to the heart controls the amount of blood available to be ejected with each heart beat. The relative volumes of incoming

blood, however, do not themselves govern the size of stroke volume though they may prove a limiting factor if venous return becomes abnormally small. The most noticeable influence of venous return is the immediate changes in stroke volume attributed to the change in venous return as the body changes from a standing to a lying or a sitting position. (5:68)

Until recently, effective filling pressure and distensibility of the ventricle in diastole appeared to be the major determinants of stroke volume. In 1918 Starling proposed a widely accepted law that implied that stroke volume was proportional to the heart's diastolic volume with the force of the heart contraction proportional to the stretched length of cardiac muscle fibers. (10:94) Karpovich continued to attribute changes in stroke volume to changes in diastolic filling volume and fiber length of cardiac muscle. (5:153) Analyzing more current theory, deVries applied Starling's law to constant conditions rather than increased or decreased workloads. With other factors constant, diastolic volume and the stretched length of cardiac fiber may influence stroke volume. Current cinefluoroscopic and rötgenological techniques, however, indicate that end diastolic volume does not increase during exercise and may decrease during prolonged work. (41) Filling pressure and distensibility of the ventricle are not major determinants of stroke volume during the changing workloads of exercise conditions. (5:67)

Arterial blood pressure determines the resistance that the blood meets as it flows from the aorta. If the heart exerts a consistent contractile force, an increase in arterial resistance lowers the volume of blood ejected. (5:67) Karpovich mentioned a positive effect of higher pressure: higher blood pressure improves the venous return by forcing greater volumes of blood to return to the heart to be ejected. (9:153)

The contractility of the heart muscle is the most important variable influencing the size of stroke volume. Greater contractility makes the heart beat more powerful. Sympathetic nerve fibers stimulate the ventricular myocardium to determine the intensity of fiber tension and the force available to produce the heart beat. (5:61) Stroke volume increases as a more forceful heart beat ejects a greater proportion of the blood contained in the ventricle and leaves a smaller systolic residue. (10:95) The increase depends upon the greater emptying of the ventricle rather than increased diastolic filling. (84) The stroke volume attains a maximum as the heart forces the ventricle to empty completely during contraction. (10:95)

A few authorities stated that a shortened time for diastolic filling limits stroke volume at high heart rates. Karpovich assumed that stroke volume improves as heart rate increases, until the rate becomes so rapid that the heart lacks adequate time for the ventricle to fill during diastole. (9:152-3) In contrast, deVries mentioned that greater contractile power during exercise speeds up the systolic emptying and allows greater time for diastolic filling. (5:67) Astrand and associates studied stroke volumes of young men and women during maximal work on the bicycle ergometer. Stroke volume showed no tendency to decrease at maximum heart rates. Lowered stroke volume appeared unrelated to high heart rate or large heart volume for the few cases showing a slight reduction in stroke volume at maximum exercise. (20) Carlsten and Grimby reported that the time available for diastolic filling does not restrict diastolic volume or stroke volume at heart rates up to two hundred beats per minute. (3:9)

Changes in stroke volume during exercise. Until the last few years evidence from indirect measuring techniques led physiologists to agree that stroke volume increased during exercise. In 1960 Brouha and Radford reported that stroke volume increased two or three times during exercise. (84) Karpovich reasoned that stroke volume during exercise must increase up to two times to account for transportation of the increased oxygen consumed. He explained that the combined effect of increased heart rate and increased oxygen absorption rate accounted for only half the increased rate of oxygen consumption during exercise and concluded that an increase in stroke volume must facilitate further increase. (9:152-3)

Stroke volume varies only slightly during exercise. The recent availability of the Fick and dye indicator processes to measure stroke volume makes assessments of changes in exercise more precise than the less reliable, indirect methods. The majority of studies applying these techniques show slight increases in stroke volume with exercise. Astrand and associates found that the average resting stroke volume for young men and women sitting on the ergometer ranged between 40 and 90 per cent with a mean of 63 per cent of the maximum value obtained during ergometer exercise. Subjects working at 40 per cent of aerobic capacity achieved maximum stroke volume at about 110 beats per minute. The volume varied only 4 per cent during exercise between 40 and 100 per cent of aerobic working capacity and did not decrease at maximal working capacity. (20) Grimby and Nilsson reported a 10 to 20 per cent increase in stroke volume from supine rest to supine exercise at nine hundred kilopond-meters per minute. (42) Rushmer summarized the results of several investigating teams showing that an increase in exercise did not cause an increase in stroke volume for normal subjects. (69) Ricci believed that stroke volume remains consistent until the body reaches the upper limits of cardiovascular response with large increases possible at high heart rates. (11:106)

A sequence of events known as the Valsalva effect alters cardiovascular response to static exercise. Increased intra-thoracic pressure caused by expiratory efforts against a closed glottis causeslower venous return and changes in stroke volume, blood pressure, and heart rate. (5:99) During the Valsalva maneuver stroke volume falls to 30 to 50 per cent of the normal value. (3:54)

The stroke volume decreases during prolonged exercise. Eklund and Holmgren reported an average 16 per cent decrease in stroke volume after eighteen to twenty-seven minutes of exercise. (37) Saltin and Stenberg found a decrease from 126 milliliters to 107 milliliters per minute following prolonged submaximal exercise both in sitting and supine positions. (70)

Factors causing changes in heart rate. Heart rate per minute depends upon the rate of impulses from the sino-auricular node. Impulses travel from the sino-auricular node to the auriocoloventricular node and through the Purkinje system to the ventricular myocardium. (5:61) The autonomic nervous system directly regulates the sino-auricular node, supplying the inhibitory fibers of the parasympathetic vagus nerve and activating fibers of the sympathetic accelerator nerve. During rest the vagus nerve bombards the sino-auricular node with impulses, slowing heart rate. Increased heart rate is a combined result of decreased vagal stimulation and increased accelerator stimulation to this pacemaker. The cardioregulatory centers of the medulla oblongata that control autonomic nerve impulses receive pressor impulses from the proprioceptors in joints and muscles, chemoreceptors in the carotid body and aortic body, and the cerebral cortex, and depressor impulses from the stretch receptors in the carotid sinus and aortic arch. (5:65) Epinephrine and norepinephrine secreted by the adrenal medulla reinforce sympathetic impulses by increasing the flow of blood in coronary vessels and acting directly upon the myocardium to increase the strength of contraction. (84) Epinephrine causes an increase in cardiac frequency; norepinephrine causes an increase followed by a decrease in cardiac frequency. Karpovich reported that during steady state muscle activity impulses from the working muscles rather than the cerebral cortex control heart rate. This conclusion relied upon the evidence of several experiments proving equal effect upon heart rate by voluntary muscle contraction and involuntary electically induced work. Karporich also attributed small changes in heart rate to the response of the pacemaker to the increased temperature of the blood in the right auricle. (9:175-6) Morehouse and Miller mentioned rise in blood temperature, rise in carbon dioxide content, and drop in blood oxygen content as non-nervous factors causing increases in heart rate. (10:107)

In 1915 Bainbridge suggested that increased pressure stimulating nerve fibers resembling pressoreceptors in the walls of the venae cavae causes the heart to beat faster. This reflex pattern would allow the muscles to regulate heart rate since the increased venous return produced by the massaging action of the muscles in exercise would increase pressure and indirectly cause the rise in heart rate. (10:107) Conflicting results from the study of the effect of pressure on the right heart suggest that the Bainbridge reflex does not affect an increase in heart rate during exercise. (58)

Changes in heart rate during exercise. Heart rate increases as soon as exercise begins. Even before exercise starts, the central nervous system may initiate an anticipatory increase in the heart rate that precedes the quick initial rise as soon as exercise starts. During light exercise the heart rate levels off or even drops slightly after the initial rise and maintains a constant rate as exercise progresses. During a medium load the heart rate continues to rise after the quick preliminary increase and gradually reaches and maintains a plateau. During severe exercise the heart rate fails to reach a plateau and continues to increase until exhaustion ends the exercise. If an individual continues moderate exercise for a long time, the heart may show a secondary rise after maintaining a plateau and continue to rise until exhaustion ends the work. (83) The level at which the heart rate reaches a plateau during light and moderate exercise depends upon the intensity of the work involved and shows a linear relationship to work load. (9:168)

The heart rate decreases as soon as work ends. The rate drops quickly at first and then gradually falls to resting rate. The intensity of the workload directly influences the length of the recovery period. The heavier the load, the higher the recovery rate and the longer the time needed to return to normal. The duration of exercise influences recovery following heavy but not light exercise. Longer exercise loads require longer recovery processes. (83)

During isometric exercise heart rate increases are very slight. deVries attributed rates lower than isotonic rates to decreased venous return and lower workloads. (5:74) Ricci explained that during the Valsava maneuver heart frequency increases during the drop in venous return and blood pressure accompanying the contraction and decreases during the increase in venous return and blood pressure following the end of contraction. (11:93) Brouha and Radford reported that the heart rate following isometric contraction is higher in proportion to the magnitude of the contraction and the muscles used. (84) Carlsten and Grimby reviewed two studies testing the heart rate during static contraction. Hanson and Maggio found that a static workload added to a constant dynamic workload caused the heart rate to increase more than the heart rate predicted for the same oxygen uptake during dynamic exercise. (3:55) Mobleck reported that six to twenty-nine repeated isometric contractions per minute increased the heart rate in proportion to the size of the contracted muscle group. (3:55) Carlsten and Grimby cautioned that heart rate during isometric contraction is unstable and unsuitable for measuring physiological load. (3:55)

The heart rate during discontinuous exercise depends upon the duration of work, the size of the workload, and the length of rest periods. With light workloads and constant periodic rest intervals, the heart rate may return to resting level during each recovery period. If rest remains constant in length, and work becomes more intense, the heart rate increases progressively during successive periods of work and recovers less completely during rest periods until the body reaches maximum working capacity and exhaustion. (83) During exercise in which workloads change, the heart rate reflects relative increases and decreases. The rate increases abruptly following marked increases and rises gradually following small increases. (84)

Astrand and Saltin reported that the period of times the heart can maintain its maximum heart rate and cardiac output may be proportional to the size of the muscle mass participating in the exercise. (22)

The heart rate increases following prolonged exercise. Ekelund and Holmgren found an increase in heart rate from 145 to 175 between ten and sixty minutes of bicycle exercise. (37) The heart rate recorded following a day of heavy work or a strenuous earlier exercise was higher than the rate following no earlier exercise. Carlsten and Grimby attributed rates five to ten beats per minute higher following heavy work to decreased mechanical efficiency and reduced stroke volume. (3:31-2)

Changes in cardiac output during exercise. The cardiac output increases during exercise and may reach thirty liters per minute in a well-trained man. (5:65) Morehouse and Miller acknowledged that trained athletes may obtain cardiac outputs of thirty liters per minute at an oxygen uptake of 4 liters per minute and normal subjects may obtain cardiac outputs of twenty-two liters per minute at an oxygen uptake of 3.3 liters per minute. (10:84) Astrand and associates found average maximum cardiac outputs of 18.5 liters per minute for women and 24.1 liters per minute for men. (19)

There is considerable variation in cardiac outputs at supine, sitting, and standing postures during exercise. Carlsten and Grimby reported two studies by Bevergard indicating that at unchanged oxygen uptake cardiac output in supine position was about two liters per minute higher than in sitting position. (3:15) Reeves and associates found the cardiac output lower during treadmill walking than supine pedalling at the same level of oxygen uptake. (64)

Cardiac output increases rapidly at the beginning of exercise and then levels off and remains fairly constant. Donald and associates found that the cardiac output was constant after three to five minutes of supine exercise. (36) Grimby and associates reported a study of young men performing thirty minutes of sitting exercise on the bicycle ergometer at workloads of six hundred and nine hundred kilopond-meters per minute. Cardiac output rose rapidly during the first two minutes and showed a small increase between the second and fifth minutes of exercise. The cardiac output during the lighter load remained at a plateau for the remaining minutes of exercise. At the heavier workload the output increased again slightly between the fifth and seventh minutes and then remained constant for the duration of exercise. (43) Astrand and associates reported no fall in cardiac output at maximal heart rates. (20)

Cardiac output remains stable during prolonged exercise and severely fatiguing exercise. In a three-hour exercise period cardiac output may rise slightly in conjunction with a higher oxygen consumption. The stable or slightly increased cardiac output reflects a decreased stroke volume and increased heart rate. (3:29-30) Grimby and associates found large variations in cardiac output with an average variation of 8 per cent during a thirty-minute moderate ergometer exercise. (43) Saltin and Stenberg found that cardiac output increased during prolonged submaximal ergometer exercise and stayed at normal values during prolonged maximal exercise. (70)

A fall in cardiac output accompanies the Valsalva maneuver during isometric exercise. Carlsten and Grimby reported that cardiac output for a fifty-year old athlete decreased from 6.8 liters per minute to 4.8 liters per minute during the Valsalva maneuver. Output increased again toward normal when the maneuver lasted twenty-five seconds. (3:54) A rise in cardiac output may follow the isometric contraction of large muscle groups. (3:56)

Blood Pressure

Arterial blood pressure is the force with which the blood presses against the walls of the arteries. The pressure varies throughout the body depending upon such factors as location of the vessel, length of the vessel, diameter of the vessel, and hydrostatic pressure. Arterial pressure is measured at heart level. For the normal young adult man, average systolic pressure is 120 millimeters and average diastolic pressure is 80 millimeters. (10:116)

Factors causing changes in blood pressure. Blood pressure within a given vessel depends upon the volume of blood flow and the resistance that it meets. Stroke volume and heart rate determine the blood flow and the vasoconstrictor tone of the vessels determines resistance. (5:97) The medulla oblongata controls impulses along sympathetic nerve pathways to the smooth muscles around arterioles that determine vasoconstriction. Increased and decreased rate of impulses result respectively in increased and decreased restriction. A supply of proprioceptive endings in the auricles and ventricles serve to minimize change in blood pressure. Increased pressure from the blood within the heart causes the vessels and heart chambers to enlarge; decreased pressure causes the vessels and heart chambers to shrink. (11:89) Carbon dioxide and oxygen content act as direct chemical regulators to vasoconstriction. The increase in carbon dioxide dilates the walls of the arterioles; an increased oxygen pressure produces vasoconstriction. Hormones produce additional regulating effects. Epinephrine secreted by the adrenal medulla causes an increase in systolic and diastolic blood pressure and a decrease in arterial resistance; norepinephrine causes an increase in systolic and diastolic blood pressure and an increase in arterial resistance. (11:91)

Changes in blood pressure during exercise. Changes in blood pressure during exercise have been difficult to measure even with telemetering techniques. (11:86) Since the type, speed, and duration of exercise effect blood pressure, generalizations made from treadmill running and ergometer pedalling must be applied very cautiously. Likewise, readings taken at the end of exercise do not accurately reflect blood pressure during exercise. (10:124) Systolic pressure increases during exercise. Jokl reported that diastolic pressure falls; deVries reported that diastolic pressure increases slightly. (8:56, 5:98)

Blood pressure may rise in anticipation of exercise. (9:182) As exercise begins, the pressure rises quickly and then gradually increases. At the end of exercise the rate falls quickly. The rate may increase slightly again following the initial fall as exercise ceases. (10:125) The time needed for arterial pressure to return to normal following exercise depends upon the severity of exercise. Following maximal exercise, both the systolic and diastolic pressure may drop below normal and require thirty to sixty minutes to return to normal. (84)

Carlsten and Grimby reported a study by Holmgren showing a correlation between blood pressure and workload on the bicycle ergometer. An average rise of eight millimeters for physically fit men and nineteen millimeters for untrained men accompanied an increase in the workload of three hundred kilopond-meters per minute. (3:22)

Studies by Holmgren and Grimby as reported by Carlsten and Grimby showed that blood pressure rose during the first two minutes of prolonged exercise and then fell continuously. (3:24) Saltin and Stenberg found a 10 per cent decrease in systolic, diastolic, and mean arterial pressure following 180 minutes of treadmill or ergometer exercise at 75 per cent of the individual's maximal volume of oxygen. (70)

During isometric exercise the Valsalva effect causes an initial sharp increase in both systolic and diastolic pressure, an intermediate drop in pressure accompanying decreased venous return, and a final increase in pressure following the end of the contraction. (5:99) The increase and decrease of pressure during static exercise is much more abrupt than the gradual changes during dynamic exercise. (10:126)

Blood Flow and Distribution

The distribution of blood depends upon changes in diameter of the small arteries and arterioles. The capillary bed contains three types of vessels: metarterioles which remain operational as preferential channels in all conditions, true capillaries, arising from the metarterioles, which may close during resting conditions, and arterio-venous-anastomoses, arising from small arteries, arterioles, and metarterioles, which open during exercise to dissipate heat. (5:90-1) The sympathetic nervous system aided by certain chemical regulators controls the diameter size and the selection of opened vessels. Adrenergic sympathetic fibers cause vasoconstriction and cholinergic sympathetic fibers cause vasodilation. During exercise nervous stimulation causes sphincters to close off circulation to inactive tissues and opens true capillaries within the active muscle. Lowered pH, increased carbon dioxide saturation, and other local changes in the concentration of metabolites stimulate further localized vasodilation after exercise begins. (5:92-3) Intracellular potassium and histamine, adenine compounds from the breakdown of ATP, and the compound bradykinin may be additional stimulants to vasodilation. (10:119)

As exercise begins, there is an immediate rise in the total volume of blood in the muscles. (3:35) Blood flow to the abdominal organs decreases and blood flow to the contracting skeletal muscles, heart, and skin increases. Blood vessels in the skin constrict initially but later open for increased blood flow to dissipate heat. Flow through the kidneys may decrease 50 to 80 per cent. (10:119) Brouha and Radford cited results showing that during exercise blood flow to the brain remains constant, blood flow to the kidneys, liver, intestines, and spleen decreases, and blood flow to the skin, heart, skeletal muscles, and respiratory muscles increases. (84)

Blood distribution to the pulmonary arteries and coronary arteries is particularly critical. The pulmonary vascular bed has a high potential blood capacity. During exercise capillaries distend and additional capillaries open to increase the surface area available for oxygen diffusion. (3:26) Although the diameter and flow rate through the pulmonary artery and the aorta are the same, the pressure in the pulmonary artery is 20 per cent of the pressure in the aorta. (3:27) Carlsten and Grimby believed that pulmonary circulation does not impose limits on oxygen diffusion or working capacity during strenuous exercise. (3:27) Brouha and Radford mentioned, however, that blood flow needed by the respiratory muscles may limit blood flow to skeletal muscles at an oxygen consumption above three liters per minute. (84) The blood pressure level in the aorta controls coronary blood flow. Higher blood pressure plus the dilating effects of lowered oxygen content causes the necessary increase in coronary flow during exercise. (10:123)

Isometric contractions occlude blood flow at exercise requiring at least 60 per cent of maximal contraction strength. (5:100) During prolonged exercise blood flow to the skin increases causing a necessary reduction to other regions. Pulmonary artery pressure also decreases. (3:33) Research methods are not yet available to measure accurately the volume of blood that flows through the working muscles during exercise. Barcroft and Dornhorst estimated the flow in calf muscles during rhymical exercise, finding a tenfold increase during exercise and a larger increase as resistance decreased immediately following exercise. (25) Black found a linear increase between blood flow and the rate of exercise up to four miles per hours. (26)

Components in the Blood

During exercise there is an increased exchange between the blood and intra- and extra-cellular fluids in the capillaries. The actual exchanges depend upon the pressure gradient across capillary walls, the membrane permeability, and the size of the effective capillary filtering area. Local metabolites may cause a large increase in the amount of fluid filtered across the membrane during exercise. The initial fluid flow is outward from the capillaries to the tissue beds causing a decrease in blood and plasma volume during short exercise. After ten minutes of exercise the blood volume remains constant. (3:45-46) Saltin and Stenberg found total blood volume 5 per cent lower following prolonged treadmill and ergometer exercise for men. (70)

As a result of lowered volumes of fluid, the hemoglobin and serum protein concentration and the proportion of cellular elements in the plasma increase. (5:177-8) The normal erythrocyte count of 5.5 million per cubic millimeter for men and 4.8 million per cubic millimeter for women may increase as much as 20 to 25 per cent in strenuous exercise. (9:178)

During exercise the number of white blood corpuscles may rise from between 5000 and 7000 per cubic millimeter to 27,000 per cubic millimeter. Karpovich hypothesized a three-stage increase: an increase in lymphocytes, an increase in neutrophils, and a further increase in neutrophils accompanying a decrease in lymphocytes. (9:143) The number of blood platelets decreases after exercise. The specific gravity of the blood increases during exercise, falls below normal following exercise, and gradually returns to normal. Blood sugar stays constant during mild exercise, increases during strenuous exercise, and may decrease during prolonged exercise. (9:145)

The buffering systems within the plasma and fluid within the erythrocytes protect the body from severe change in pH during exercise. Lactic acid in the blood and carbonic acid in the fluid within the erythrocytes change in reactions with salts to weaker acids. (5:135-6) As the oxygen debt increases during exercise, blood lactate increases proprotionately. deVries classified two types of oxygen debt: alactacid debt without lactate increases and lactacid debt with lactate increases. (5:157) After the oxygen debt passes four liters, blood lactate level increases in proportion to further increases in oxygen debt. (11:185) deVries cited experiments showing that intermittent work caused much lower increases in lactic acid than the same continuous workloads. (5:157) Astrand and associates found a successive reduction in blood lactate concentration following prolonged exercise: skiers at the end of a ten kilometer race lasting thirty-five to thirty-six minutes had 130 milligrams of lactic acid per 100 milliliters of blood while skiers at the end of a fifty kilometer race lasting over three hours had 39 milligrams of lactic acid per 100 milliliters of blood. (19)

Variable Influence of Age, Sex, Environmental Factors, and Training on the Cardiovascular System During Exercise

Age. The resting heart rate at birth ranges near 130. This rate decreases gradually until a child reaches adolescence. (5:71) The maximum heart rate attainable decreases after twenty-five years of age. (83) The maximum attainable heart rate drops from between 190 and 200 for young adults to between 160 and 170 for older people. (5:285)

Older subjects require a larger increase in heart rate for mild exercise and a longer recovery time following exercise. (83) Carlsten and Grimby reported, however, that heart rates did not increase with age during submaximal work. (3:57)

A sharp increase in systolic blood pressure occurs at puberty. (10:116) Both systolic and diastolic blood pressure increase gradually after age twenty. (5:96) In older men the systolic pressure may reach two hundred millimeters during submaximal exercise. Pressure increases more per unit increase in cardiac output during exercise than it does for younger men. (3:61)

Sex. Since a large majority of research deals with male subjects, the responses of women and girls to exercise remains less documented. The following paragraph summarizes the limited available evidence. The resting heart rate averages five to ten beats higher for adult women than adult men. (5:71) During light exercise women reach higher heart rates than men, with similar recovery patterns. During heavy exercise women reach markedly higher heart rates with slower recovery times. (84) Men reach higher stroke volumes and higher cardiac outputs than women. (84) Astrand and associates compared well-trained men and women students during maximal and submaximal exercise. Women reached a lower average maximum cardiac output of 18.5 liters per minute in comparison to an average maximum of 24.1 liters per minute for men. Women had higher cardiac outputs for a given oxygen uptake than men. (20) Bouha reported that women showed higher heart rates than men with similar recovery patterns following submaximal bicycle work at 360 kilogram-meters per minute. At heavier exercise at 540 or 750 kilogram-meters per minute women showed markedly higher heart rates and longer recovery times than men. Women reached exhaustion at a lower workload than men. (83) Cardiac cost for girls twelve to fifteen years old becomes lower for a given work load with no further improvement as the girl matures. In contrast, cardiac cost becomes increasingly more advantageous for men in their twenties and thirties. (5:404) Blood pressure in women compares lower than men before menopause and higher than men following menopause. (5:96)

Environmental factors. During work in warm climates skin vessels dilate and heart rate increases above normal. Brouha mentioned a linear relationship between environmental temperature and increase in heart rate at rest and during work. The heart rate takes longer to return to resting levels during recovery. (83) Carlsten and Grimby reported a 10 per cent increase in cardiac output during one hour of resting conditions at 37 degrees centigrade. (3:81) As a person becomes acclimatized to higher temperatures, heart rate decreases and changes occur in the vascular tone of the vessels. (3:81)

At any given temperature and workload the heart rate increases with higher humidity. (5:72) Heart rate response under constant workload is higher in a hot wet environment than a hot dry environment. (5:274)

At higher altitudes a lowered proportion of oxygen in the air promotes a rise in heart rate and cardiac output after a sudden change from lower altitudes. (3:82) Pugh reported higher heart rates, lower stroke volume, and normal cardiac output for submaximal work at 5800 meters. Maximal cardiac cost and heart rate were lower at the higher altitude. (61)

Training. Brouha and Radford classified training as the most significant variable determining the level of cardiovascular activity. (84) Training causes physiological changes in the body which include more efficient cardiac and circulatory function. Considerable differences may exist between a trained and untrained person's ability to work under similar conditions. As a result training must be a controlled factor in studies of cardiovascular response to exercise. This section describes the differences in cardiac output, blood pressure, blood distribution and flow, and blood components that may occur between a trained and untrained person.

A greater contractility causes more complete systolic emptying and consequently larger stroke volume for trained men during exercise. deVries suggested that stroke volume for trained athletes is higher at rest as well as at exercise. (5:76) Jokl, however, cited a study by Millerowicz showing lower resting stroke volume for conditioned men. Athletes had an average resting stroke volume of sixty-seven milliliters with distance runners as low as forty-four milliliters in comparison to the normal value of eighty milliliters. (8:37) Ricci mentioned equal resting stroke volumes for trained and untrained persons. (11:104) Carlsten and Grimby explained that increases in the filling pressure of the left heart allow a well-trained athlete to maintain a larger stroke volume at higher heart rates. (3:10)

With other variables constant at a given workload, a trained person has a lower heart rate than an untrained person.

The heart rate for a specific individual at a given workload will decrease as training progresses. (5:76) Trained athletes have lower resting heart rates than untrained persons. (8:49) Carlsten and Grimby reported that thirty minutes running three days per week proved strenuous enough to lower the heart rate significantly both at rest and during exercise. (3:69) Frich and co-workers found a seven beat per minute decrease in heart rate at the same workload after two months of training for previously sedentary young men. (40) Karnoven studied the training effect from treadmill running at various rates on changes in the heart rate in exercise. A subject showed no changes from running at 135 beats per minute but showed progressive improvement from running at 150 beats per minute. Karnoven concluded that the heart rate in training must reach an intensity of 60 per cent of the range between resting and maximum heart rate in order to affect changes in heart rate. (89)

A trained person recovers to resting heart rate more quickly following exercise. (83) Training will not improve the maximum heart rate attainable but does increase the workload that may be maintained at maximum rates. (5:76) A fit subject performs more work than an unfit subject before obtaining maximum rate. (83)

The combined training effects of lower exercise heart rate and higher exercise stroke volume may cause small changes in cardiac output. Carlsten and Grimby summarized a study by Bevegard showing that cardiac output was higher for trained athletes at submaximal work but not at heavy work. (3:64) Freeman and associates found no changes for moderate workloads. (39)

Training decreases systolic pressure during exercise. Consequently, pressure is lower following exercise. (9:188) The pressure for trained men returns to normal more rapidly following exercise. (10:257) Jokl reported that training decreases resting systolic pressure and increases resting diastolic pressure. (8:54) Karpovich reported a lack of constant differences after training. (9:188)

Training causes increased capillarization in active muscles. Jokl summarized studies by Petren and Eckstein proving that intensive training led to the formation of new capillaries in the heart and skeletal muscles. (8:45-6) Morehouse and Miller mentioned that training also promotes the growth of capillaries in the motor cortex and ventral horn of the spinal cord. (10:260)

Carlsten and Grimby reported that physical training normalizes the distribution of blood flow. ECG's are less pronounced after exercise. Training leads to more adequate regulations of peripheral blood flow with more vasoconstriction in non-exercising areas. (3:72) Rohter and associates found that swimmers trained five weeks had a 60 per cent increase in blood flow in forearm flexors during exercise. (67)

After training the body has a capacity for greater oxygen debt which deVries felt may be attributed in part to an improved alkaline reserve in the blood. The body develops a greater ability to tolerate acid metabolites. (5:181 and 333) Morehouse and Miller inferred that training also diminishes the rate of lactic acid formation in moderate exercise. (10:262) The total volume of blood is significantly higher following training. The total amount of hemoglobin increases with the parallel increase in blood volume. (5:181) Morehouse and Miller explained that training increases the number and diameter of erythrocytes but decreases the hemoglobin concentration in each cell. Training lowers the osmotic resistance of the red blood corpuscles. (10:262)

IV. HEART RATE AS A PHYSIOLOGICAL MEASURE

Heart Rate as a Criterion for Cardiovascular Response, Work Load, Fatigue, and Energy Cost.

A number of physiological indices are employed to evaluate the strain or energy cost for the body during varying exercise workloads and to compare the responses of different people to the same working conditions. Such indices provide an objective numerical measure of the amount of work a person accomplishes and his physical adjustment for the work. In controlled exercise such as treadmill running or ergometer riding the workload can be measured easily in relation to the distance and force applied or running speed and incline. The relatively stable body positions facilitate procedures to measure heart rate, blood pressure, body temperature, and ventilation rate and to collect air samples and blood samples. During sports in game situations, however, the workload is not constant and movement patterns hamper physiological measurements. The use of telemetering techniques does provide a continuous record of heart rate during a contest. The purpose of this section is to justify the use of heart rate and the related index of cardiac cost in a game situation to indicate the workload and energy cost during exercise. Heart rate and cardiac cost are defined and then explained in terms of their direct relationship to workload and other physiological responses to exercise.

Heart rate and cardiac cost. The heart rate is a widely acknowledged scale to measure the response to different degrees of exercise and individual differences during exercise. The number of times that the heart beats per minute in response to a workload provides an easy and quick observation of the "total stress upon an individual's cardiovascular system." (5:75) deVries labelled heart rate "the most important variable in the response to the demands of exercise." (5:72) Brouha and Radford explained that heart rate evaluates "the stress imposed by muscular activity upon the heart and circulation" and depicts the "cardiovascular adjustment of the individual to muscular activity." (84:197)

Cardiac cost utilizes heart rate to compare different workloads. The cardiac cost is the total number of heart beats above the pre-exercise resting level needed to perform the work. The cardiac cost of recovery is the total number of heart beats above the resting rate that occur between the end of exercise and the heart rate return to pre-exercise rates. The total cardiac cost is the sum of the cardiac cost of work and the cardiac cost of recovery. (84) Brouha, who devised the cardiac cost index, suggested that the measure be used to compare "different workloads, various kinds of exercise, or different individuals." (83:183) deVries feels that cardiac cost provides "reasonably valid information" about the stress to the cardiac system under varied environmental conditions. (5:75) Maxfield and Brouha argued that, unlike steady state or maximal heart rate, cardiac cost takes the duration of exercise into consideration and allows for the "cardiac debt" repaid during recovery. They believed that the cardiac cost adjusts to individual changes in resting rates and provides a higher correlation with work output than exercise heart rate above zero. (50)

Relationship of heart rate and cardiac cost to work output and muscular fatigue. Maxfield and Brouha studied the validity of cardiac cost as a measure of work output for three subjects on the bicycle ergocycle at sixty revolutions per minute and the treadmill at 3.2 miles per hour at progressively increasing workloads. There was a parabolic relationship between both cardiac cost and exercise heart rate above zero and the work accomplished within a given time. Cardiac cost of recovery showed a parabolic relationship to work accomplished and a linear relationship to total cardiac cost. Maxfield and Brouha concluded that total cardiac cost was the most complete measure of "cardiac strain" during exercise but acknowledged the usefulness of cardiac cost and cardiac cost during recovery as scales whenever total cardiac cost cannot be measured. (50)

LeBlance studied the relationship of heart rate to workload under normal, hot, and cold temperatures. Heart rate increased proportionately with increases in workload and proved a more accurate measure of workload than oxygen consumption at high and low temperatures. LeBlance stated that the pulse rate may be used as a measure of the fatigue from muscular activity. Six male subjects walked at 3.4 to 4.5 miles per hour and ran at 5.1 and 9.5 miles per hour for a one-mile distance. At the higher speeds, heart rate continued to increase throughout the run. In a second experiment the subjects ran at constant speeds over varying distances. The pulse rates were higher for higher speeds. Heart rates increased progressively throughout one run at a given speed. LeBlance reasoned that the inability of the heart rate to remain at a steady state "would appear to indicate that fatigue is experienced by the heart." He concluded that heart rate may be "an index of work output as well as an indicator of the level of fatigue caused by muscular work" with the duration and intensity of the work controlling the "magnitude of the fatigue expressed." (47)

Relationship of heart rate and cardiac cost to energy cost. The physiological strain imposed by an activity is often evaluated by determining the energy necessary to perform the imposed workload. Since the body's metabolic processes utilize oxygen, energy cost is related directly to the amount of oxygen that the body consumes. (5:149) Thus, oxygen consumption may be used to classify levels of metabolic intensity. (11:176) The energy cost of a physical activity is often defined as the amount of oxygen required during the exercise and the recovery from exercise or the kilocalorie or kilogram-meter equilavent. (11:281) Heart rate during activity has a linear relationship to oxygen consumption and thus indirectly indicates relative degrees of energy cost for an activity.

Dill stated that the heart rate increases in "an almost linear fashion" with the metabolic rate when other conditions are controlled. At high heart rates the relationship breaks down because there may be an increase in the metabolic rate if the body utilizes stored energy reserves after the heart reaches a maximum rate. (86) Brouha and associates found also that heart rate increases were not proportionate to oxygen consumption increases in a warm environment. Oxygen consumption attained a steady state for a given workload and pulse rate continued to rise. (28)

Carlsten and Grimby acknowledged a well-established rectilinear relationship between heart rate and oxygen uptake with an asymptotic increase in oxygen uptake at very heavy exercise close to maximum oxygen uptakes and heart rates. They allowed that energy costs may be calculated from heart rate during submaximal exercise with the exception of abnormal situations such as acute starvation, administered drugs, fever, acute heat exposure, and dehydration. (3:14)

Nagle and Bedecki found a linear relationship between ventilation and heart rate up to 170 beats per minute and a disproportionately larger increase in ventilation rate between 170 and 180 beats per minute. Oxygen consumption increased linearly with heart rate with a tendency to rise asymptotically between 180 and maximum rate. (54)

Malhotra and associates computed regression equations for seven young men from pulse rates and oxygen consumption during work at varying workloads on the ergometer and found the error in predicting energy cost from heart rate by measuring heart rate and energy costs during field tasks such as marching, running, hopping, and hammering. There was a linear relationship between heart rate and energy cost with two significantly different components for heart rates between seventy-five and ninety-five and rates above ninety-five. Each subject required a different regression line. The variation between predicted and actual energy cost for the field tasks fell between .3 and 4 per cent for rates below ninety-five and between .06 and 7 per cent for rates above ninety-five. (48)

Wyndham and associates compared both oxygen consumption and heart rate to various levels of work on the bicycle ergometer. Both oxygen consumption and heart rate showed a linear relationship to workload at low rates of work but increased asymptotically at high rates. Oxygen consumption approached an asymptote more slowly than heart rate. Thus when heart rate was equated to oxygen consumption the relationship was linear until near maximum values when the oxygen uptake predicted by heart rate was an underestimate of actual oxygen uptake. (81)

Davis and Harris studied the relationship between working capacity as measured by maximum oxygen consumption and four indices based on heart rate. The pulse deficit defined as the difference between the mean rate during the first four minutes and the mean rate during the second four minutes of exercise provided a good measure of "relative working capacity." (32)

As a part of a study to develop a nomogram to calculate maximal oxygen intake from heart rate and oxygen intake during submaximal work, Astrand and Rhyming found a linear relationship between heart rate and oxygen consumption for heart rates between 120 and 170. (21)

Some discrepancies cloud a proposed relationship between cardiac output and oxygen consumption accompanying the relationship between heart rate and oxygen consumption. Riley wrote that as cardiac output increases oxygen consumption increases proportionately to maintain a constant saturation of oxygen in mixed venous blood. (90) Astrand and associates reported that the increases in cardiac output during exercise were much lower for proportionate increases in oxygen consumption near maximum values. (20) Tabakin and co-workers found a good correlation between increases in cardiac output and increases in heart rate, oxygen consumption, and minute volume of ventilation for normal men during progressively increasing treadmill exercise. Cardiac output, however, did not show uniform and constant increases with workload. Stroke volume did not correlate with the other indices. (77) Reeves and associates found that cardiac cost was not defined as a linear function of oxygen consumption for varying workloads of supine exercise. A sharp increase in cardiac output during exercise occurred after the femoral and central arterio-venous oxygen differences stopped increasing. (65) In a separate report Reeves mentioned a linear relationship between oxygen consumption and cardiac output during resting conditions. (63)

Heart Rates of Women During Selected Sporting Events

This section reviews the limited number of studies telemetering the heart rates of women in actual sports events. The first paragraphs summarize sports other than basketball. The final paragraphs present a detailed analysis of the study of heart rate during basketball games.

Skubic and Hilgendorf telemetered the heart rate of five highly trained high school girls in the 220-yard, 440-yard, 880-yard, and mile events. Anticipatory rates above rest equalled 59 per cent of heart adjustment to exercise. The mean heart rates were 183 in the 220, 183 in the 440, 182 in the 880, and 188 in the mile run. The difference between mean rates in the events was not significant. Peak heart rates ranged from 185 to 215 beats per minute with the mean heart rates near the end of the race similar in all events and at a mean rate of 193 beats per minute. (73)

Armstrong and Cant in separate studies investigated heart rate during badminton, contempory dance, and basketball. Mean anticipatory rates for performers in both studies were respectively 84 and 88 for badminton, 90 and 89 for contempory dance, and 99 and 92 for basketball. Mean exercise heart rates were 147 and 144 for badminton, 121 and 129 for contemporary dance, and 167 and 169 for basketball. (94, 95)

Skubic and Hodgkins telemetered the heart rates of subjects in archery, badminton, bowling, golf, tennis, basketball, field hockey, softball, and volleyball, reporting game heart rates and estimated oxygen uptakes in each situation. Gas samples taken at five representative heart rates during a treadmill run were used to determine regression lines for oxygen uptake for all heart rates. The mean heart rates for two respective subjects were 97 and 95 in archery, 161 and 135 in badminton, 90 and 80 in bowling, 102 and 103 in golf, and 150 and 130 in tennis. The mean heart rates for the first of the two subjects above and for an additional subject were 132 and 134 in softball, and 146 and 120 in volleyball and 180 and 180 in hockey. (76)

Two of Skubic and Hodgkins' subjects played five basketball games in various positions. The games were regulation length running time with a single one minute time out per quarter. The mean heart rate after twenty minutes was not significantly different from the mean rate for the entire game. The wide range of heart rates indicated variation in the intensity within each game. The results for each girl as a forward, guard, and rover were as follows:

	Resting HR	Mean HR (entire game)	Range	Mean HR (20 minute game)	Recovery Rate Above Rest (after 10 minutes)
Subject 1	74				
Forward		142	104-180	138	41
Guard		156	92-228	150	51
Rover		195	149-216	192	70
Subject 2	69				
Forward		143	100-175	152	20
Guard		142	107-194	147	30
Rover		177	128-201	173	45

The entire oxygen uptake for each subject indicated that the roving player required a significantly greater expenditure of energy than a forward or guard. The roving position in basketball and the center halfback position in hockey had a significantly higher energy cost than the other sports tested. (76)

Armstrong studied the effects of participation in class, club, intramural, and extramural basketball games on the heart rates of six college women. The one subject that played in extramural competition had a resting heart rate of 68, anticipatory heart rate of 99, average game rate of 167, a game range between 160 and 198, and recovery times for five minutes of 145, 140, 124, 134, and 127. In comparison her anticipatory and mean activity rates in other situations were respectively class 98 and 151, club 113 and 168, and intramural 82 and 166. The data does not designate forwards, guards, and rovers. The anticipatory and game rates for the subject in extramural play were higher than the mean rates for all subjects in class, club, or intramural games. (94)

Cant duplicated the procedure used in Armstrong's thesis. The only subject recorded during extramural competition had a resting heart rate of 63, anticipatory rate of 92, average game rate of 167, a game range between 134 and 195, and respective recovery times of 124, 108, and 107 after one, three, and five minutes. In comparison her anticipatory and average game rates in other levels of games were respectively 82 and 155 in club, and 82 and 166 in intramural. The subject's mean anticipatory and game heart rates were lower than the average rates for all subjects in all subjects in all types of games. (95)

Heart Rate Indicating Fatigue During Skill Learning and Execution

Two studies defined heart rate as an index of fatigue during skill learning or execution. Balke and associates telemetered heart rate as a criterion for fatigue during a stressful situation and tests preceding and following the stressful situation. A series of tests were made to determine normal heart rates for airplane pilots during supine rest, sitting, standing, and a working capacity test with increasing resistance on the bicycle ergometer. The pilots flew missions lasting five hours to search for brush fires. The heart rates telemetered during the flights remained near resting level for the first two hours and increased an average of twenty beats during the final three hours of flight. Post-flight laboratory tests revealed no physiological symptoms of fatigue. After a short rest the subjects' heart rates dropped to normal rates and responded normally to the working capacity test. A post-flight test for the one pilot that flew eight-hour missions for three consecutive days did reveal decreased exercise capacity and orthostatic tolerance on the third day. (24)

Nunney measured pulse rate as a criterion for exercise intensity of motor tasks preceding a motor learning task. Pulse rates reached during activity were highly related to the students' subjective rating of their own fatigue. However, the differences between the pulse rates reached during a five minute ride on the bicycle ergometer with no load, a five minute ride on the bicycle ergometer with a seven pound load, a five minute run on the treadmill at six miles per hour at 0 per cent grade, and a five minute run on the treadmill at six miles per hour at 25 per cent grade were not related to the amount of learning on the Snoddy Stabilometer. (100)

CHAPTER III

PROCEDURE

I. PURPOSE

The purpose of this study was to investigate the relationship between the performance of selected basketball skills and the cardiac cost for the roving player during college varsity basketball games.

II. SUBJECTS

The subjects selected for the study were the roving players on the women's varsity basketball team at the University of North Carolina at Greensboro. The five undergraduates that participated in the testing appeared to be skilled players in good physical condition. The testing was scheduled after the first two months of the season in order to insure all subjects the opportunity to develop their endurance and to practice with the squad in the roving position.

III. SELECTION OF TESTS

Leilich Basketball Tests

The tests selected to measure basketball skill were the Push Pass test and a modified version of the Bounce and Shoot test from the Leilich Basketball Battery. (1:283) In an analysis of a rotated factor design from fourteen basketball tests and selected strength, speed, motor ability, gross body coordination and agility, flexibility, hand-eye coordination, and kinesthetic tests, Leilich found that the Push Pass test and the Bounce and Shoot test measured a ball handling factor involving passing accuracy and speed and a general motor ability factor. (99:64) The tests were assumed to measure the relative level of basketball performance for the five subjects in the study.

The Push Pass test requires subjects to pass a basketball as rapidly as possible against a round wall target for thirty seconds. Since the concentric circles required for the wall target were larger than the unobstructed wall space in the gymnasium, the investigator fastened a painted plywood target to the wall for the testing. Testing procedures and scoring techniques followed standardized directions. (See Appendix)

The Leilich Bounce and Shoot test requires subjects to pick up a basketball from a chair, dribble once, shoot, rebound, and pass the ball to a receiver standing behind the chair. The subject executes ten trials in succession, alternating attempts from the right and left side of the basket. She receives one score based upon the number of seconds required to complete the test and one score based upon the number of attempts that enter the basket. The experimental design for this study necessitated a change to allow every subject to exercise for the same amount of time. Each subject received as many alternate trials from the right and left side of the basket as she could complete within sixty seconds. Her score was the number of points scored for each legal attempt that hit the ring and that failed to enter the basket and for each legal attempt that entered the basket. (See Appendix)

The subjects were not allowed to warm up prior to testing, but were permitted to practice the tests outside of the testing sessions. Two subjects that were familiar with the Leilich battery had taken the tests as a part of a physical education class during the semester.

Cardiac Cost

The cardiac cost was selected as an indication of the subjects' energy cost and work output during basketball games and skill tests. The cardiac cost equals the total number of heart beats above the resting level needed to complete a specified amount of work. (83) As a measure of the difference between a subject's response to different types of exercise and a measure of different subjects' responses to the same exercise, the cardiac cost indicated the difference between a subject's response to non-game and post-game basketball tests and the relative level of the five subjects' responses to basketball games. (83) The cardiac cost of play was assumed to measure the relative levels of the subjects' energy costs and workloads during the basketball games. The investigator considered the high heart rates and cardiac cost that a roving player attains during basketball games a general index of the rover's fatigue. (47,76)

The cardiac cost was computed from the formula:

Cardiac Cost = Total heart beats during exercise minus resting rate for the same period of time. (5:75)

where:

Resting rate was a subject's average heart rate recorded during a five minute rest in sitting position and total heart beats during exercise was the number of heart beats telemetered during the exercise.

The cardiac cost of a basketball game equalled the sum of the exercise heart rate recorded during each minute of the game minus twenty times the resting heart rate. The cardiac cost of skills tests equalled the sum of the exercise heart rate recorded during the ninety seconds of testing and the thirty seconds between the tests minus two times the resting heart rate.

Basketball Games

Play under the actual conditions during a basketball game was selected as the most effective manner to subject the rovers to a situation equivalent to play during a varsity game. Although the uncontrolled variables during a game produce differences in the amount of activity by the same player at different minutes during a game and for players in different games, the game play is more realistic than a strenuous exercise such as treadmill running or bench stepping used to imitate the strenuous activity during a basketball game. The investigator chose to accept the limitation of the uncontrolled differences among the five games rather than to subject the rovers to similar working conditions that were not realistic play situations.

It was not feasible to require the same subject to rove during an entire intercollegiate varsity game. Each subject, however, was able to play during a twenty minute intrasquad game between members of the University of North Carolina at Greensboro varsity team. Twenty minutes of play was selected to approximate the first half of a woman's basketball game. Skubic and Hodgkins asserted that there was no significant difference between the average heart rate during a twenty-minute game and an entire game. (76) The heart rate recorded during the twenty-minute game represented the exercise heart rate during the first half of a game and may have assimulated the average heart rate for an entire game. The investigator considered twenty minutes of play a long enough session to begin to induce fatigue rather than to serve only as a possible warm-up period for basketball skills. Each game included two nine-minute quarters with a two-minute time out between playing periods. The twenty minutes of play with running time included the time that the ball was "dead" for foul shots and jump balls.

The investigator attempted to insure similar playing conditions during all five games. The same two nationally rated DGWS officials refereed each game. The majority of the members of the roving subject's team and the opposing team were members of the varsity basketball team. Graduate students and several varsity members that became academically ineligible after the first semester played to complete the teams. The same five teammates and six opponents were not assigned for each roving subject. An official scorer kept a record of the game. Both teams were encouraged to compete seriously to win. No other attempt was made to equalize the players' motivation and interest within the five games or to create the emotional environment that accompanies an intercollegiate varsity game.

The investigator did not control the rover's style of play during the game. A statistician kept a record of the number of fouls, violations, and jump balls called during each game. Individual statistics for the roving subject included a record of the number of times she participated in a jump ball, the number of times she rebounded the ball, the number of foul shots attempted and made, and the number of field goals attempted and made. An additional variable noted was the number of times that the subject crossed the center court line and passed the top of the key and the number of times that the subject crossed the center line but did not pass the top of the key before returning across the center line. These statistics provided a limited comparison between the rovers' activity during the game but did not control their play or evaluate such factors as the speed used to move down the floor or the length and types of shots utilized during the game.

IV. MEASURING INSTRUMENTS

Timing Devices

A stop watch and a Dimco Gray Universal Timer were used to time the length of the basketball games and skill tests.

Physiograph

The heart rate during exercise and rest was measured by the Physiograph "Four". (6) The investigator conducted practice sessions prior to this study to determine the best procedure to use to attach the electrodes and transmitter to a subject. The electrodes and transmitter cannot be located on an area affected by strong muscle contractions that may break the contact between the electrode and body surface or cause electrical artifacts in the transcribed record of heart rate. The arm and shoulder movements for guarding, passing, dribbling, and shooting and the chest movement during heavy breathing were difficult to overcome. The preliminary testing indicated that the most successful arrangement was to place one electrode in the center of the manubrium, the second electrode on a flat surface two to four inches to the left side of the base of the body of the sternum between the fifth and sixth ribs, and the transmitter at the base of the body of the sternum. The subject stood with her arms raised. The technician cleaned the skin with alcohol and then attached the electrodes with electrode paste and two-sided tape or adhesive washers. The electrodes and lead wires were covered with short pieces of adhesive tape placed horizontally to prevent vertical stretching from loosening the tape and electrodes. The subject wore an ace bandage wrapped snugly around the body three or four inches above the waist with the transmitter protected on the back and sides with rubber foam and taped to the ace bandage at the base of the body of the sternum. The lead wires from the electrodes passed through the front of the gym tunic and were attached to the transmitter in the front of the body.

V. TESTING PROCEDURE

Each subject took the Push Pass test and the Bounce and Shoot test two times under non-game conditions and one time under post-game conditions. The purpose of the non-game and post-game testing was to measure the difference between a subject's "normal" ability to execute basketball skills and the subject's ability to execute basketball skills following the strenuous activity during a basketball game. The subjects repeated the non-game testing in order to lessen the effects of a testing practice factor and provide a more accurate indication of "normal" ability. In order to control training conditions all three tests for the same subject were completed within the same week and the tests for all subjects were completed within three and a half weeks. In order to prevent the influence of a test upon the performance of a later test, the subjects took the test on three separate days. In all instances the two non-game tests preceded the post-game test. All tests were performed in Rosenthal Gymnasium between 2:00 P. M. and 7:30 P. M.

The physiograph recorded a continuous record of heart rate during each two minute period of skill testing, each twenty minute game, and each five minute period of rest in the sitting position. Paper speed was one centimeter per second with time signals every second. The heart rate per minute was the middle score from three readings of the graphic representation of the heart rate recorded by the physiograph.

The testing required a technician to operate the physiograph, a scorer to call the scores during the skill tests, and a timer to operate the clock and stop watch. The same two graduate students served as scorer and technician and the investigator served as timer during all testing. The scorer, technician, and timer received a copy of the testing procedure. (See Appendix) The varsity team members received a copy of the testing information and the subjects received a written schedule of test appointments. (See Appendix)

The testing procedure followed the same format during both non-game testing situations. The subject reported to the laboratory. The investigator explained the testing procedure and skill test directions to the subject while the technician attached the electrodes and transmitter. The subject walked to the gymnasium and rested while the technician tested the physiograph.

The subject sat in a chair facing away from the physiograph and toward the back of the gymnasium. A buzzer sounded at the end of five minutes. The subject waited two minutes before beginning the basketball tests. She remained seated until fifteen seconds before the test and then moved approximately ten feet to the wall to begin the Push Pass test. The scorer read the testing directions to the subject while she sat waiting for the testing to begin. (See Appendix) The subject began the Push Pass test with the timer's verbal signal and stopped the test with the buzzer at the end of thirty seconds. The scorer stood behind the subject and called the test scores to the technician to record. The subject received thirty seconds to move from the Push Pass test to the Bounce and Shoot test. She began the test with the timer's verbal signal and stopped with the buzzer at the end of sixty seconds. The scorer received passes behind one chair and called the scores to the technician to record. The timer received passes behind the second chair.

Prior to the first non-game test the scorer recorded the subject's age and measured her weight and height.

The subject reported to the laboratory thirty minutes before her scheduled game and post-game test. The technician attached the electrodes and transmitter and checked the physiograph, and then allowed the subject to warm up as she would for a varsity game. The remaining players, the scorer, the statistician, and the officials reported five minutes before game time.

The subject played as the roving player during a twenty-minute game with two nine-minute quarters divided by a two-minute time out. None of the players left the court during half time. An undergraduate scorer kept score during the game and the graduate scorer and an undergraduate assistant kept a statistical record of the game. At the end of the game the subject walked over and sat in a chair facing the wall. All other players and officials left the gymnasium. Two minutes separated the end of the game and the beginning of skill testing. The subject moved to the wall area fifteen seconds before the time to begin the Push Pass test. The subject took the Push Pass test and the Bounce and Shoot test conducted in the same manner as the non-game tests.

VI. TREATMENT OF DATA

The Wilcoxen Matched-Pairs Signed-Ranks Test was used to test the following null hypotheses concerning the non-game testing:

1. There is no difference between the roving players' skill scores on the first non-game Push Pass test and the second non-game Push Pass test.

2. There is no difference between the roving players' skill scores on the first non-game Bounce and Shoot test and the second non-game Bounce and Shoot test.

3. There is no difference between the roving players' resting heart rates recorded during the first testing session and the roving players' resting heart rates recorded during the second testing session.

4. There is no difference between the roving players' cardiac cost for the first non-game skill tests and the roving players' cardiac cost for the second non-game skill tests.

The 10 per cent level of confidence was deemed acceptable to indicate a significant difference between scores. The Wilcoxen Matched-Pairs Signed-Ranks Test assumes continuous data and applies to paired data with differences that may be ranked in order of absolute size. (14:101) The power of the Signed-Ranks Test is about 95 per cent relative to the standard Fisher's "t" test for normally distributed data. (14:103)

The investigator selected test scores to represent the resting heart rate, the non-game Push Pass score, the non-game Bounce and Shoot score, and the cardiac cost of non-game skills tests for each subject.

The Wilcoxen Matched-Pairs Signed-Ranks Test was used to test the following null hypotheses concerning non-game and post-game testing:

5. There is no difference between the roving players' skill scores on the non-game Push Pass test and the post-game Push Pass test.

6. There is no difference between the roving players' skill scores on the non-game Bounce and Shoot test and the post-game Bounce and Shoot test.

7. There is no difference between the roving players' cardiac cost for the non-game skills tests and the roving players' cardiac cost for the post-game skills tests.

The 10 per cent level of confidence was deemed acceptable to indicate a significant difference between scores.

The Spearman Rank Correlation Coefficient was used to test the following null hypotheses concerning the difference between non-game and post-game testing and the cardiac cost during the basketball games: (13:202-13)

8. There is no relationship between a player's cardiac cost during a twenty-minute basketball game and the difference between the player's non-game and post-game Push Pass test scores.

9. There is no relationship between a player's cardiac cost during a twenty-minute basketball game and the difference between the player's non-game and post-game Bounce and Shoot test scores.

The 5 per cent level of confidence was deemed acceptable to test the critical value of the correlation.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

I. PRESENTATION OF DATA

Table I presents the subjects' resting heart rates, non-game Push Pass scores, non-game Bounce and Shoot scores, and non-game cardiac cost for skill during both non-game tests. The cardiac cost for the first and second non-game tests are based respectively on the exercise heart rates and resting heart rates during the first and second testing sessions.

The significance of the difference between the two non-game sets of data was tested with the Wilcoxen Matched-Pairs Signed-Ranks Test to determine whether or not both non-game tests represent the rovers' normal ability. (14:101-3) Four null hypotheses were tested with the following conclusions:

1. There is no difference between the roving players' skill scores on the first non-game Push Pass test and the second non-game Push Pass test.

   The hypothesis was found tenable. There was no significant difference between the rovers' Push Pass scores during the two non-game testing sessions. (Table II)

2. There is no difference between the roving players' skill scores on the first non-game Bounce and Shoot test and the second non-game Bounce and Shoot test.

TABLE I

RESTING HEART RATES, PUSH PASS SCORES, BOUNCE AND SHOOT SCORES, AND CARDIAC COST VALUES FOR FIVE ROVING PLAYERS

Variables	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Age (years)	19	20	18	19	18
Height (inches)	64	64	63	59	66
Weight (pounds)	122	129	140	124	126
Resting Heart Rate					
Test 1	98	86	75	67	93
Test 2	84	80	72	61	104
Push Pass Scores					
Non-game 1	101	100	100	113	98
Non-game 2	103	110	105	106	98
Post-game	96	120	120	104	108
Bounce and Shoot Scores					
Non-game 1	18	12	17	12	13
Non-game 2	18	14	16	19	17
Post-game	14	17	20	16	15
Cardiac Cost of Skills Tests					
Non-game 1	107	123	101	162	134
Non-game 2	136	138	108	191	106
Post-game	174	184	145	213	123
Cardiac Cost of Twenty-minute Game	1789	2003	1658	2158	1214

TABLE II

WILCOXEN MATCHED-PAIRS SIGNED-RANKS TESTS OF SIGNIFICANCE BETWEEN THE FIRST AND SECOND NON-GAME SCORES

Variables	N	T*
Push Pass test	4	3
Bounce and Shoot test	4	1
Resting heart rate	5	4
Cardiac cost during skill tests	5	3

* T_{20} = 0 for N of 4.

T_{10} = 0 for N of 5.

The hypothesis was found tenable. There was no significant difference between the rovers' Bounce and Shoot scores during the two non-game testing sessions. (Table II)

3. There is no difference between the roving players' resting heart rates recorded during the first testing session and the roving players' resting heart rates recorded during the second testing session.

   The hypotheses was found tenable. There was no significant difference between the rovers' resting heart rates during the two testing sessions. (Table II)

4. There is no difference between the roving players' cardiac cost for the first non-game skill tests and the roving players' cardiac cost for the second non-game skill tests.

   The hypothesis was found tenable. There was no significant difference between the rovers' cardiac cost for skills during the two non-game testing sessions. (Table II)

Since there were no significant differences between the two sets of data collected during the non-game testing sessions, the investigator concluded that either non-game testing session represented the subjects' usual or "normal" heart rates and skill scores. The second non-game test was selected to represent a player's normal skill. Although the lack of significant differences between the scores for the non-game tests indicated that practice did not affect the scores, the second non-game test showed the subjects' performance after a practice session allowing them to adjust to the testing procedure and testing equipment.

Table I presents the subjects' post-game Push Pass scores, Bounce and Shoot scores, and cardiac cost for skills during the post-game tests.

The Wilcoxen Matched-Pairs Signed-Ranks Test was used to test the difference between the second non-game test scores and the post-game test scores. (14:101-3) Three null hypotheses were tested with the following conclusions:

5. There is no difference between the roving players' skill scores on the non-game Push Pass test and the post-game Push Pass test.

   The hypothesis was found tenable. There was no significant difference between the rovers' non-game and post-game scores on the Push Pass test. (Table III)

6. There is no difference between the roving players' skill scores on the non-game Bounce and Shoot test and the post-game Bounce and Shoot test.

   The hypothesis was found tenable. There was no significant difference between the rover's non-game and post-game scores on the Bounce and Shoot test. (Table III)

7. There is no difference between the roving players' cardiac cost for the non-game skill tests and the roving players' cardiac cost for the post-game skill tests.

   The hypothesis was rejected at the 10 per cent level of confidence. Therefore it can be assumed that the cardiac cost for skills was significantly higher than normal during a post-game test following a twenty-minute basketball game. (Table III)

Table I presents the subjects' cardiac costs for playing during the basketball games.

The Spearman Rank Correlation coefficient was used to test the relationship between the non-game and post-game score

TABLE III

WILCOXEN MATCHED-PAIRS SIGNED-RANKS TESTS OF SIGNIFICANCE BETWEEN THE SECOND NON-GAME SCORES AND THE POST-GAME SCORES

Variables	N	T*
Push Pass test	5	9
Bounce and Shoot test	5	7
Cardiac cost during skills tests	5	0

* T_{10} = 0 for N of 5.

differences and the cardiac cost during the basketball game. (13:202-13) Skills test changes ranked from high positive changes to low negative changes and cardiac cost ranked from low cardiac costs to high cardiac costs. The two null hypotheses were tested with the following conclusions:

8. There is no relationship between a player's cardiac cost during a twenty-minute basketball game and the difference between the player's non-game and post-game Push Pass test scores.

   A correlation of .49 existed between the subjects' cardiac costs during the basketball games and the differences between the subjects' non-game and post-game test scores. For five subjects the observed relationship differed from zero by chance. The hypothesis was found tenable. Therefore it can be assumed that there was no relationship between the change in a player's non-game and post-game Push Pass scores and the cardiac cost for a basketball game preceding the post-game test. (Table IV)

9. There is no relationship between a player's cardiac cost during a twenty-minute basketball game and the difference between the player's non-game and post-game Bounce and Shoot test scores.

   A correlation of .30 existed between the subjects' cardiac costs during the basketball games and the differences between the subjects' non-game and post-game test scores. For five subjects the observed relationship differed from zero by chance. The hypothesis was found tenable. Therefore it can be assumed that there was no relationship between the change in a player's non-game and post-game Bounce and Shoot scores and the cardiac cost for a basketball game preceding the post-game test. (Table IV)

II. INTERPRETATION OF DATA

The subjects' skill scores indicated a range of ability on the basketball tests. Scores varied from 98 to 110 on the

TABLE IV

SPEARMAN RANK CORRELATION COEFFICIENTS
BETWEEN THE CARDIAC COST OF PLAYING
IN A BASKETBALL GAME AND THE
DIFFERENCE BETWEEN NON-GAME
AND POST-GAME SKILL TEST
SCORES
N=5*

Skill Test	Cardiac Cost
Push Pass test	.49
Bounce and Shoot test	.30

* for N=5, r_s = .90 at the 5 per cent level of significance.

second non-game Push Pass test, from 96 to 120 on the post-game Push Pass test, from 14 to 19 on the second non-game Bounce and Shoot test, and from 14 to 20 on the post-game Bounce and Shoot test. The modified version of the Bounce and Shoot test does not compare with standardized norms. The Push Pass scores evaluated by a scale for college major students were all between the fiftieth and ninety-first percentiles during the non-game tests and between the forty-fifth and ninety-eighth percentiles during the post-game tests. (1:284) The plywood Push Pass target, which appeared to deaden the ball rebound from the wall, may have promoted lower than normal scores.

Statistical analysis of the data revealed no significant differences between the second non-game skill test scores and the post-game skill test scores. (Hypotheses 5 and 6) The twenty-minute game prior to the post-game skill tests did not influence the roving subjects' ability to perform the skills needed for the Push Pass test or the Bounce and Shoot test. The game proved to be neither a warm-up period nor a strenuous exercise period fostering either improved or lower test scores. Two rovers had higher post-game scores on both tests, two rovers had lower post-game scores on both tests, and one rover had a higher score on the Push Pass test and a lower score on the Bounce and Shoot test. The twenty-minute period of play did not appear to tire the well-conditioned subjects and may not have been a long enough game to test the effects of strenuous exercise on skill.

Statistical analysis of the data revealed a significant difference at the 10 per cent level of confidence between the players' cardiac cost for the non-game and post-game skill tests. (Hypothesis 7) Following a twenty-minute basketball game, the cardiac cost for executing the skill tests was higher than normal for each subject including the rovers with lower skill scores following play. The increases ranged between twenty-two and forty-six. Additional compensatory cardiovascular mechanisms appeared necessary to enable the players to complete the assigned tasks. Elevated recovery heart rates two minutes following the game may have influenced the higher cardiac cost during the post-game tests.

The cardiac cost of play during the games for the five rovers ranged between 1214 and 2158. Each subject's heart rate for each minute during the game was depicted in Figure 1 through Figure 5. The average heart rates were between 155 and 180. Each player had a wide range of heart rates with a substantial drop during the two-minute time out between the ninth and eleventh minutes of play. The average heart rates recorded compared with the rates of 173 and 192 recorded by Skubic and Hodgkins for the roving player during twenty-minute games. (76)

The transmitter had to be adjusted prior to the second, third, and fourth basketball games. The heart rates recorded during these games may have been influenced by an emotional

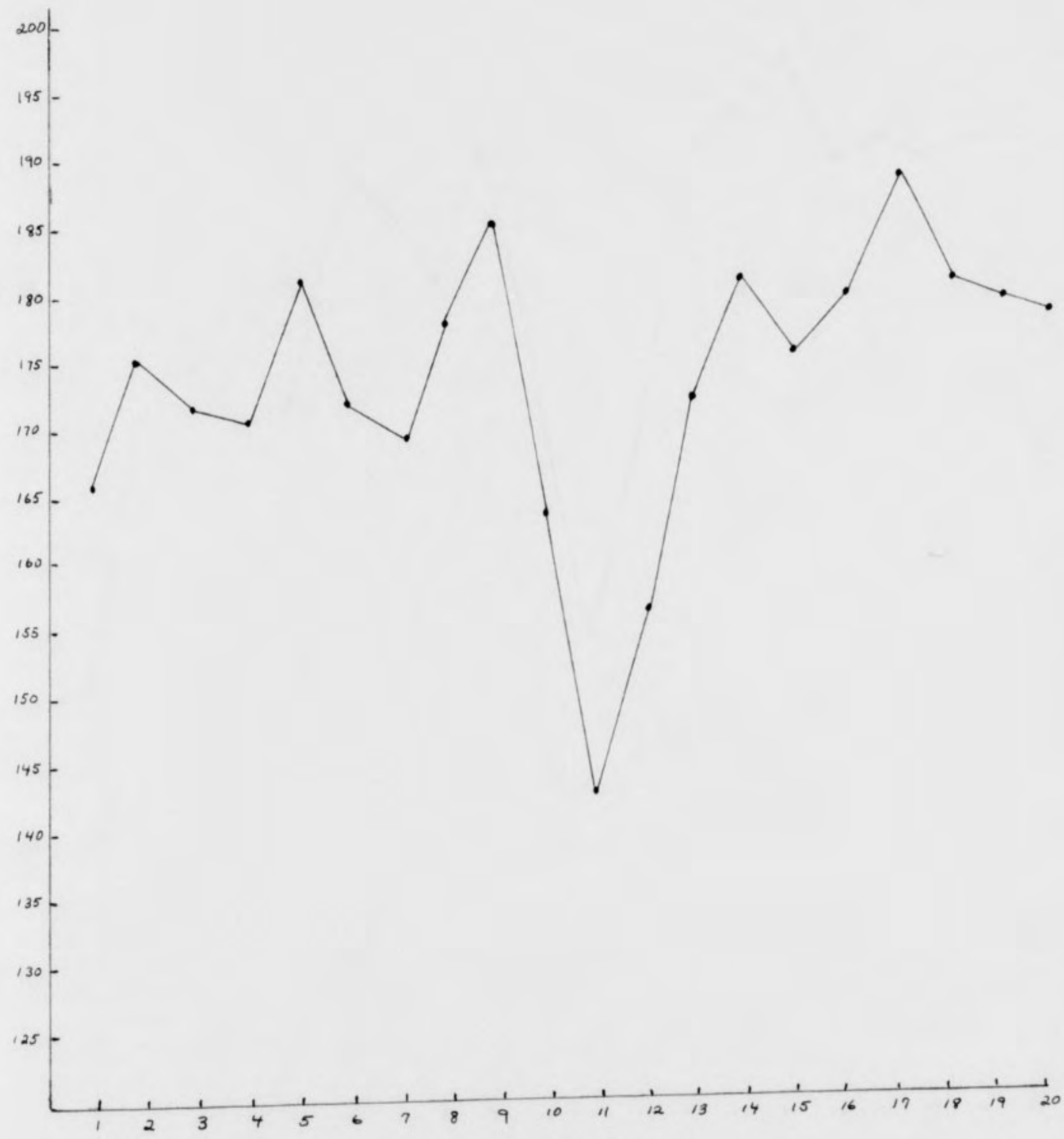


FIGURE 1

EXERCISE HEART RATE DURING BASKETBALL GAME FOR SUBJECT 1

Average heart rate = 173 Range = 142-187

Resting heart rate = 84 Cardiac cost = 1789

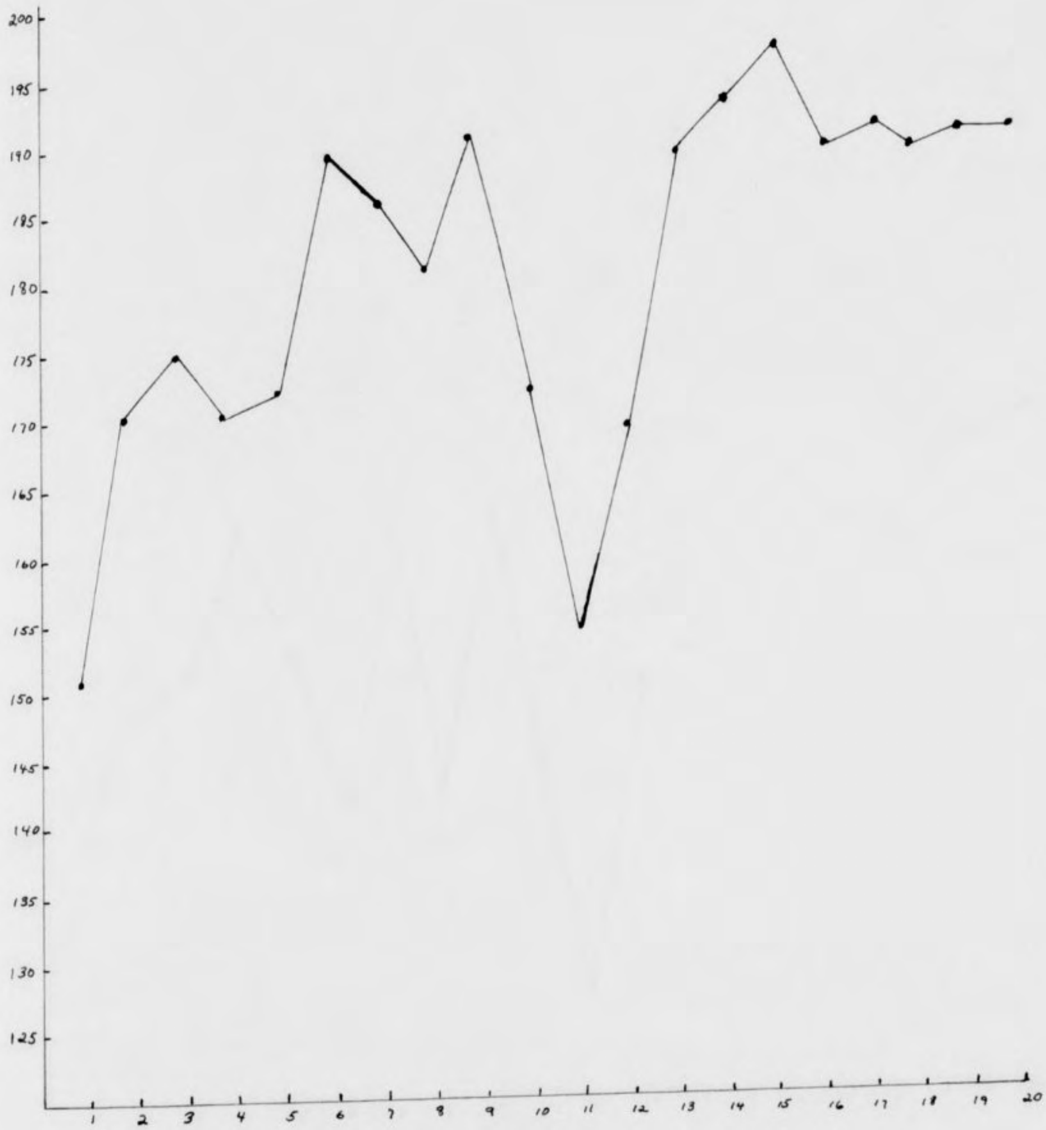


FIGURE 2

EXERCISE HEART RATE DURING BASKETBALL GAME FOR SUBJECT 2

Average heart rate = 180 Range = 151-195

Resting heart rate = 80 Cardiac cost = 2003

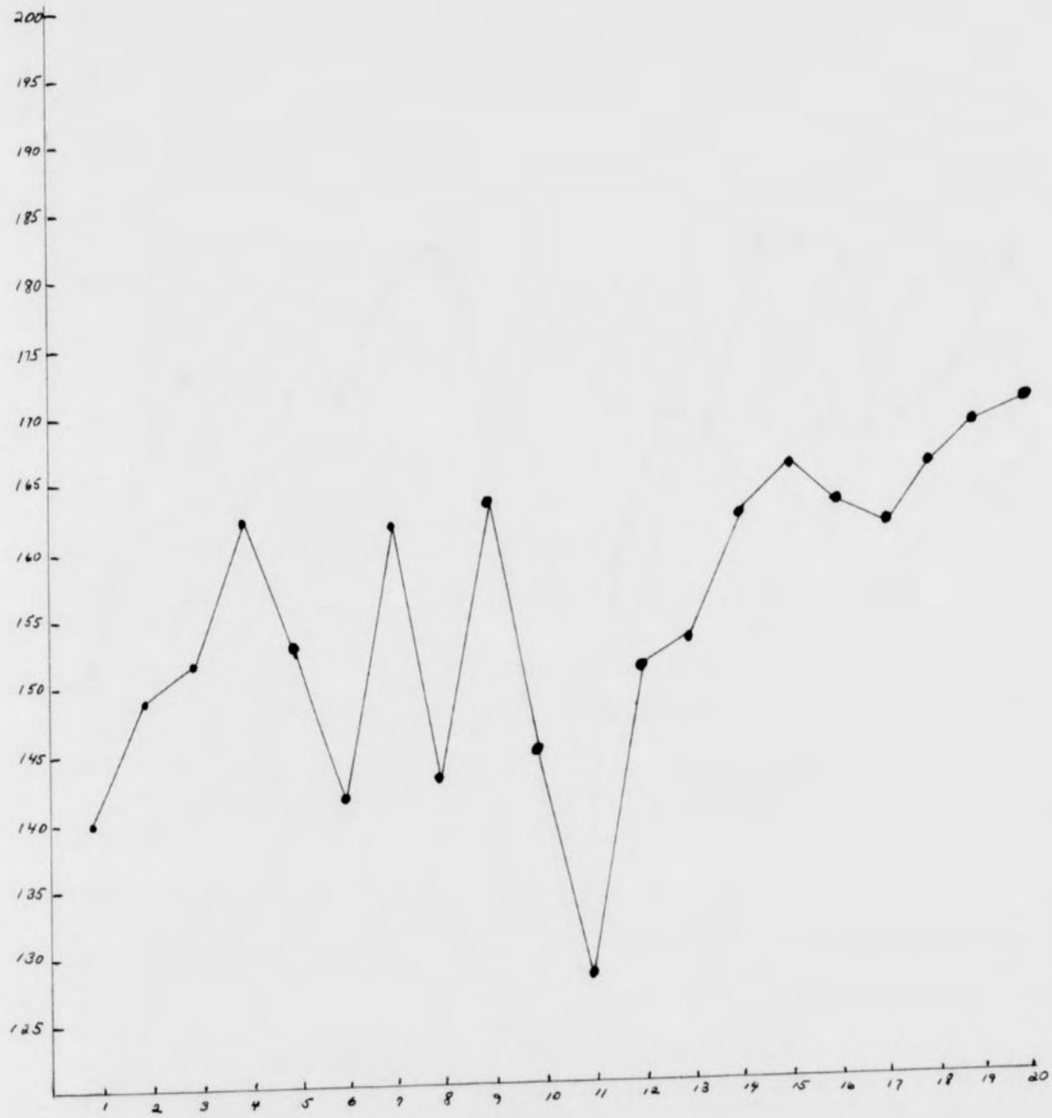


FIGURE 3

EXERCISE HEART RATE DURING BASKETBALL GAME FOR SUBJECT 3

Average heart rate = 155 Range = 128-170

Resting heart rate = 72 Cardiac cost = 1658

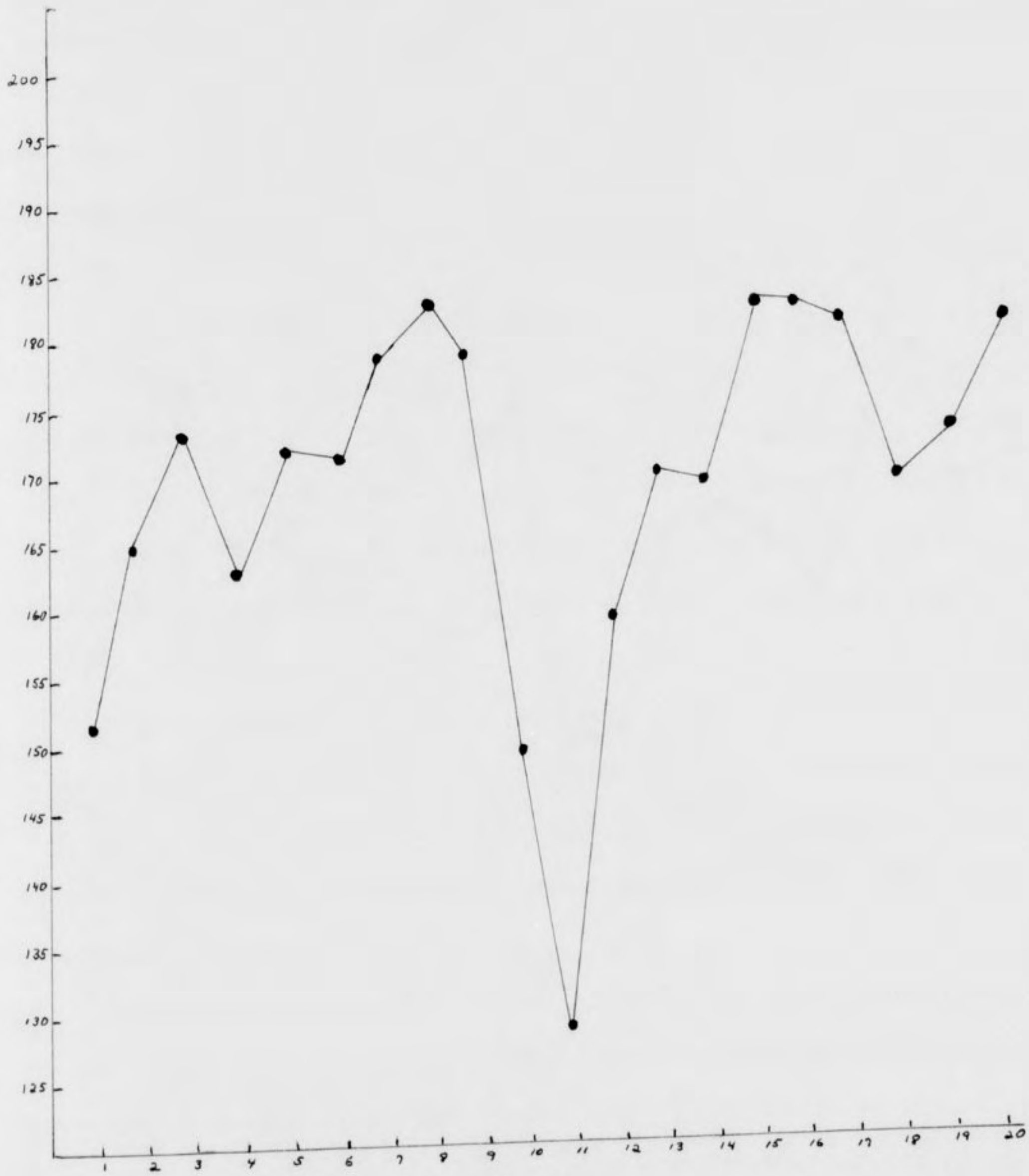


FIGURE 4

EXERCISE HEART RATE DURING BASKETBALL GAME FOR SUBJECT 4

Average heart rate = 169 Range = 129-182

Resting heart rate = 61 Cardiac cost = 2158

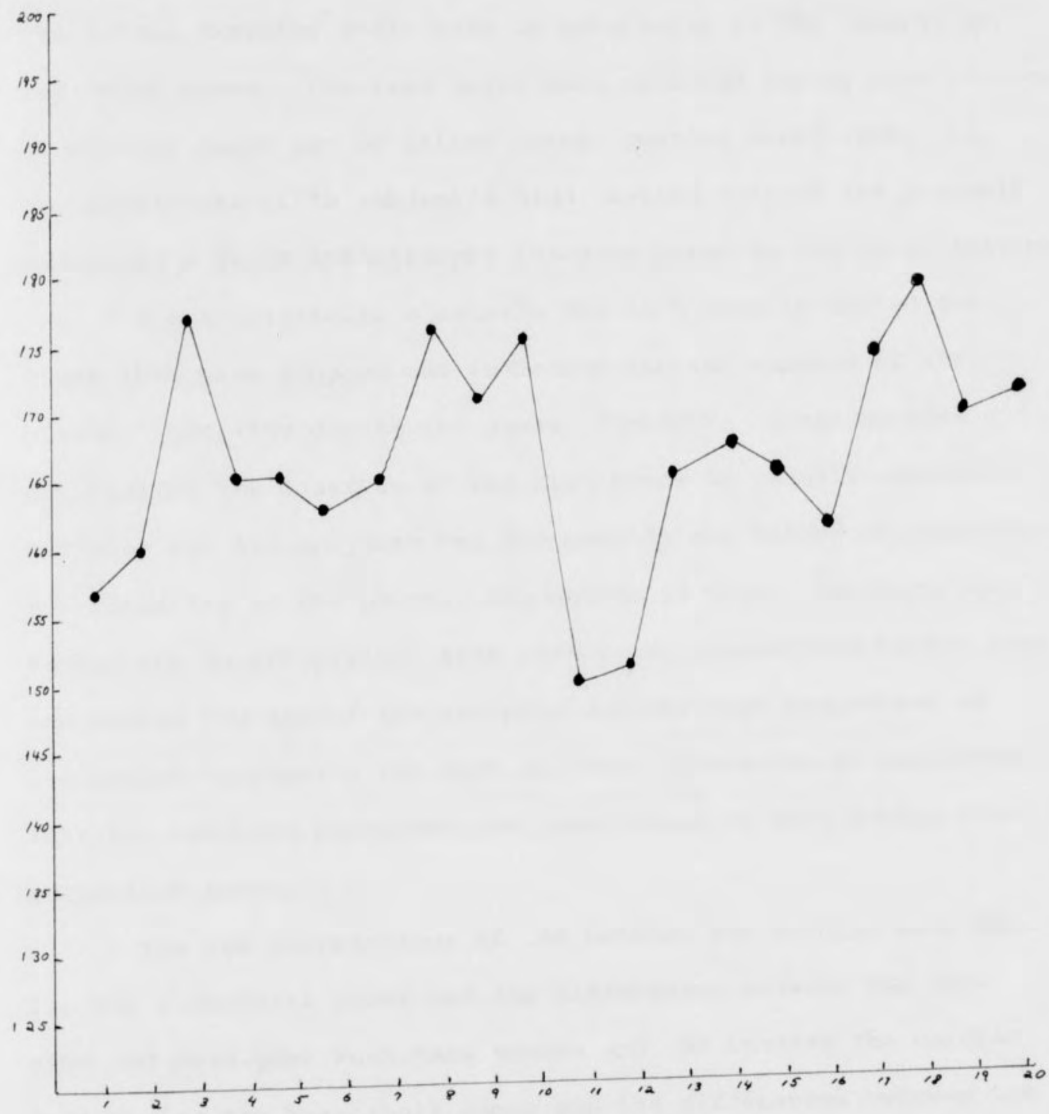


FIGURE 5

EXERCISE HEART RATE DURING BASKETBALL GAME FOR SUBJECT 5

Average heart rate = 166 Range = 150-176

Resting heart rate = 104 Cardiac cost = 1241

factor caused by concern about the testing situation. The graphic record telemetered during the first five minutes of the third basketball game was difficult to read and may not have represented the actual exercise heart rate as accurately as the records during other games. The rest heart rate recorded during five minutes of sitting could not be called "true" resting heart rate. In particular the fifth subject's high resting rate of 104 probably reflected a large anticipatory increase prior to the skill testing.

The statistician's records for each game indicated the times that play stopped and indicated limited aspects of the players' activity during the games. (Table V) These numbers did not justify the equation of the five games as equally strenuous activity for the subjects but did provide one method of comparing the intensity of the games. The number of times, ranging from thirty-six to fifty-five, that each rover crossed the center line and passed the top of the key provided the best comparison of the amount of running for each subject. There was no guarantee that the subjects performed the same amount of work during their respective games.

The low correlations of .49 between the cardiac cost during the basketball games and the differences between the non-game and post-game Push Pass scores and .30 between the cardiac cost during the basketball games and the differences between the non-game and post-game Bounce and Shoot scores indicated that there was no relationship between the change in skill performance

TABLE V

STATISTICAL RECORDS FOR FIVE ROVING PLAYERS DURING BASKETBALL GAMES

Variables	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Game Statistics					
Fouls called	6	13	6	6	1
Jump balls called	7	9	3	3	5
Violations called	6	10	15	19	18
Individual Statistics					
Rebounds	1	4	4	0	0
Jump balls*	1	4	1	0	0
Field goals attempted	7	4	11	6	8
Field goals made	2	2	4	1	3
Foul shots attempted	1	5	7	0	0
Foul shots made	1	4	6	0	0
Center line-key**	36	36	50	53	49
Center line-no key***	4	2	8	8	11

* Number of times a subject jumped in a jump ball.

** Number of times a subject crossed the center line and passed the top of the key before recrossing the line.

*** Number of times the subject crossed the center line but did not pass the top of the key before recrossing the line.

and the cardiac cost of playing in the basketball games. (Hypotheses 8 and 9) The high energy costs and workloads indicated by the cardiac cost of playing the games did not influence changes in skill between normal and post-game skills for the five rovers in this study. If the cardiac costs for the rovers during the games may be considered a relative index of fatigue, the level of fatigue did not influence the rovers' changes in ability to execute game skills following a period of strenuous play.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

The purpose of this study was to investigate the relationship between the performance of selected basketball skills and the cardiac cost for the roving player during college varsity basketball games. Five members of the University of North Carolina at Greensboro women's varsity basketball team took the Leilich Push Pass test and a modified version of the Leilich Bounce and Shoot test during two non-game testing sessions. Each subject played in the roving position during a twenty-minute basketball game at a later date and repeated the Leilich tests during a post-game test at the end of the game. The investigator used the E & M. Physiograph "Four" to telemeter each subject's heart rate during two five-minute periods of rest, the two non-game tests, the twenty-minute game, and the post-game test. The cardiac cost, defined as the difference between the total number of heart beats recorded during exercise and the resting heart beats for the same period of time, was selected to represent the subjects' response to the strenuous exercise during the games and skill tests.

The Wilcoxen Matched-Pairs Signed-Ranks Test was used to test the significance of the difference between (1) the two non-game skill tests, (2) the second non-game skill tests and the post-game skill tests, (3) the cardiac cost during the two non-game skill tests, (4) the cardiac cost during the second non-game skill tests and the post-game skill tests, and (5) the resting heart rates during two testing sessions. The Spearman Rank Correlation Coefficient was used to determine the relationship between the cardiac cost during the basketball games and the differences between the non-game and post-game skill tests.

Statistical analysis revealed no significant differences between the players' non-game and post-game skill scores. The cardiac cost during the post-game tests was significantly higher at the 10 per cent level of confidence than the cardiac cost during the non-game tests. There was no relationship between the players' cardiac cost during a game and the difference between the non-game and post-game skill test scores.

II. CONCLUSIONS

Within the limitations of this study the following conclusions appear warranted for the five roving players that participated in the testing:

1. Play during a twenty-minute basketball game did not change the rovers' normal ability to execute selected basketball skills.
2. The rovers' cardiac cost for two skill tests was higher than normal following play during a twenty-minute basketball game.
3. The rovers' cardiac cost during a twenty-minute basketball game was not related to the difference between their normal skill and their skill following the basketball game.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

1. Barrow, Harold M., and Rosemary McGee. A Practical Approach to Measurement in Physical Education. Philadelphia: Lea & Febiger, 1964.

2. Bartley, S. Howard. Fatigue Mechanism and Management. Springfield, Illinois: Charles C. Thomas, 1965.

3. Carlsten, Arne, and Gunnar Grimby. The Circulatory Response to Muscular Exercise in Man. Springfield, Illinois: Charles C. Thomas, 1966.

4. Consolazio, C. Frank, Robert E. Johnson, and Louis J. Pecora. Physiological Measurements of Metabolic Functions in Man. New York: McGraw-Hill Book Company, Inc., 1963.

5. deVries, Herbert A. Physiology of Exercise for Physical Education and Athletics. Dubuque, Iowa: Wm. C. Brown Company, 1966.

6. E & M Physiograph Instruction Manual. Houston, Texas: E & M Instrument Company, Inc., 1964.

7. Johnson, Warren R. (ed.). Science and Medicine of Exercise and Sports. New York: Harper and Row, 1960.

8. Jokl, Ernst. Heart and Sport. Springfield, Illinois: Charles C. Thomas, 1964.

9. Karpovich, Peter V. Physiology of Muscular Activity. Sixth edition. Philadelphia: W. B. Saunders Company, 1965.

10. Morehouse, Laurence E., and Augustus T. Miller. Physiology of Exercise. Fourth edition. St. Louis: The C. V. Mosby Company, 1963.

11. Ricci, Benjamin. Physiological Basis of Human Performance. Philadelphia: Lea & Febiger, 1967.

12. Rosenbaum, Francis, and Elston Belknap (eds.). Wisconsin Conference on Work and the Heart: Transactions of the First Wisconsin Conference on Work and the Heart. New York: Paul B. Hoeber, Inc., 1959.

13. Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, Inc., 1956.

14. Tate, Merle W., and Richard C. Clelland. Nonparametric and Shortcut Statistics in the Social, Biological, and Medical Sciences. Danville, Illinois: Interstate Printers and Publishers, Inc., 1957.

15. Welford, A. T., and W. F. Floyd (eds.). The Ergonomics Research Society Symposium on Fatigue. London: H. K. Lewis and Company, Ltd., 1953.

B. PERIODICALS

16. Alderman, Richard B. "Influence of Local Fatigue on Speed and Accuracy in Motor Learning," The Research Quarterly, 36:131-40, May, 1965.

17. Alderman, Richard B. "Specificity of Individual Differences in Arm Movement Fatigue Within Two Levels of Work Load," The Research Quarterly, 36:227-32, October, 1965.

18. Asmussen, Erling, and Marius Nielsen. "Cardiac Output During Muscular Work and Its Regulation," Physiological Reviews, 35:778-800, October, 1955.

19. Astrand, Per Olof, and others. "Blood Lactates After Prolonged Severe Exercise," Journal of Applied Physiology, 18:619-22, May, 1963.

20. Astrand, Per Olof, and others. "Cardiac Output During Submaxinal and Maximal Work," Journal of Applied Physiology, 19:268-74, March, 1964.

21. Astrand, Per Olof, and Irma Rhyming. "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) From Pulse Rate During Submaximal Work," Journal of Applied Physiology, 7:218-21, September, 1954.

22. Astrand, Per Olof, and Bengt Saltin. "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, 16:977-81, November, 1961.

23. Astrand, Per Olof, and Bengt Saltin. "Oxygen Uptake During the First Ten Minutes of Heavy Muscular Exercise," Journal of Applied Physiology, 16:971-6, November, 1961.

24. Balke, Bruno, Carleton E. Melton, Jr., and Clifford Blake. "Physiological Stress and Fatigue in Aerial Missions for the Control of Forest Fires," Aerospace Medicine, 37: 221-7, March, 1966.

25. Barcroft, H., and A. C. Dornhorst. "The Blood Flow Through the Human Calf During Rhythmic Exercise," Journal of Physiology, 109:402-11, September, 1949.

26. Black, John E. "Blood Flow Requirements of the Human Calf After Walking and Running," Clinical Science, 18:89-93, February, 1959.

27. Bousfield, W. A. "The Influence of Fatigue on Tremor," Journal of Experimental Psychology, 15:104-7, February, 1932.

28. Brouha, Lucien, and others. "Descrepancy Between Heart Rate and Oxygen Consumption During Work in the Warmth," Journal of Applied Physiology, 18:1095-8, November, 1963.

29. Clarke, David H. "Strength Recovery from Static and Dynamic Muscular Fatigue," The Research Quarterly, 33:349-55, October, 1962.

30. Clarke, David H., and George E. Stelmach. "Muscular Fatigue and Recovery Curve Parameters at Various Temperatures," The Research Quarterly, 37:468-79, December, 1966.

31. Colville, Frances. "Effect of Duration of Exercise on Neuromuscular Hand Tremor," The Research Quarterly, 31:7-11, March, 1960.

32. Davis, C. T. M., and E. A. Harris. "Heart Rate During Transition from Rest to Exercise in Relation to Exercise Tolerance," Journal of Applied Physiology, 19:857-62, September, 1964.

33. deVries, Herbert. "Effect of Various Warm-Up Procedures on 100 yd. Times of Competitive Swimmers," The Research Quarterly, 30:11-20, March, 1959.

34. Dill, David Bruce. "Physiology of Fatigue: Factors and Criteria of Endurance," Journal of Laboratory and Clinical Medicine, 28:596-601, 1942.

35. Domato, Anthony N., James G. Galante, and William M. Smith. "Hemodynamic Response to Treadmill Exercise in Normal Subjects," Journal of Applied Physiology, 21:959-66, May, 1966.

36. Donald, K. W., and others. "The Effect of Exercise on the Cardiac Output and Circulatory Dynamics of Normal Subjects," Clinical Science, 14:37-73, 1955.

37. Ekelund, L. G., and A. Holmgren. "Circulatory and Respiratory Adpatation, During Long-Term, Non-Steady State Exercise in the Sitting Position," Acta Physiologica Scandinavia, 62:240-55, November, 1964.

38. Elbel, Edwin R. "A Study of Response Time Before and After Strenuous Exercise," The Research Quarterly, 11:86-95, May, 1940.

39. Freedman, M. E., and others. "Effects of Training and Response of Cardiac Output to Muscular Exercise in Athletics," Journal of Applied Physiology, 8:37-47, July, 1955.

40. Frick, M. Heikki, Aarne Konttenen, and H. S. Samuli Sarajas. "Effects of Physical Training on Circulation at Rest and During Exercise," American Journal of Cardiology, 12:142-7, August, 1963.

41. Gauer, Otto H. "Volume Changes of the Left Ventricle During Blood Pooling and Exercise in the Intact Animal: Their Effects on Left Ventricular Performance," Physiological Review, 35:143-55, 1955.

42. Grimby, Gunnar, and Nils Johan Nilsson. "Cardiac Output During Exercise in Pyrogen-induced Fever," Scandenavian Journal of Clinical and Laboratory Investigation, Volume 15-Supplementum 69:44-61, 1963.

43. Grimby, Gunnar, Nils Johan Nilsson, and H. Sanne. "Serial Determination of Cardiac Output During Prolonged Exercise," Scandenavian Journal of Clinical and Laboratory Investigation, Volume 15-Supplementum 76:52, 1963.

44. Grose, Joel E. "Depression of Muscle Fatigue Curves by Heat and Cold," The Research Quarterly, 29:19-31, March, 1958.

45. Hipple, Joseph E. "Warm-up and Fatigue in Junior High School Sports," The Research Quarterly, 25:246-7, May, 1955.

46. Hueting, J. E., and H. R. Sharphate. "Measuring Fatigue," Journal of Applied Psychology, 50:535-8, December, 1966.

47. LeBlance, J. A. "Use of Heart Rate as an Index of Work Output," Journal of Applied Physiology, 10:275-80, March, 1957.

48. Malhotra, M. S., J. Sen Gupta and R. M. Rai. "Pulse Count as a Measure of Energy Expenditure," Journal of Applied Physiology, 18:994-6, September, 1963.

49. Mathews, Donald K., and Alan H. Snyder. "Effect of Warm-up on the 440-Yard Dash," The Research Quarterly, 30:446-51, December, 1959.

50. Maxfield, Mary E., and Lucien Brouha. "Validity of Heart Rate as as Indicator of Cardiac Strain," Journal of Applied Physiology, 18:1099-104, November, 1963.

51. Michael, E. D., and S. M. Horvath. "Physical Work Capacity of College Women," Journal of Applied Physiology, 20:263-6, March, 1965.

52. Michael, E. D., Vera Skubic, and R. H. Rochelle. "Effect of Warming-up on Softball Throw for Distance," The Research Quarterly, 28:357-63, December, 1957.

53. Mitchem, John C., and W. W. Tuttle. "Influence of Exercise, Emotional Stress and Age on Static Neuromuscular Tremor Magnitude," The Research Quarterly, 25:65-74, March, 1954.

54. Nagle, Francis J., and Thomas G. Bedecki. "Use of 180 Heart Rate Response as a Measure of Cardiorespiratory Capacity," The Research Quarterly, 34:361-9, October, 1963.

55. Nelson, Dale O., and Lewis W. Finch. "Effect of Audio-Analygesia on Gross Motor Performance Involving Acute Fatigue," The Research Quarterly, 33:588-98, December, 1962.

56. Pacheco, Betty A. "Effectiveness of Warm-up Exercises in Junior High School Girls," The Research Quarterly, 30:202-13, May, 1959.

57. Pacheco, Betty A. "Improvement in Jumping Performance Due to Preliminary Exercise," The Research Quarterly, 28:55-62, March, 1957.

58. Pathak, C. L. "Alternative Mechanism of Cardiac Acceleration in Bainbridge's Infusion Experiments," Americal Journal of Physiology, 197:441-4, August, 1959.

59. Pierson, William R. "Fatigue, Work Decrement, and Endurance in a Simple Repetitive Task," British Journal of Medical Psychology, 36:279-81, 1963.

60. Pierson, William R., and Aileene Lockhart. "Fatigue, Work Decrement, and Endurance of Women in a Simple Repetitive Task," Aerospace Medicine, 35:724-5, August, 1964.

61. Pugh, L. G. C. E. "Cardiac Output in Muscular Exercise at 5,8000 m (19,000 ft.)," Journal of Applied Physiology, 19:441-7, May, 1964.

62. Pugh, L. G. C. E., and others. "Muscular Exercise at Great Altitudes," Journal of Applied Physiology, 19:431-40, May, 1964.

63. Reeves, John T., and others. "Cardiac Output in Normal Resting Man," Journal of Applied Physiology, 16:276-8, March, 1961.

64. Reeves, John T., and others. "Cardiac Output Response to Standing and Treadmill Walking," Journal of Applied Physiology, 16:283-8, March, 1961.

65. Reeves, John T., and others. "Circulatory Changes in Man During Mild Supine Exercise," Journal of Applied Physiology, 16:279-82, March, 1961.

66. Rochelle, R. H., Vera Skubic, and E. D. Michael. "Performance as Affected by Incentive and Preliminary Warm-up," The Research Quarterly, 31:499-504, October, 1960.

67. Rohter, Frank D., Rene H. Rochelle, and Chester Hyman. "Exercise Blood Flow Changes in the Human Forearm During Physical Training," Journal of Applied Physiology, 18:789-93, July, 1963.

68. Ross, Sherman, T. A. Hussman, and T. G. Andrews. "Effects of Fatigue and Anxiety on Certain Psychomotor and Visual Functions," Journal of Applied Physiology, 38:119-25, April, 1954.

69. Rushmer, Robert F. "Constancy of Stroke Volume in Ventricular Response to Exertion," American Journal of Physiology, 196:745-50, April, 1959.

70. Saltin, Bengt, and Jesper Stenberg. "Circulatory Response to Prolonged Severe Exercise," Journal of Applied Physiology, 19:833-8, September, 1964.

71. Scott, M. Gladys, and Helen Matthews. "A Study of Fatigue Effects Induced by an Efficiency Test for College Women," The Research Quarterly, 20:134-41, May, 1949.

72. Shaw, Daniel L., Jr., and others. "Management of Fatigue: A Physiologic Approach," American Journal of the Medical Sciences, 243:738-69, June, 1962.

73. Skubic, Vera, and Jane Hilgendorf. "Anticipatory, Exercise, and Recovery Heart Rates of Girls as Affected by Four Running Events," Journal of Applied Physiology, 19:853-6, September, 1964.

74. Skubic, Vera, and Jean Hodgkins. "Effect of Warm-up Activities on Speed, Strength, and Accuracy," The Research Quarterly, 28:147-52, May, 1957.

75. Skubic, Vera, and Jean Hodgkins. "Emergy Expenditure of Woman Participants in Selected Individual Sports," Journal of Applied Physiology, 21:133-7, January, 1966.

76. Skubic, Vera, and Jean Hodgkins. "Relative Strenuousness of Selected Sports as Performed by Women," The Research Quarterly, 38:305-13, May, 1967.

77. Tabakin, Burton S., and others. "Hemodynamic Response of Normal Men to Graded Treadmill Exercise," Journal of Applied Physiology, 19:457-64, May, 1964.

78. Thompson, Hugh. "Effect of Warm-up Upon Physical Performance in Selected Activities," The Research Quarterly, 29:231-46, May, 1958.

79. Tuttle, W. W., and others. "Effect of Exercise of Graded Intensity on Neuromuscular Tremor as Measured by a Strain Gauge Technique," Journal of Applied Physiology, 3:732-5, June, 1951.

80. Witte, Fae. "Effects of Participation in Light, Medium, and Heavy Exercise Upon Accuracy in Motor Performance of Junior High School Girls," The Research Quarterly, 33:308-12, May, 1962.

81. Wyndham, C. H., and others. "Maximum Heart Rate During Strenuous Work," Journal of Applied Physiology, 14:927-36, November, 1959.

C. ARTICLES IN COLLECTIONS

82. Bartlett, Sir Frederic. "Psychological Criteria of Fatigue," The Ergonomics Research Society Symposium on Fatigue, A. T. Welford and W. F. Floyd, editors. London: H. K. Lewis and Company, Ltd., 1953. Pp. 1-2.

83. Brouha, Lucien A. "Effect of Work on the Heart," Wisconsin Conference on Work and the Heart: Transactions of the First Wisconsin Conference on Work and the Heart, Frances F. Rosenbaum, and Elston L. Belnap, editors. New York: Paul B. Hoeber, Inc., 1959. Pp. 180-95.

84. Brouha, Lucien, and Edward P. Radford, Jr. "The Cardiovascular System in Muscular Activity," Science and Medicine of Exercise and Sport, Warren R. Johnson, editor. New York: Harper and Row, 1960. Pp. 178-205.

85. Dill, David B. "Fatigue and Physical Fitness," Science and Medicine of Exercise and Sport, Warren R. Johnson, editor. New York: Harper and Row, 1960. Pp. 384-402.

86. Dill, David B. "Regulation of the Heart Rate," Wisconsin Conference on Work and the Heart: Transactions of the First Wisconsin Conference on Work and the Heart, Frances F. Rosenbaum, and Elston L. Belknap, editors. New York: Paul B. Hoeber, Inc., 1959. Pp. 60-73.

87. Eagles, J. R., A. M. Halleday and J. W. T. Redfearn. "The Effects of Fatigue on Tremor," The Ergometics Research Society Symposium on Fatigue, A. T. Welford, and W. F. Floyd, editors. London: H. K. Lewis and Company, Ltd., 1953. Pp. 41-58.

88. Hemingway, A. "The Physiological Background of Fatigue," The Ergonomic Research Society Symposium on Fatigue, A. T. Welford and W. F. Floyd, editors. London: H. K. Lewis and Company, Ltd., 1953. Pp. 69-76.

89. Karvonen, Martti J. "Effects of Vigorous Exercise on the Heart," Wisconsin Conference on Work and the Heart: Transactions of the First Wisconsin Conference on Work and the Heart, Francis Rosenbaum, and Elston Belknap, editors. New York: Paul B. Hoeber, Inc., 1959. Pp. 199-209.

90. Riley, Richard L. "Pulmonary Function in Relation to Exercise," Science and Medicine of Exercise and Sports, Warren R. Johnson, editor. New York: Harper and Row, 1960. Pp. 162-77.

91. Schawb, Robert S. "Motivation in Measurement of Fatigue," The Ergonomics Research Society Symposium on Fatigue, A. T. Welford and W. F. Floyd, editors. London: H. K. Lewis and Company, Ltd., 1953. Pp. 143-8.

92. Singleton, W. T. "Deterioration of Performance on a Short-Term Perceptive-Motor Task," The Ergonomics Research Society Symposium on Fatigue, A. T. Welford and W. F. Floyd, editors. London: H. K. Lewis and Company, Ltd., 1953. Pp. 163-72.

93. Warren, James V. "Control of Cardiac Output in Man," Wisconsin Conference on Work and the Heart: Transactions of the First Wisconsin Conference on Work and the Heart, Frances F. Rosenbaum and Elston L. Belknap, editors. New York: Paul B. Hoeber, Inc., 1959. Pp. 54-9.

D. UNPUBLISHED MATERIAL

94. Armstrong, Joan. "The Effects of Participation in Selected Activities on the Heart Rate of College Women." Unpublished Master's thesis, University of Washington, Seattle, 1964. (Microcard)

95. Cant, Margaret Vance. "A Further Investigation of the Effect of Participation in Selected Activities on the Heart Rate Responses of College Women." Unpublished Master's thesis, University of Washington, Seattle, 1965. (Microcard)

96. Culhane, Mary Joan. "The Effect of Leg Fatigue Upon Balance." Unpublished Master's thesis, State University of Iowa, Iowa City, 1956. (Microcard)

97. Dial, Betty Ann. "The Effect of Arm Fatigue on Kinesthetic Performance." Unpublished Master's thesis, State University of Iowa, Iowa City, 1955. (Microcard)

98. Dohrmann, Paul Frank. "The Effect of Strenuous Exercise of the Lower Extreminities Upon the Strength of the Hands and the Forearms." Unpublished Master's Thesis, State University of Iowa, Iowa City, 1956. (Microcard)

99. Leilich, Avis. "The Primary Components of Selected Basketball Tests for College Women." Unpublished Doctoral dissertation, Indiana University, Bloomington, 1952.

100. Nunney, Derek Normond. "Physical Activity, Fatigue, and Motor Learning." Unpublished Doctoral dissertation, University of California, Los Angeles, 1961.

101. Reading, Lynn James. "The Effect of Fatigue as Induced by the Harvard Step Test on the Speed of the Offensive Charge in Football." Unpublished Master's thesis, Washington State University, Pullman, 1961. (Microcard)

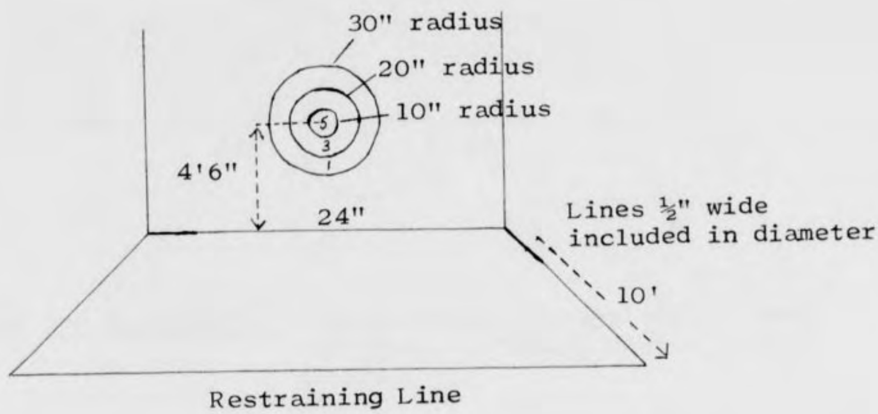
102. Slocum, Helen Margaret. "The Effect of Fatigue Induced by Physical Activity on Certain Tests in Kinesthesis." Unpublished Doctoral dissertation, State University of Iowa, Iowa City, 1953.

103. Thoden, James A. "An Investigation of Overarm Throwing Accuracy Before and After Heavy and Severe Treadmill Exercise." Unpublished Master's thesis, University of Wisconsin, Madison, 1966. (Microcard)

104. Ware, Lanetta T. "A Study of the Effect of Fatigue on Balance, Kinesthetic Positioning and Steadiness." Unpublished Master's thesis, Smith College, Northampton, 1962.

APPENDIX

LEILICH PUSH PASS TEST
(1:282-3)

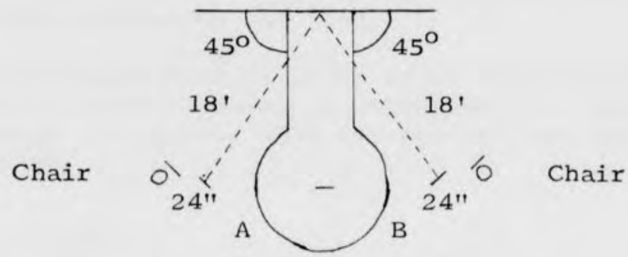


Facilities and Equipment: A target area, a basketball, and a timing device.

Procedure: The subject stands behind a 10-foot restraining line facing a target placed on the wall. She uses a two-handed chest pass to throw to the target for 30 seconds. The subject must have both feet behind the restraining line when she passes. She may go beyond the line to retrieve the ball.

Scoring: The score is the total points made in 30 seconds. The center circle scores 5 points, the second circle scores 3 points, and the outer circle scores 1 point. A ball that lands on a line counts the value of the inner circle.

MODIFIED LEILICH BOUNCE AND SHOOT TEST
(1:281-2)



Facilities and Equipment: 2 basketballs, a regulation basketball goal, a timing device, and 2 chairs.

Procedure: The subject starts from behind the 18-foot mark on the B side of the basket. When the signal is given, she picks up the ball from the chair, bounces, shoots, rebounds, and passes the ball back to the receiver who is standing behind the B chair. She then runs to the chair on the A side, picks up the ball, bounces, shoots, rebounds, and throws the ball to the receiver standing behind the A chair. This pattern is followed for 60 seconds. The bounce must start from behind the 18-foot line.

Scoring: The score comprises 2 points for making the basket, 1 point for hitting the rim but missing the basket, and no points for missing the rim and the basket. No score is awarded if the subject travels, fails to bounce, bounces more than once, or fails to start behind the line.

TESTING PROCEDURE

BASIC FORMAT

Each subject will be tested three times. Two tests are in non-game situations to determine normal skill scores, normal cardiac cost for skill tests, and resting heart rate. The non-game test will not be the same day of the post-game test, but within six days preceding the test.

The post-game test is given after twenty minutes of play in a basketball game in order to determine the changes in skill and the changes in cardiac cost between the non-game and post-game conditions.

NON-GAME SITUATION

5 minutes	Subject sits quietly in a chair facing the far end of the gym: feet on the floor and no talking.
2 minutes	Subject listens to the directions for the tests. She moves to the first test in the last fifteen seconds prior to testing.
30 seconds	Subject takes the Leilich Push Pass test.
30 seconds	Subject moves to the second test.
1 minute	Subject takes a modified form of the Leilich Bounce and Shoot test.

GAME AND POST-GAME TESTING SITUATION

20 minutes	Subject plays as the rover in a game situation. Time is running time with a two-minute time out after nine minutes of play.
2 minutes	Subject sits and listens to the directions for the tests. She moves to the first test in the last fifteen seconds.
30 seconds	Subject takes the Leilich Push Pass test.
30 seconds	Subject moves to the second test.
1 minute	Subject takes a modified form of the Leilich Bounce and Shoot test.

TESTING INFORMATION

TO: Varsity Basketball Players

As a part of my thesis I plan to study the change in skill performance after a period of playing basketball. An additional purpose is to study the heart rate and cardiac cost for the roving player during a game. The Physical Education Department recently purchased a physiograph which allows one to attach two electrodes and a transmitter to a player and monitor and record the actual heart rate during a game. Each rover will be monitored for a twenty minute period of play.

Each game must be as much as possible like a varsity game situation. The play will stop for foul shots and jump balls. However, officials have been instructed to keep the game moving as fast as possible. The varsity team should insure the necessity that the rover being tested plays a "hard and fast" game.

Five twenty-minute games are scheduled for the next three weeks. Plan to come to Rosenthal dressed to play.

TESTING DIRECTIONS FOR THE SUBJECTS

After you sit for two minutes you will take the Push Pass test and the Bounce and Shoot test. Listen carefully to these directions.

PUSH PASS TEST

Stand behind the line and pass to the target using a push pass. You will be timed for 30 seconds. The center circle scores 5 points, the second circle scores 3 points, and the outer circle scores 1 point. A ball that lands on a line counts the value of the inner circle. No score is given if you step over or on the line or fail to hit the target.

BOUNCE AND SHOOT TEST

Stand behind the line. When the "go" signal is given, pick up the ball from the chair, bounce it once, shoot for the basket, rebound, and pass the ball back to the receiver standing behind the chair. Run immediately to get the ball in the chair on the left hand side of the basket and repeat the procedure. Continue alternating sides until the buzzer sounds after 1 minute. The score is 2 points for making the basket, one point for hitting the rim but missing the basket, and no points for missing the rim and basket. No score will be awarded if you travel, bounce more than once, or fail to start behind the line.

The timer will warn you 15 seconds before the tests are to begin. Pick up the ball and move to the Push Pass test. After the Push Pass test you will have 30 seconds to move to the Bounce and Shoot test. The timer will signal for you to begin both tests with, "Ready, Go."

TABLE VI

RESTING HEART RATES

Variable	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Testing Session #1					
Minute 1	100	77	75	67	89
Minute 2	94	87	67	67	89
Minute 3	96	87	78	65	93
Minute 4	101	85	79	67	96
Minute 5	97	92	75	71	98
Average	98	86	75	67	93
Testing Session #2					
Minute 1	76	77	69	65	105
Minute 2	82	81	68	58	104
Minute 3	88	80	74	64	104
Minute 4	84	80	71	57	103
Minute 5	88	80	77	59	105
Average	84	80	72	61	104

TABLE VII

EXERCISE HEART RATES DURING SKILL TESTS

Variable	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Non-game Test #1					
Minute 1	145	139	110	142	152
Minute 2	158	156	141	154	168
Average	152	148	126	148	160
Non-game Test #2					
Minute 1	140	136	111	145	157
Minute 2	162	162	141	168	157
Average	152	149	126	157	157
Post-Game Test					
Minute 1	165	171	144	164	170
Minute 2	177	173	145	171	166
Average	171	172	145	168	168

TABLE VIII

EXERCISE HEART RATES DURING
BASKETBALL GAMES

Variable	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Minute 1	166	151	140	152	157
Minute 2	175	170	148	165	160
Minute 3	172	175	152	173	171
Minute 4	171	170	163	163	165
Minute 5	181	172	153	172	165
Minute 6	172	189	142	171	163
Minute 7	168	185	162	177	165
Minute 8	178	180	142	182	176
Minute 9	185	190	164	177	170
Minute 10	163	172	145	150	175
Minute 11	142	154	128	129	150
Minute 12	156	168	151	159	151
Minute 13	173	187	152	170	165
Minute 14	182	192	161	169	167
Minute 15	174	195	166	182	165
Minute 16	181	190	163	182	159
Minute 17	187	191	161	181	173
Minute 18	182	190	166	170	179
Minute 19	181	191	169	173	169
Minute 20	180	191	170	181	170
Average	173	180	155	169	166