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A COMPARISON OF THE HEART RATES AND WORKLOAD
LEVELS OF SELECTED MALE FRESHMAN
BASKETBALL PLAYERS AT UTAH STATE
UNIVERSITY DURING ACTUAL GAME COMPETITION

by

C. David Leo

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Health, Physical Education, and Recreation

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1973

ACKNOWLEDGMENTS

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I express my sincere thanks and appreciation to Dr. Lanny J. Nalder, my committee chairman, for his patience and encouragement during this study.

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C. David Leo

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
LIST OF TABLES	v
LIST OF FIGURES	vi
ABSTRACT	vii
Chapter	
I. INTRODUCTION	1
Justification of the Study	2
Statement of the Problem	2
Basic Assumptions	2
Delimitations	3
Limitations	3
Definition of Terms	3
II. REVIEW OF RELATED LITERATURE	5
Heart Rates	5
Volume of Oxygen and Workload	23
III. METHOD OF PROCEDURE	28
Subjects	28
Recording System	28
Electrode Structure and Attachment	28
Recording Procedure	30
Åstrand's Nomogram	32
IV. ANALYSIS OF DATA	34
Analysis of Variance	34
Newman Keuls Sequential Range Test	35
Heart Rate	37
Volume of Oxygen	37
Workload	40

TABLE OF CONTENTS (Continued)

	Page
V. SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS	42
Summary	42
Findings and Conclusions	44
Recommendations	49
SELECTED BIBLIOGRAPHY	50
APPENDIXES	53
VITA	58

LIST OF TABLES

Table	Page
1. Results of the Newman Keuls Sequential Range Test	36

LIST OF FIGURES

Figure		Page
1.	Mean Heart Rates (beats/minute) of the Five Subjects During Eight Different Game Situations	38
2.	Mean $\dot{V}O_2$ (liters/minute) of the Five Subjects During Eight Different Game Situations	39
3.	Mean Workload Levels (kilopondmeters/minute) of the Five Subjects During Eight Different Game Situations	41

ABSTRACT

A Comparison of the Heart Rates and Workload Levels
of Selected Male Freshman Basketball Players
at Utah State University During Actual
Game Competition

by

C. David Leo, Master of Science

Utah State University, 1973

Major Professor: Dr. Lanny J. Nalder
Department: Health, Physical Education, and Recreation

The purpose of this study was to determine the effects of physical exertion upon the heart rates and workload levels of five selected male freshman basketball players at Utah State University during actual game competition.

One hour prior to each of the ten home basketball games, two E&M Surface Electrodes were mounted to the chest of the test subject with disposable double-sided adhesive washers. A biotelemetry transmitter, used for sending electrical signals from the player to a biotelemetry receiver and polygraph, was placed in a plastic sack and taped to the beltline of the subjects athletic supporter. The telemetry receiver and polygraph were located behind the Utah State University team bench.

One subject was tested per game and each subject was tested twice throughout the study. The same subject was tested once every fifth home game.

The data was collected with a polygraph, by means of radiotelemetry, and recorded according to mean heart (beats per minute), mean volume of oxygen (liters per minute), and mean workload (kilopondmeters per minute), which were the measurements used for the data in the statistical design. In each of these three categories, consideration and comparisons were made of: (A) offensive play, (B) ball handling, (C) defensive play, (D) defense on the ball, (E) fastbreak, (F) shooting, (G) scoring, and (H) rebounding. Data, concerning mean volume of oxygen and mean workload, were processed according to Åstrand's Nomogram. A two way analysis of variance test was applied to the data to determine the significant difference between the variables. Another statistical analysis that was conducted on the data was a Newman Keuls Sequential Range Test for determining the significant difference between the eight different game situations studied throughout this study.

The two way analysis of variance showed that there was a significant difference at the .05 level of confidence in the mean heart rate, mean volume of oxygen, and mean workload levels of the five subjects during the game situations mentioned above. The Newman Keuls Sequential Range Test indicated that a significant difference occurred at the .05 level between the ball handling activities (fastbreak, ball handling, and shooting) and the

non-ball handling activities (rebounding, scoring, defense on the ball, defensive play, and offensive play). Also, this test showed that no significant difference occurred at the .05 level within the two groups of activities mentioned above.

(67 pages)

CHAPTER I

INTRODUCTION

The nature and extent of the stress imposed upon the human body varies according to the type of the activity. When muscles function and the body moves, energy is expended. When the body performs either a relaxation type activity (sitting, lying, watching television, etc.), occupation type activity (engineering work, coal mining, farming, etc.) or recreation type activity (golf, tennis, swimming, etc.), energy must be expended in order for the task to be completed.

When the degree of an activity increases, the heart rate and workload (the amount of work placed upon an individual expressed in kpm, watts, or oxygen uptake) will also increase.

When measuring the amount of stress being placed upon the body during a given activity, the heart rate represents one of the most sensitive indicators of the intensity of the workload being performed.

During athletic events, athletes are faced with various workload intensities which they must execute. Therefore, it is important for athletes to be in good physical condition in order to accomplish the various workload intensities which they must carry out for a designated period of time.

Justification of the Study

In everyday life, we are constantly confronted with situations that require the body to withstand varying degrees of stress and strain. The amount of stress and strain that is imposed upon the participant depends on the nature and extent of the activity. In reviewing literature, it was discovered that no extensive study has ever been conducted associating heart rates with workloads of individuals during athletic events. Therefore, this study sought to compare the heart rates and workload levels of selected male freshman basketball players at Utah State University during actual game competition.

Statement of the Problem

The purpose of this study was to determine the effects of physical exertion upon the heart rates and workload levels of selected male freshman basketball players at Utah State University during actual game competition.

Basic Assumptions

At the beginning of this study, the subjects who participated were encouraged not to use amphetamine or barbiturate type drugs. Also, each subject had an opportunity to become familiar with the surface electrodes and telemetry transmitter by wearing them during a practice session. After the practice session, each subject reported that he was

not aware or hampered in any way by the placement of the electrodes or transmitter. Since the subjects reported that they were not aware or hampered by the placement of the surface electrodes or telemetry transmitter, it was also assumed that they played in a natural game atmosphere.

Delimitations

This study was delimited to five male members of the Utah State University Freshman Basketball Team, two guards, two forwards, and one center, whose ages ranged from eighteen to twenty years.

Limitations

The following were considered as limitations to this study:

1. A selected group at hand rather than a random sample of subjects was used for this study.
2. The emotional attitudes of the subjects were considered as limitations of this study. The degree of emotional stress applied upon the subjects, by the opposing teams, could effect their heart rates.

Definition of Terms

1. Cardiac Pre-Amplifier--An instrument used for amplification of low cardiac signals.
2. Electrocardiographic Signal--A signal which makes a graphic record of the electrical changes caused by contraction of the heart muscle.

3. Kilopondmeters--One kilopond is the force acting on the mass of one kilogram at normal acceleration of gravity.
4. Polygraph--A clinical instrument used to take tracings from several points in the circulation, e. g. , jugular vein, radial artery, apex of heart, etc.
5. Radiotelemetry (Telemetry Transmitter)--A method used for remote monitoring of physiological data from subjects in relatively inaccessible locations by means of radio waves to a distant station, and there indicating or recording the data.
6. Receiver--An instrument that converts electric currents or waves into visible or audible signals.
7. Surface Electrode--A conductor that is placed on the surface of the subject to establish electrical contact with a nonmetallic part of a circuit.
8. $\dot{V}O_2$ --The volume of oxygen extracted from the inspired air, usually expressed as liters per minute.
9. Workload--The amount of work placed upon an individual expressed in kilopondmeters per minute, watts, or oxygen uptake.

CHAPTER II

REVIEW OF RELATED LITERATURE

This study sought to investigate the influences of physical exertion upon the heart rates, $\dot{V}O_2$ and workload levels of male basketball players while participating in actual game competition.

This review is divided into two sections that relate to energy expenditure during various types of activities. These areas are: (1) Heart Rates and (2) $\dot{V}O_2$ and Workload.

In the studies cited below, unless otherwise stated, radiotelemetry was the method used for the recording of heart rates.

Heart Rates

Stockholm and Morris conducted a study on a baseball pitcher's heart rate for a university team during actual competition and found that the combination of pre-inning tosses and the excitement of facing the first batter forced the subject's pregame heart rate to 174 BPM. A peak heart rate of 193 BPM was recorded during the third inning of play, and on several occasions before and thereafter the heart rate exceeded 180 BPM. Throughout the contest, the subject appeared capable of recovering during the half inning in which his team was at bat, except for the innings in which he was batting or his team was in the process of scoring. Even with the longer rests between pitching bouts, the subject's heart rate failed to decline

below 100 BPM and on all but three occasions (119 BPM while resting in the dugout, 115 BPM while resting in the dugout, and 108 BPM while waiting on deck) it remained above 120 BPM. A five minute recovery period following the completion of the contest allowed the heart rate to decline to 120 BPM. Also, a combination of physical and emotional stress caused the pitcher's heart rate to exceed 180 BPM several times during the nine-inning college freshman intercollegiate baseball game. The heart rate failed to decline below 100 BPM for the two hours of competition.¹ It was noted that Stockholm and Morris failed to describe the method used for controlling the emotional factor upon the baseball pitcher throughout their study.

Hanson studied the heart rate response of ten volunteer Little League baseball players whose ages ranged from nine-twelve years. They represented all fielding positions excluding pitchers and catchers. The first seven subjects were measured in games that were a part of their regular season play. Subjects eight, nine and ten were participants in the championship tournament, being players from two divisional championship teams. Heart rate response for each of the ten subjects was greatest when they were "at bat." Of the three highest heart rates recorded for each subject, only two of a possible thirty were in situations other than while at bat. The median response for "at bat" was 163 BPM with the greatest being

¹ Alan Stockholm and Harold H. Morris, "A Baseball Pitcher's Heart Rate During Actual Competition," Research Quarterly, XL (October, 1969), 649.

204 BPM and the least 145 BPM. The median at rest pregame sitting rate was ninety-five BPM as compared to the median postgame sitting at rest rate of 100 BPM. The median pregame standing at rest rate was 112 BPM as compared to the median post game at rest standing rate of 121 BPM. The median rate for fielding was 127 BPM while the median rate for sitting in the dugout when not associated with a turn at bat was 112 BPM.²

Ramsey, Ayoub, Dudek, and Edgar looked at the heart rate recovery during a college basketball game of two university freshman basketball players, a starting regular who played basically the entire game, and a reserve who played only a small portion of the game. Results indicated that apparently brief intervals of rest as short as forty to sixty seconds in duration do provide substantial opportunity for physiological recovery in terms of significant decreases in heart rate response. In the basketball game these occur during time-out periods and also during those periods of time when some other player is taking a foul shot. Those foul shots in which the player himself is involved do not show any decrease in heart response, thus indicating a higher degree of physical and emotional involvement in this particular type of activity. Neither the game score nor any particular type of player activity such as rebounding, shooting or scoring was directly reflected in the heart response. However, there was a

²Dale L. Hanson, "Cardiac Response to Participation in Little League Baseball Competition as Determined by Telemetry," Research Quarterly, (October, 1967), 385-87.

definite response of decreasing heart rate to the periods of rest that occurred during the game.³ Foul shooting, kneeling and sitting were considered as rest periods throughout the game.

Gazes, Sovell, and Dellastatious measured the heart rate response of thirty football and basketball coaches, ages twenty-four to fifty-six, throughout a period from five minutes before game time, during the entire game, and five minutes afterward with the half time period excluded. Prior to monitoring, twenty-eight of the coaches had a history taken; the physical examination included chest x-ray or cardiac flouroscopy, a routine twelve-lead electrocardiogram, a double Master's exercise test, complete blood count, urinalysis, urea nitrogen, fasting blood sugar, cholesterol, and total and fractional lipid determinations. Of those examined, one had sustained a myocardial infarction two years previously with subsequent infrequent anginal episodes. He had a normal resting electrocardiogram with a positive Master's exercise test. Another coach had a history of rheumatic fever and a Grade 1/V1 apical systolic murmur but was asymptomatic. There was one hypertensive subject in the group with a diastolic pressure of ninty mm. Hg. The remainder had essentially normal physical findings and laboratory studies and were asymptomatic. All coaches exhibited sinus arrhythmia during the monitoring period which

³J. D. Ramsey, et al., "Heart Rate Recovery During a College Basketball Game," Research Quarterly, XLI (December, 1970), 529-35.

became less evident as the rate increased. Three had pregame heart rates less than 100 BPM, the others had rates ranging upward to 150 BPM. After the beginning of the game each coach rapidly reached a rate which was sustained with minor changes throughout the game period. The maximum rate observed was 188 BPM in a coach who maintained an average rate of 166 BPM throughout a game. All responded to the stress of the game with an increase in heart rate averaging forty-two BPM over resting rates in the pregame period and with an additional increase of twenty-one BPM during the game period. The coach who had had a prior myocardial infarction occasionally showed frequent ventricular ectopic beats of multifocal origin. There was one short period of paroxysmal atrial tachycardia in a coach who did not have a premonitoring work-up. None of them developed symptoms or significant S-T, T, or QRS changes.⁴

Husman, Hanson, and Walker analyzed the pulse rate of a varsity basketball coach, age forty-three, and a varsity swimming coach, age forty. Two contests, publicized as being high competitive, were selected for this study, since it was the desire of the investigators to create an emotionally charged environment under which to study the coaches. The pulse rate of each coach was recorded under the following situations: (1) in his office under as normal conditions as possible, (2) during a practice session, and

⁴ Peter C. Gazes, M. D., Broadus F. Sovell, M. D., and J. William Dellastatious, Colonel, USA Charleston, S. C., "Continuous Radio-electrocardiographic Monitoring of Football and Basketball Coaches During Games," American Heart Journal, (October, 1969), 509-11.

(3) prior to, during and after a contest. The resting pulse rate of the basketball coach was eighty-three BPM. However, his pulse taken intermittently during practice averaged 102 BPM and ranged from a low of ninety-one BPM to a high of 113 BPM. The high pulse rate occurred during a controlled scrimmage when the coach stopped the scrimmage to scream angrily at a player. Prior to the game the average pulse rate of the coach was 103 BPM. The range was from a low of eighty-nine BPM recorded when he was standing joking with the opposing coach to a high of 115 BPM just before the start of the game. From the start of the game, during half time, and during the first eight minutes of the second half of the game, the coach's pulse varied very little and averaged 113 BPM. Early in the second half the coach's team retained a four to eight point lead. The rise in the pulse rate apparently was caused by a narrowing of the gap in the score from seventy-sixty-two to seventy-five-seventy-four. With one minute to play and the score seventy-five-seventy-four, it was decided to record the pulse continuously until the end of the game. During this time the coach's average pulse rate was 135 BPM and ranged from 120 BPM to 150 BPM. The high pulse rate of 148 BPM and 150 BPM occurred during the shooting of a free throw by the opposing team. The sudden drop from 150 BPM to 120 BPM took place after the opposing team made both free throws and led in the game for the first time since the start of the second half. The other high pulse rates of 142 BPM and 148 BPM occurred when the coach's team, either by means of free throw or

control of the ball, had an opportunity to tie or win the game. The final score was seventy-seven to seventy-nine. At the end of the game, after congratulating the opposing coach, and walking to the locker room, there was a sudden decrease in the coach's pulse rate to 109 BPM. The resting pulse rate of the swimming coach was seventy-nine BPM while during a practice session his pulse averaged eighty-five BPM. However, during the freshmen swimming meet, the coach's pulse ranged from a high of 168 BPM to a low of eighty-six BPM, with a mean of 116 BPM. On two occasions the coach's pulse rate became elevated. These two occasions were during the swimming of the fifty-yard free style event by an outstanding swimmer who was expected to tie or break the American record and during the swimming of the last event, which decided the winner of the freshmen meet. At the beginning of the fifty-yard free style event the coach's pulse was 136 BPM. It rose to 168 BPM during the twenty-one seconds it took his star freshman swimmer to tie the American record for the event. The pulse rate of the swimming coach averaged 137 BPM during the varsity swimming meet. The pulse of the coach increased during the entrance of the team into the pool and during the swimming of each event. The coach's pulse decreased considerably during the diving, except for one period when an argument ensued over the scoring.⁵

⁵ Burris F. Husman, Dale Hanson, and Ross Walker, "The Effect of Coaching Basketball and Swimming Upon Emotion as Measured by Telemetry," Contemporary Psychology of Sport, 2nd International Congress of Sports Psychology, (1968), 287-91.

McArdle, Foglia, and Patti recorded the cardiac response prior to, during, and in recovery from selected track events of eighteen male varsity trackmen with a mean age of nineteen years and four untrained subjects with a mean age of twenty-one years. The track events studied were the sixty-yard, 220-yard, 440-yard, 880-yard, one-mile, and two-mile runs. It was concluded that: (1) in trained runners the heart rate immediately preceding the start of the race was highest in the sixty-yard dash and successively lower in events of longer distance. This anticipatory increase in heart rate represented seventy-four percent of the total heart rate adjustment to exercise in the sixty-yard dash and thirty-three percent in the two-mile run, (2) the heart rate increased rapidly during the initial stages of each race with the heart rate reaching approximately 180 BPM within twenty-eight seconds during the one-mile and two-mile runs and within ten seconds in the 220-yard run. Heart rate pattern during the race and in recovery was similar in the untrained group, (3) significantly higher peak heart rates were elicited in events of longer distance. There were no significant differences in maximum heart rates of trained and untrained, and (4) recovery from the sixty-yard dash was significantly more rapid than from any of the longer distances. No significant differences were demonstrated in recovery pattern of the 220-yard, 440-yard, 880-yard, one-mile, and two-mile runs.⁶

⁶William D. McArdle, Guido Foglia, and Anthony V. Patti, "Telemetered Cardiac Response to Selected Running Events," Journal of Applied Physiology, (October, 1967), 566.

Bowles and Sigerseth measured the heart rate response of sixteen track athletes, ages eighteen to twenty-four, under the following conditions: (1) while the subjects were at rest, (2) during a one-mile run at a steady pace, (3) during a one-mile run at a fast-slow pace, (4) during a one-mile run at a slow-fast pace, and (5) during recovery. It was concluded that the heart rate response to exercise is very rapid, regardless of the pace pattern, and will reach the slope of the exercise heart rate response line before the subject has reached the end of the first 220-yards while running a mile. The fast-slow pace pattern brought about a significantly higher heart rate response than any other pace pattern in the one-mile runs. During recovery, there were no significant differences between the pace patterns followed in the time necessary for the heart to reach a rate which was within ten percent of the warm-up heart rate. Eleven of the subjects were able to run the last 440-yard portion of the mile in the shortest time when they had followed the slow-fast pace pattern in running the preceding 1,320 yards of the mile run.⁷

Skubic and Hilgendor studied the heart rate response to running various distances. Throughout this study, five highly trained girls served as subjects. The findings indicated that: (1) anticipatory heart rate just prior to exercise represented fifty-nine percent of the total adjustment to exercise, (2) the heart rates during exercise were 2.5 times the resting

⁷Charles J. Bowles and Peter O. Sigerseth, "Telemetered Heart Rate Responses to Pace Patterns in the One-Mile Run," Research Quarterly, (March, 1968), 36.

values, and (3) heart rates observed at the end of the 220-, 440-, 880-yard, and mile events were similar.⁸

Bayley, Orban, and Merriman conducted a study on the heart rate response to interval running. The heart rate of five active subjects under three conditions of interval running and one all out run were continuously recorded from five minutes before to ten minutes after each test run. Each subject ran five one-minute runs of 330 yards alternately with controlled active recovery intervals between runs. The recovery intervals were one, two, three minutes on three successive days. On the fourth day the subjects ran all out for five minutes with no recovery intervals. The mean heart rate was determined for both twenty-second and one-minute periods for the entire test. The results indicated that the absolute value in each run interval is inversely related to the length of the recovery interval; the pattern of the recovery interval remains constant; the maximum rates in the interval runs differ from the continuous run only in the two terminal minutes; the final recovery rate pattern indicates no significant differences.⁹

Magel, McArdle, and Glaser determined the heart rate response prior to, during, and in recovery from selected competitive swimming events

⁸Vera Skubic and Jane Hilgendorf, "Anticipatory, Exercise, and Recovery Heart Rates of Girls as Affected by Four Running Events," Journal of Applied Physiology, (September, 1964), 853.

⁹D. A. Bayley, W. A. R. Orban, and J. E. Merriman, "Heart Rate Response to Interval Running Using Radio Telemetry," Journal of Sports Medicine and Physical Fitness, (December, 1963), 252-53.

in seven male varsity swimmers. The swimming events studied were the fifty-, 100-, 200-, 500-, and 1,000-yard swims. Results showed that the heart rate increased rapidly during the initial stages of each race and then climbed progressively toward maximum as the race proceeded. Several plateaus in heart rate and swimming speed were reached during the 500- and 1,000-yard events. The longer swimming events tended to elicit higher peak heart rates (181 BPM) than the shorter, spring events (173 BPM). Recovery from the fifty-yard event was more rapid than any of the longer distances. In an attempt to control for the effects of work duration when comparing heart rates running and swimming, all subjects ran distances comparable in time to those they had swum. The pattern of heart rate response in running was essentially similar to swimming, but the magnitude of the response was greater in all running events. The maximum heart rates during running were significantly greater than those obtained during swimming for a similar time period.¹⁰

Kozar collected heart rate recordings of a Big Ten all-round gymnastic champion during routines performed on the high bar (first and second routine), parallel bars, side horse, and still rings and found that for the two parallel bars routines (the first, a "big time" routine, was followed by a second routine which lasted five seconds longer and was not as complex

¹⁰John R. Magel, William D. McArdle, and Roger M. Glaser, "Telemetered Heart Rate Response to Selected Competitive Swimming Events," Journal of Applied Physiology, (June, 1969), 764.

and strenuous as the first), the initial routine on the parallel bars produced a peak heart rate of 169 BPM as compared to 150 BPM for the routine that followed. Following this the "tough" routine demonstrated an increase in the heart rate of fifteen to twenty beats for the subject during the next few seconds. In the second routine on the parallel bars a period of thirteen seconds was required for the subject to reach a heart rate equal to the initial performance at the twenty-one second mark of each routine. After this the subject's heart rate in the second routine increased only three beats to reach the maximum and leveled off for the last twelve seconds. In contrast the "tougher" routine caused the subject's heart rate to increase rapidly to its peak in the next nine seconds. In what is considered a warm-up routine on the high bar, the first execution of this routine, which took two seconds less than the second routine, produced a peak heart rate twenty-two BPM less than the second attempt. At the nine second mark of execution for both attempts the heart rates were similar but during the last six seconds, the second performance produced a significantly rapid increase in the subject's heart rate. The heart rate response of the subject to work on the side horse nearly duplicated the heart rate response of the second performance on the high bar which also lasted fifteen seconds. The final two performances during which the heart rate was monitored consisted of a good short routine repeated on the still rings. Both performances produced a similar cardiovascular response for the first twenty seconds, after which the first routine caused the subject's heart rate to level, and

the second routine caused the heart rate to rise to a peak at the termination of the event.¹¹

Faria and Phillips recorded the heart rates of thirty untrained boys and thirty untrained girls between the ages of seven and thirteen years of age (the mean age of the boys was 9.5 years, while that for girls was 9.0 years) during twenty minutes of gymnastics activity. The gymnastic activities that were selected for the boys included: (1) waiting to perform, (2) warm-up, (3) vaulting, (4) tumbling, (5) floor exercise, (6) rope climb, and (7) trampoline. The activities that were selected for the girls included: (1) waiting to perform, (2) warm-up, (3) balance beam, (4) tumbling, (5) vaulting, (6) floor exercise, and (7) trampoline. Results of this study indicated that the cardiac rate for boys was significantly higher during rope climb (180 BPM) and trampoline activity than during vaulting, tumbling and floor exercise. Significantly higher heart rates were observed for girls during trampoline than during balance beam, tumbling, floor exercise and vaulting activities. Balance beam exercise exhibited the lowest mean heart rate for girls, while vaulting for boys resulted in the lowest cardiac acceleration. There was no significant difference between the boys and girls heart rate response to trampoline, floor exercise, tumbling and vaulting activities.¹²

¹¹Andrew J. Kozar, "Telemetered Heart Rates Recorded During Gymnastic Routines," Research Quarterly, (March, 1963), 102-5.

¹²Irvin E. Faria and Alice Phillips, "A Study of Telemetered Cardiac Response of Young Boys and Girls During Gymnastic Participation," Journal of Sports Medicine and Physical Fitness, (September, 1970), 145-48.

Faulkner, Greey, and Hunsicker conducted a study on the heart rate of forty-two boys between the ages of seven and twelve years during a daily thirty-five minute physical education period which consisted of swimming, gymnastics, and sports skills. A random sample of fourteen boys was drawn from the boys who took each of the three activities during the first period. The sampling rate was approximately half. A three to four second heart rate reading was made every five minutes during the thirty-five minute period on each subject. Six heart rate readings were taken on each subject in each period, one during the pre-period activity and five during instruction or practice. Through reference to the time period for three cardiac cycles the reading was transferred to BPM. A subject's mean daily heart rate was obtained by averaging the six readings. The extreme variability of heart rate among subjects apparently involved in the same activity was evidenced by the lowest and highest mean heart rates-eighty-eight BPM and 166 BPM in swimming; ninety-seven BPM and 166 BPM in gymnastics; and 122 BPM and 180 BPM in sports skills. The amount of physiologic stress placed on some boys, at least intermittently during the program, was reflected in the peak individual heart rate readings of 200 BPM in swimming, 192 BPM in gymnastics, and 220 BPM in sports skills. The lowest peak individual hearts recorded were ninety-nine BPM in swimming, 130 BPM in gymnastics, and 145 BPM in sports skills. The daily variance in mean heart rate was significant ($P < .001$) in swimming and not significant in gymnastics ($P > .5$), or sports skills ($P > .25$).

The composite mean heart rate for sport skills was higher than that of gymnastics ($P < .001$), and swimming ($P < .05$). There was no difference between the composite mean heart rates of gymnastics and swimming ($P > .1$).¹³ It was noted, that Faulkner, Greey, and Hunsicker failed to describe the sport skills used throughout their study.

Reid and Doeer analyzed the heart rate of seven military parachutists (five USN, two USAF/nineteen to thirty-nine years old), with experience levels ranging from zero to 1,109 parachute jumps. The parachutists participated in twenty-seven individual jumps completed to date. Egress altitude for free-fall jumps varied from 5,000 to 20,000 foot mean sea level (MSL). Heart rate accelerates in the parachutist seated in the aircraft during the three minutes just before egress and peaks at manual ripcord pull. After parachute deployment, heart rate decreases an average of thirty-five BPM, but accelerates again at approximately 1,000 ft. MSL prior to landing, and attains a second peak at impact. Highest rates observed were at parachute deployment; the second highest occurring at landing. The highest heart rate value observed was from a novice parachutist making his third free-fall jump: Baseline-ninety BPM; three second egress-196 BPM; during free-fall-200 BPM; at parachute deployment (4,000 ft. MSL)-220 BPM; at 2,500 feet under the canopy-168 BPM; at ground impact-205 BPM; and one minute post-impact-180 BPM. The subject was subsequently

¹³John Faulkner, George Greey, and Paul Hunsicker, "Heart Rate During Physical Education Periods," Research Quarterly, (March, 1963), 95-97.

instrumented during free-fall jumps seventeen, eighteen, and nineteen. During the latter descent heart rate at parachute deployment was 170 BPM and at impact 176 BPM. Heart rate values from experienced parachutists neither attained quantitative values as great as for novice, nor was the lability of change as dramatic; however, the same qualitative pattern was observed. Thus, for a thirty-nine year old navy Chief making his 1,107th jump, heart rate at deployment was 160 BPM and at impact 148 BPM compared with a baseline value of seventy BPM. Lowest rates observed during free-fall parachuting were from a twenty year old parachutist with sixty previous jumps: Baseline-fifty-eight BPM; at parachute deployment-150 BPM, and at impact-136 BPM. The only heart rate value that exceeded 200 BPM was from a novice jumper. However, heart rates of 175-185 BPM were frequently observed at parachute deployment in subjects having ninety-four to 840 jumps. Heart rate at ground impact averaged ten BPM less than at parachute opening. Heart rate during the jumping process in a novice parachutist decreased as experience was gained.¹⁴

Shephard conducted a study relating to the heart and circulation under stress of Olympic conditions and stated that psychological stress is greater during anticipation of exercise than during actual performance. He also

¹⁴ Donald H. Reid and Joseph E. Doerr, "Physiological Studies of Military Parachutists Via FM/FM Telemetry," Aerospace Medicine, (November, 1970), 1295-97.

stated that, "Åstrand has found pulse rates of 150 beats per minute prior to skiing contests, and British racing drivers awaiting the starter's flag have had pulse rates as high as 200 to 205 beats per minute." Therefore, concluding that the intensity of the stress imposed upon the heart by an anxiety reaction may exceed that incurred during maximum exercise.¹⁵

Taggart and Gibbons measured heart rate response of nine subjects (seven men and two women), ages twenty-one to fifty-four (mean twenty-eight), while driving in peak London traffic, and on three during competitive circuit racing. Results indicate that driving in dense fast-moving traffic raised the heart rate from the resting range of seventy-eight-five BPM to 100-140 BPM. In competitive motor-racing three healthy, experienced racing drivers had an increase in the heart rate to between 190 and 205 BPM. The rate was recorded at 150-180 BPM in the fifteen minutes before the start and at the signal indicating two minutes before the start a rate in excess of 180 BPM was usual. This increased up to 200 to 205 BPM by the time of the start and in some cases was maintained at this level continuously throughout the event.¹⁶

¹⁵ Roy J. Shephard, M. D., Ph.D., "The Heart and Circulation Under Stree of Olympic Conditions," Journal of American Medical Association, CCV (11), (September 9, 1968), 151.

¹⁶ Peter Taggart, M. B., B. S., M. R. C. P., M. R. C. P. ED. and David Gibbons, M. S. C. T., "Motor-Car Driving and the Heart Rate," British Medical Journal, (February, 1967), 411-12.

Hanson and Tabakin conducted an electrocardiographic study on four male members (twenty to twenty-three years old) of the Middlebury College, Middlebury, Vermont, ski team during the downhill racing, cross-country racing and jumping events. The subjects had been in training for approximately three months and were also active in other sports during the school year. Results indicated that it is apparent that the prestart rate for all subjects represents a highly significant "anticipatory" increase above resting levels, being most marked in the cross-country data, in which increments of 100 to 219 percent of resting values were observed. Also, restitution of heart rate sixty seconds after the finish of an event involved decrements of thirty-one to fifty-six percent of the finish rate. Two minutes after landing from the jump the subjects exhibited rates from -two to +twenty-three BPM above their resting, prestart values.¹⁷

Goodwin and Cumming carried out a study on heart rates of six water polo players under various game conditions. Electrocardiographic tracings were obtained frequently during the game and at rest periods. Results indicated that before arising in the morning, the mean resting heart rate of these athletes was fifty-six BPM. The mean rate after twenty minutes rest in a laboratory was thirty BPM greater than the resting rate. Just prior to the start of a water polo match, the mean heart rate was 109 BPM.

¹⁷ John S. Hanson, M. D. and Burton S. Tabakin, M. D., "Electrocardiographic Telemetry in Skiers," New England Journal of Medicine, (July 23, 1964), 181-85.

The maximal pulse rates of 180 to 195 BPM were usually obtained during actual scoring or potential scoring plays on offense where the player would be expected to be going all-out, as well as during key defensive plays. The rate during defensive plays tended to be slightly less than for offensive plays, suggesting that most players did not go all-out on defense. Throughout the entire game, pulse rates remained above 150 BPM. At times of relative inactivity, such as remaining in position in the shallow end resting the feet on the bottom, the pulse rates were over 160 BPM. At the end of the rest period between periods, pulse rates ranged from 156 to 170 with a mean of 167 BPM. Two minutes of recovery seemed to be no better than a slack period in the middle of the game in allowing the pulse rate to return towards normal. The mean pulse rate immediately after the contest was above 170 BPM and the mean morning minute pulse rate, taken by the subject at home shortly after arising, was fifty-six (range: forty-seven to seventy-one). The mean resting heart rate in the laboratory after a twenty minute rest was thirty-four BPM greater than the resting rate at home.¹⁸

Volume of Oxygen and Workload

Malhotra, Gupta, and Rai conducted a study to investigate the pulse count as a measure of energy expenditure. Throughout this study, seven

¹⁸A. B. Goodwin, B. P. E. and Gordon R. Cumming, M. D., F. R. C. P. (G), "Radio Telemetry of the Electrocardiogram, Fitness Test and Oxygen Uptake of Water-Polo Players," Canadian Medical Association Journal, XCV (August 27, 1966), 403-4.

young male adults served as subjects. The subjects were given standard tasks on a bicycle ergometer, with a workload varying from fifty to 600 kg-m/minute. After about eight to nine minutes of cycling, when the steady state had been reached, expired gases were collected using a respirometer; pulse rate was recorded by palpation during the gas-collection period. The expired gases were analyzed using a Scholander microgas analyzer, and the energy expenditure calculated. The relationship between the pulse rate and energy expenditure was then determined. Results indicated that a linear correlation had been found between the pulse rate and the energy expenditure in all the subjects.¹⁹

Åstrand, Åstrand, and Rodahl studied the maximal heart rates in older men during work. Nine fifty-six to sixty-eight year old male subjects performed muscular work up to maximal loads on a bicycle ergometer while breathing both ambient air and oxygen. Heart rate increased to an average maximum of 163 BPM. The maximal O₂ intake averaged 2.24 l/m and the blood lactic acid concentration eighty-five mg/100 ml. In no case was the maximal heart rate higher when breathing O₂ than when breathing air. Four subjects were able to work for about one hour without any sign of exhaustion on a workload requiring an O₂ consumption of about fifty percent of their maximal aerobic work capacity.²⁰

¹⁹M. S. Malhotra, J. Sen Gupta, and R. M. Rai, "Pulse Count as a Measure of Energy Expenditure," Journal of Applied Physiology, XVIII (1963), 994-96.

²⁰Irma Åstrand, Per-Olof Åstrand, and Kaare Rodahl, "Maximal Heart Rate During Work in Older Men," Journal of Applied Physiology, XIV (1959), 562.

Åstrand and Saltin studied seven subjects performing maximal work of various types. The following exercises were studied: (A) cycling a bicycle ergometer in a sitting position, (B) cycling a bicycle ergometer in a supine position, (C) simultaneous arm and leg work on bicycle ergometers, (D) running on a treadmill, (E) skiing, (F) swimming, and (G) arm work (cranking). Results indicated that: (1) $\dot{V}O_2$ was a few percent higher in running uphill than in cycling, cranking plus cycling, and skiing, (2) heart rates were similar during running uphill, cycling, cranking plus cycling, and skiing, (3) supine cycline gave a maximal $\dot{V}O_2$ that was about fifteen percent lower than in sitting cycling, (4) a similar reduction in maximal $\dot{V}O_2$ was noted in swimming, and (5) maximal work with the arms gave an oxygen uptake that was about seventy percent of maximal $\dot{V}O_2$ when cycling. It was also concluded that the aerobic capacity and maximal heart rate are the same in maximal running or cycling, at least in well-trained subjects.²¹

Åstrand and Saltin tested the oxygen uptake, heart rate, pulmonary ventilation, and blood lactic acid of five subjects performing maximal work on a bicycle ergometer. After a ten minute warming up period workloads were varied so that exhaustion terminated exercise after about two to eight minutes. Results of this study indicated that the peak oxygen

²¹Per-Olof Åstrand and Bengt Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, XVI (1961), 977.

uptake and heart rate were practically identical (SD 3.1 percent and 3 beats per minute) [sic]. The heavier the work was and the shorter the work time the higher became the pulmonary ventilation. There was a more rapid increase in the functions studied when the heaviest work loads were performed. From this study, it was concluded that aerobic capacity can be measured in a work test of from a few minutes up to about eight minutes in duration, with the severity of the work determining the actual work time necessary.²²

Saltin and Åstrand conducted a study on ninety-five males and thirty-eight female subjects, twenty-four (range thirteen-forty-seven) years of age representing the Swedish National Team in nineteen different sports events for the males and nine different events for the females, during maximal running (treadmill) or bicycling. The mean maximal oxygen uptake for the fifteen males with the highest values was 5.75 l/m with a upper extreme of 6.17 l/m. The mean maximal pulmonary ventilation was 158.7 (140.0-203.3) l/m and the mean maximal heart rate was 185 (169-200) BPM. As a team, five cross-country skiers achieved the highest value with eighty-three ml/kg x minute (5.6 l/m). The highest individual value, 85.1 ml/kg x minute (5.7 l/m), occurred in a world champion cross-country skier. The mean maximal oxygen uptake

²² Per-Olof Åstrand and Bengt Saltin, "Oxygen Uptake During the First Minutes of Heavy Muscular Exercise," Journal of Applied Physiology, XVI (1961), 971.

for the best ten female athletes was 3.6 l/m. The maximal pulmonary ventilation was 111.8 (91.6-131.0) l/m and the maximal heart rate was 195 (185-204) BPM.²³

Grimby, Nilsson, and Saltin determined the oxygen uptake, cardiac output, heart rate, and arterial blood pressure at rest in the supine and sitting positions, and during submaximal and maximal exercise in the sitting position. The heart volume was measured at rest (prone). Subjects for this study were nine physically well-trained and active male athletes (cross-country runners and/or skiers with at least twenty years of continuous intensive training and competition) between the ages of forty-five and fifty-five (\bar{X} fifty-one) years. Results indicated that the maximal oxygen uptake was 3.56 l/m and the maximal cardiac output was 26.8 l/m. The stroke volume was nineteen percent lower at rest supine than during exercise and reached an average maximal value of 163 ml. Also, the arteriovenous oxygen difference was forty-five ml/l at rest supine, but increased only to 133 ml/l during maximal exercise.²⁴

²³Bengt Saltin and Per-Olof Åstrand, "Maximal Oxygen Uptake in Athletes," Journal of Applied Physiology, (September, 1967), 353.

²⁴Gunner Grimby, Nils Johan Nilsson, and Gengt Saltin, "Cardiac Output During Submaximal and Maximal Exercise in Active Middle-Aged Athletes," Journal of Applied Physiology, XXI (1966), 1150.

CHAPTER III

METHOD OF PROCEDURE

Subjects

Subjects for this study were five male members of the Utah State University Freshman Basketball Team, two guards, two forwards, and one center, whose ages ranged from eighteen to twenty years.

Recording System

The heart rate responses of the five freshman basketball players used throughout this study were measured by means of radiotelemetry.

The recording system included: (1) Polygraph, PMP-4A, (2) Biotelemetry Transmitter, (3) Biotelemetry Receiver, and (4) Cardiac Pre-Amplifier. The recording system mentioned above is the property of the human performance laboratory in the Department of Health, Physical Education, and Recreation at Utah State University. (See Appendix A.)

Electrode Structure and Attachment

One hour prior to game time, two E&M Surface Electrodes were mounted on the chest of the test subject with disposable double-sided adhesive washers. Each electrode consisted of a silver disc with a diameter of 1.2 centimeters and a surface area of 1.13 square centimeters recessed into a soft plastic cover. The plastic cover, which had the shape of a

beveled disc, was one inch in diameter with a thickness of $3/16$ inch. The entire electrode, silver disc and plastic cover, weighed 2.545 grams. Attached to the electrode and plastic cover was a twenty three inch lead of strong, extremely flexible, lightweight wire that terminated in a standard phone jack which had a diameter of 0.081. The purpose of the plastic cover was to provide a large self-contouring surface for adhesion and also to hold the electrode from direct contact with the skin.

The two E&M Surface Electrodes were mounted to the sixth rib, lateral to the sternum and ventral to the origin of the serratus anterior muscle of the sixth and seventh ribs. A conductive cream was used to make electrical contact between the recessed silver disc and the body surface. When properly placed, these electrodes were designed to be relatively free from artifact due to movement, however they will reproduce electrical potentials generated by adjacent muscle tissue. Therefore, care was taken to place the electrodes properly in order to transmit a good signal free from artifacts caused by muscle mass adjacent to the electrodes. (See Appendix B.) Due to the great amount of interference created during a basketball game, as a result of the activity involved in playing the game, and based on the placement of the electrodes and the accuracy of the equipment, it was impossible to record any arrhythmia in the subjects.

The procedure used for mounting the electrodes to the subjects was as follows:

1. Shave off the long hair with clippers.
2. Shave the surface with a razor.
3. Clean the area with cotton soaked in acetone.
4. Rub the area where the electrode is to be placed with a stiff brush (until pink or red).
5. Clean the area with cotton soaked in acetone.
6. Tear off one adhesive washer and peel off one protective cover.
7. Attach the adhesive side to the electrode and press the electrode firmly onto the adhesive surface.
8. Fill the electrode with E&M Electrode Cream, leaving no air pockets.
9. Wipe off excess electrode cream.
10. Remove the remaining protective cover and press the electrode into place over the rubbed area.

Recording Procedure

One hour prior to each of the ten home basketball games, two E&M Surface Electrodes were mounted to the chest of the test subject with disposable double-sided adhesive washers. A biotelemetry transmitter, used for sending the electrical signals from the player to a biotelemetry receiver and polygraph, was placed in a plastic sack and taped to the belt-line of the subjects athletic supporter. (See Appendix C.) The transmitter was a small, lightweight, battery operated FM transmitter which weighed

eight grams and had case dimensions of 12.5 x 12.5 x 32 mm. The frequency, at which transmission of the electrical signals occurred, was 91 MHz. Care was taken to provide sufficient play in the electrode lead wires to permit the basketball players complete freedom of motion while playing. The heart rates were then recorded by a polygraph. Preparations were completed well before the start of the game to provide time for checking the telemetry receiver and recordings and to allow the subject to participate in normal pregame activities. The telemetry receiver and polygraph were located behind the Utah State University team bench. Also, a videotape recorder and microphone was positioned behind the polygraph for the purpose of recording and analyzing game situations. As each recording session progressed, it became possible to record specific game situations on the polygraph read out. Therefore, the videotape recordings were used only when conditions occurred that required a second viewing. After the data were collected, the game situations were reviewed and classified into the following categories:

(A) Offensive Play--the subject is playing offense, but not handling the ball, (B) Ball Handling--a period when the subject is holding, dribbling, or passing the ball, (C) Defensive Play--the subject is playing defense but not defending the ball handler, (D) Defense on the Ball--a phase of the game when the subject is guarding the ball handler, (E) Fastbreak--a category which includes all types of situations associated with fastbreaks, (F) Shooting--the subject is involved in shooting shots during actual game

action. Foul shots are not included in this category, (G) Scoring--a period when the subject scores after shooting a shot during actual game action. Foul shots are not included in this section, and (H) Rebounding--a category which includes all types of situations associated with rebounding.

One subject was tested per game and each subject was tested twice throughout the study. The same subject was tested once every fifth home game.

The data was collected with a polygraph, by means of radiotelemetry and recorded according to mean heart rates, HR (\bar{X} beats per minute, BPM), mean $\dot{V}O_2$ (\bar{X} liters per minute, l/m), and mean workload (\bar{X} kilopondmeters per minute, kpm). Data concerning \bar{X} $\dot{V}O_2$ and \bar{X} workload, was processed according to Åstrand's Nomogram.

Åstrand's Nomogram

Åstrand's Nomogram is designed for calculating maximal oxygen uptake from submaximal pulse rate and O_2 -uptake during a work test (cycling, running or walking, and step test). In tests without direct O_2 -uptake measurement it can be estimated by reading horizontally from the "body weight" scale (step test) or "work load" scale (cycle test) to the " O_2 uptake" scale. The point on the O_2 -uptake scale ($\dot{V}O_2$, liters) shall be connected with the corresponding point on the pulse rate scale, and the predicted maximal O_2 read on the middle scale. (See Appendix D.)

The standard error of the method for the prediction of maximal oxygen uptake from submaximal exercise test and the nomogram is about ten percent in relatively well-trained individuals of the same age, but up to fifteen percent in moderately trained individuals of different ages when the age factor for the correction of maximal oxygen uptake is applied. Untrained persons are often underestimated; the extremely well-trained athletes are often overestimated.²⁵ In order to account for the standard error of the method for the prediction of $\dot{V}O_2$ from submaximal exercise and Åstrand's Nomogram, a post test was conducted to confirm the indications of the error, which was found to be true in this study. Correction of the error (-ten percent in this study) was made in order to establish a more accurate indicator of $\dot{V}O_2$ and workload.

²⁵Per-Olof Åstrand and Kaare Rodahl, Textbook of Work Physiology (New York: McGraw-Hill, 1970), p. 357.

CHAPTER IV

ANALYSIS OF DATA

The data was collected with a polygraph by means of radiotelemetry, and recorded according to mean heart rate, HR, (\bar{X} beats per minute, BPM), mean $\dot{V}O_2$ (\bar{X} liters per minute, l/m), and mean workload (\bar{X} kilopondmeters per minute, kpm). Data, concerning $\bar{X} \dot{V}O_2$ and \bar{X} workload, was processed according to Åstrand's Nomogram. A two way analysis of variance test was applied to the data to determine the significant difference between the variables. Another statistical analysis that was conducted on the data was a Newman Keuls Sequential Range Test for determining the significant difference between the eight different game situations used throughout this study.

The analysis of data has been divided into three major categories:

(1) Heart Rate, (2) $\dot{V}O_2$, and (3) Workload. In each of these three categories, consideration and comparisons will be made of (A) offensive play, (B) ball handling, (C) defensive play, (D) defense on the ball, (E) fastbreak, (F) shooting, (G) scoring, and (H) rebounding.

Analysis of Variance

The two way analysis of variance permitted an overall indication of the differences between the means of HR, $\dot{V}O_2$, and workload as compared to offensive play, ball handling, defensive play, defense on the ball, fastbreaks, shooting, at the time the subject scored, and during rebounding situations.

The use of a F-distribution provided a critical value at a given level that would produce significance. For variance to be significant at the .05 level of confidence in this study, a calculated F equal to or greater than 3.56 was required.

The computed F for the \bar{X} HR, $\bar{X} \dot{V}O_2$, and \bar{X} workload levels of the subjects and the eight game situations was 9.28. Based upon these findings, there was a significant difference between HR, $\dot{V}O_2$, and workload of the five subjects as compared to the eight game situations.

Newman Keuls Sequential Range Test

The Newman Keuls Sequential Range Test determined whether or not a significant difference occurred between the eight game situations which were analyzed throughout this study. The results of this test, which are shown in table 1, indicated that the subjects were under a significantly higher workload at a time when they were involved in a fastbreak than when they were involved in any of the other seven game situations. It was noted that significantly higher workloads occurred during the game situations when the subjects were handling the ball as compared to those of the non-ball handling nature. The Newman Keuls Sequential Range Test also indicated that a significant difference at the .05 level between the ball handling activities (fastbreaks, ball handling, and shooting) and the non-ball handling activities (rebounding, scoring, defense on the ball, defensive play, and offensive play). No significant difference occurred at the .05 level within the two groups of activities.

Table 1. Results of the Newman Keuls Sequential Range Test.

	\bar{X}	HR	$\dot{V}O_2$	KPM	Offensive Play	Defensive Play	Defense on the Ball	Scoring	Rebounding	Shooting	Ball Handling		
Fastbreak		196	2.6	1364	18	18	17	14	13	9	6		
Ball Handling		190	2.9	1353	12	12	11	8	7	3			
Shooting		187	2.9	1337	9	9	8	5	4				
Rebounding		183	3.0	1326	5	5	4	1					
Scoring		182	3.0	1326	4	4	3						
Defense on the Ball		179	3.1	1320	1	1							
Defensive Play		178	3.1	1320	0								
Offensive Play		178	3.1	1320	0								
						2	3	4	5	6	7	8	
						Range Value:	2.90	3.50	3.86	4.12	4.32	4.48	4.62
						Critical Value:	6.01	7.30	8.002	8.50	8.96	9.30	9.60

Heart Rate

Figure 1 compares the \bar{X} HR (BPM) of the five subjects to the following game situations: (A) offensive play, (B) ball handling, (C) defensive play, (D) defense on the ball, (E) fastbreak, (F) shooting, (G) scoring, and (H) rebounding. The data indicated that the range of the \bar{X} HR for the five subjects was from 162 to 218 BPM.

The highest \bar{X} HR range was 195-218 BPM (\bar{X} 203) and occurred with subject five, who played guard. The lowest \bar{X} HR range was 162-185 BPM (\bar{X} 170) and occurred with subject four, who played forward. In comparing the \bar{X} HR of all five subjects to the eight game situations mentioned above, the highest occurred during fastbreaks (196 BPM), while the lowest occurred during offensive and defensive play (178 BPM).

Volume of Oxygen

Figure 2 compares the \bar{X} $\dot{V}O_2$ (l/m) of the five subjects to the eight game situations mentioned above. The data indicated that the range of the \bar{X} $\dot{V}O_2$ for the five subjects was from 1.8-3.7 l/m. The highest \bar{X} $\dot{V}O_2$ range was 3.2-2.7 l/m (\bar{X} 3.4) and occurred with subject four, who played forward. The lowest \bar{X} $\dot{V}O_2$ range was 1.8-2.1 l/m (\bar{X} 2.0) and occurred with subject five, who played guard. In comparing the \bar{X} $\dot{V}O_2$ ratings of all five subjects to the eight game situations mentioned above, the highest occurred during offensive play, defensive play, and when the

Figure 1. Mean Heart Rates (beats/minute) of the Five Subjects During Eight Different Game Situations.

Subjects, Playing Positions, Ranges, and Mean Heart Rates

Game Situations	1 Guard	2 Center	3 Forward	4 Forward	5 Guard	Range	Mean
Offensive Play	176	176	179	164	196	164 to 196	178
Ball Handling	200	181	187	171	210	171 to 210	190
Defensive Play	176	173	182	162	196	162 to 196	178
Defense on the Ball	175	168	184	168	200	168 to 200	179
Fastbreak	195	187	195	185	218	185 to 218	196
Shooting	188	186	186	168	209	168 to 209	187
Scoring	188	174	185	167	198	167 to 198	182
Rebounding	191	169	185	177	195	169 to 195	183
Range	175 to 200	168 to 187	179 to 195	162 to 185	195 to 218		
Mean	186	177	185	170	203		

Figure 2. Mean $\dot{V}O_2$ (liters/minute) of the Five Subjects During Eight Different Game Situations.

Subjects, Playing Positions, and Mean $\dot{V}O_2$							
Game Situations	1	2	3	4	5	Range	Mean
	Guard	Center	Forward	Forward	Guard		
Offensive Plan	3.2	3.4	3.4	3.6	2.1	2.1 to 3.6	3.1
Ball Handling	2.6	3.3	3.1	3.3	1.9	1.9 to 3.3	2.9
Defensive Play	3.2	3.5	3.3	3.7	2.1	2.1 to 3.7	3.1
Defense on the Ball	3.2	3.7	3.2	3.5	2.0	2.0 to 3.7	3.1
Fastbreak	2.8	3.1	3.0	3.2	1.8	1.8 to 3.2	2.6
Shooting	2.9	3.1	3.1	3.5	2.1	2.1 to 3.5	2.9
Scoring	2.9	3.5	3.2	3.5	2.1	2.1 to 3.5	3.0
Rebounding	2.9	3.6	3.2	2.1	2.1	2.1 to 3.6	3.0
Range	2.6 to 3.2	3.1 to 3.7	3.0 to 3.4	3.2 to 3.7	1.8 to 2.1		
Mean	3.0	3.4	3.2	3.4	2.0		

subject's were playing defense on the ball (3.1 l/m). The lowest rating occurred during fastbreaking situations (2.6 l/m).

Workload

Figure 3 compared the \bar{X} workload levels (kpm) of the five subjects to the eight game situations mentioned above. The data indicated that the range of the \bar{X} workload for the five subjects was from 1067-1496 kpm. The highest \bar{X} workload range was from 1452-1496 kpm (\bar{X} 1467) and occurred with subject three, who played forward. The lowest \bar{X} workload range was from 1067-1128 kpm (\bar{X} 1087) and occurred with subject five, who played guard. In comparing the \bar{X} workload levels of all five subjects to the eight game situations mentioned, the highest \bar{X} workload occurred during fastbreaking situations (1364 kpm). The lowest workload occurred during offensive play, defensive play, and when the subjects were playing defense on the ball (1320 kpm).

Due to the interpolation of Åstrand's Nomogram when processing the data concerning $\dot{V}O_2$ and workload, the highest HR, $\dot{V}O_2$, and workload levels were not the same.

Figure 3. Mean Workload Levels (kilopondmeters/minute) of the Five Subjects During Eight Game Situations.

Subjects, Playing Positions, Ranges, and Mean Workload Levels

Game Situations	1	2	3	4	5	Range	Mean
	Guard	Center	Forward	Forward	Guard		
Offensive Play	1342	1441	1452	1309	1067	1067 to 1452	1320
Ball Handling	1403	1458	1474	1331	1100	1100 to 1474	1353
Defensive Play	1342	1436	1463	1315	1067	1067 to 1463	1320
Defense on the Ball	1342	1419	1463	1320	1089	1089 to 1463	1320
Fastbreak	1397	1474	1496	1364	1128	1128 to 1496	1364
Shooting	1375	1469	1469	1320	1100	1100 to 1469	1337
Scoring	1375	1452	1463	1320	1073	1073 to 1463	1326
Rebounding	1375	1430	1463	1342	1067	1067 to 1463	1326
Range	1342 to 1403	1419 to 1474	1452 to 1496	1309 to 1364	1067 to 1128		
Mean	1368	1448	1467	1328	1087		

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the effects of physical exertion upon the heart rates and workload levels of selected male freshman basketball players at Utah State University during actual game competition.

Subjects for this study were five members of the Utah State University Freshman Basketball Team, two guards, two forwards, and one center, whose ages ranged from eighteen to twenty years.

One hour prior to each of the ten home basketball games, two E&M Surface Electrodes were mounted to the chest of the test subject with disposable double-sided adhesive washers. A biotelemetry transmitter, used for sending electrical signals from the player to a biotelemetry receiver and polygraph, was placed in a plastic sack and taped to the beltline of the subjects athletic supporter. The telemetry receiver and polygraph were located behind the Utah State University team bench.

Each electrode consisted of a silver disc with a diameter of 1.2 centimeters and had a surface area of 1.13 square centimeters recessed into a soft plastic cover. The plastic cover, which had the shape of a beveled disc, was one inch in diameter with a thickness of 3/16 inch. The entire electrode, silver disc and plastic cover, weighed 2.545 grams.

Attached to the electrode and plastic cover was a twenty three inch lead of strong, extremely flexible, lightweight wire that terminated into a standard phone jack which had a diameter of 0.081. The purpose of the plastic cover was to provide a large self-contouring surface for adhesion and also to hold the electrode from direct contact with the skin. The electrodes were mounted to the sixth rib, lateral to the sternum and ventral to the origin of the serratus anterior muscle of the sixth and seventh ribs. A conductive cream was used to make electrical contact between the recessed silver disc and the body surface.

The biotelemetry transmitter was a small, lightweight, battery operated FM transmitter which weighed eight grams and had case dimensions of 12.5 x 12.5 x 32 mm. The frequency, at which transmission of the electrical signals occurred, was 91 MHz. Care was taken to provide sufficient play in the electrode lead wires to permit the basketball players complete freedom of motion while playing. The heart rates were then recorded by a polygraph. Preparations were completed well before the start of the game to provide time for checking the telemetry receiver and recordings and to allow the subject to participate in normal pregame activities.

The data was collected with a polygraph, by means of radiotelemetry, and recorded according to mean heart rate, HR, (\bar{X} beats per minute, BPM), mean $\dot{V}O_2$ (\bar{X} liters per minute, l/m), and mean workload (\bar{X} kilopondmeters per minute, kpm), which were the measurements used in the statistical

design. In each of these three categories, consideration and comparisons were made of: (A) offensive play, (B) ball handling, (C) defensive play, (D) defense on the ball, (E) fastbreak, (F) shooting, (G) scoring, and (H) rebounding. Data, concerning $\bar{X} \dot{V}O_2$ and \bar{X} workload, was processed according to Astrand's Nomogram. A two way analysis of variance and Newman Keuls Sequential Range Test was applied to the data.

Findings and Conclusions

The two way analysis of variance indicated that there was a significant difference between the HR, $\dot{V}O_2$, and workload of the five subjects as compared to: (A) offensive play, (B) ball handling, (C) defensive play, (D) defense on the ball, (E) fastbreak, (F) shooting, (G) scoring, and (H) rebounding.

Results of the Newman Keuls Sequential Range Test indicated that the subjects were under a significantly higher workload at a time when they were involved in a fastbreak than when they were involved in any of the other seven game situations. It was noted that significantly higher workloads occurred during the game situations when the subjects were handling the ball as compared to those of the non-ball handling nature. The Newman Keuls Sequential Range Test also indicated that a significant difference occurred at the .05 level between the ball handling activities (fastbreaks, ball handling, and shooting) and the non-ball handling activities (rebounding, scoring, defense on the ball, defensive play, and offensive play). No significant difference occurred at the .05 level within

the two groups of activities.

Heart rate

During the pregame activities, the \bar{X} HR for the five subjects increased up until the time the starting lineups were introduced. At this time, there was a decrease of fifteen BPM in the \bar{X} HR. At the time the subjects were introduced, their \bar{X} HR increased seventeen BPM. After the subjects had been introduced and walked to the center of the court for the opening game tip-off, their \bar{X} HR decreased six BPM up until the tip-off, which resulted in an increase of fifteen BPM. It was also noted that no change occurred in the \bar{X} HR of the subjects during the time their teammates were being introduced as compared to the introduction of the opposing players.

The range of the \bar{X} HR for the five subjects was from 162-218 BPM. The highest \bar{X} HR range was 195-218 BPM (\bar{X} 203) and occurred with subject five, who played guard. The lowest \bar{X} HR range was 162-185 BPM (\bar{X} 170) and occurred with subject four, who played forward. In comparing the \bar{X} HR of all five subjects to the eight game situations mentioned above, the highest occurred during fastbreaks (196 BPM), while the lowest \bar{X} HR occurred during offensive and defensive play (178 BPM). Results of this study also indicate that the subjects \bar{X} HR for shooting (187 BPM) and rebounding (183 BPM) are both higher than their \bar{X} HR for scoring (182 BPM). This could indicate that when the subjects were shooting and rebounding,

their anxiety would build up and once the subjects had scored, their anxiety would tend to reduce.

A maximum HR of 240 BPM was recorded at three different occasions throughout the course of this study. Subject one, a guard, reached a HR of 240 BPM when dribbling against a press at a time when his team lead by eight points. This resulted in a seventy-two BPM increase in HR. Subject five, a guard, reached a HR of 240 BPM on two different occasions. First, at a time when he was playing defense, intercepted a pass, and dribbled in for a lay-up and scored. However, the shot was not allowed due to a goal tending violation committed by a teammate. This resulted in a forty-eight BPM increase in HR. The second situation that caused subject five to reach a HR of 240 BPM was at a time when he committed a turnover with his team maintaining a one point lead with forty seconds left in the first half. This resulted in a sixty BPM increase in HR. Throughout this study, the subjects appeared capable of recovering during various stages of the games. Their HR never declined below 120 BPM during time out periods and at the time a teammate or opponent was shooting a foul shot. There was very little decline in HR at the time the subjects were shooting foul shots. The subjects also appeared capable of recovering from game competition while sitting on the team bench after being removed from the game. A seven minute recovery period following competition produced a recovery of 102 BPM. No HR data was collected

on the subjects during half time. The reason being that the electrical signals could not be transmitted from the subjects, who were in the locker room, to the polygraph, which was located behind the Utah State University team bench.

Volume of oxygen

The range of the $\bar{X} \dot{V}O_2$ for the five subjects was from 1.8-3.7 l/m. The highest $\bar{X} \dot{V}O_2$ range was 3.2-2.7 l/m (\bar{X} 3.4) and occurred with subject four, who played forward. The lowest $\bar{X} \dot{V}O_2$ range was 1.8-2.1 l/m (\bar{X} 2.0) and occurred with subject five, who played guard. In comparing the $\bar{X} \dot{V}O_2$ ratings of all five subjects to the eight game situations mentioned above, the highest occurred during offensive play, defensive play, and when the subjects were playing defense on the ball (3.1 l/m). The lowest rating occurred during fastbreaking situations (2.6 l/m).

Workload

The range of the \bar{X} workload levels for the five subjects was from 1067-1496 kpm. The highest \bar{X} workload range was from 1452-1496 kpm (\bar{X} 1467) and occurred with subject three, who played forward. The lowest \bar{X} workload range was from 1067-1128 kpm (\bar{X} 1087) and occurred with subject five, who played guard. In comparing the \bar{X} workload levels of all five subjects to the eight game situations mentioned above, the highest \bar{X} workload occurred during fastbreaking situations (1364 kpm). The lowest

workload occurred during offensive play, defensive play, and when the subjects were playing defense on the ball (1320 kpm).

Due to interpolation of Åstrand's Nomogram when processing the data concerning $\dot{V}O_2$ and workload, the highest HR, $\dot{V}O_2$, and workload levels were not the same.

Some general observations were made of the subject's during the course of this study. They expressed the fact that at no time, during the games they were being tested, were they aware of the electrode and transmitter placement or of the heart rate readings being recorded by the polygraph.

Throughout this study, the guards had higher \bar{X} HR and \bar{X} workload levels than the forwards or the center, despite the fact that in distance traveled, both the forwards and the center traveled a further distance. This indicated that the guards worked harder during the basketball games than did the forwards or the center.

Player possession of the ball resulted in an increased HR and workload. The subject's \bar{X} HR and \bar{X} workload for ball handling (190 BPM-1353 kpm) and shooting (187 BPM-1337 kpm) are higher than their \bar{X} HR and \bar{X} workload for scoring (182 BPM-1326 kpm), defense on the ball (179 BPM-1320 kpm), defensive play (178 BPM-1320 kpm), or offensive play (178 BPM-1320 kpm).

Activities such as fastbreaking, ball handling, shooting, rebounding, and scoring resulted in higher \bar{X} HR and \bar{X} workload levels than did activities such as defense on the ball, defensive play, and offensive play.

Recommendations

The following recommendations for further studies were based upon the findings and conclusions of this study:

1. A similar study could be conducted comparing the heart rate and workloads of basketball players during practice sessions and actual game competition.
2. A study could be conducted comparing the heart rates and workloads of male and female basketball players during practice sessions and actual game competition.
3. Research into the psychological effects on athletes during competition should be done.
4. A study could be conducted concerning the effects of the crowd and other participants upon the heart rate of officials.

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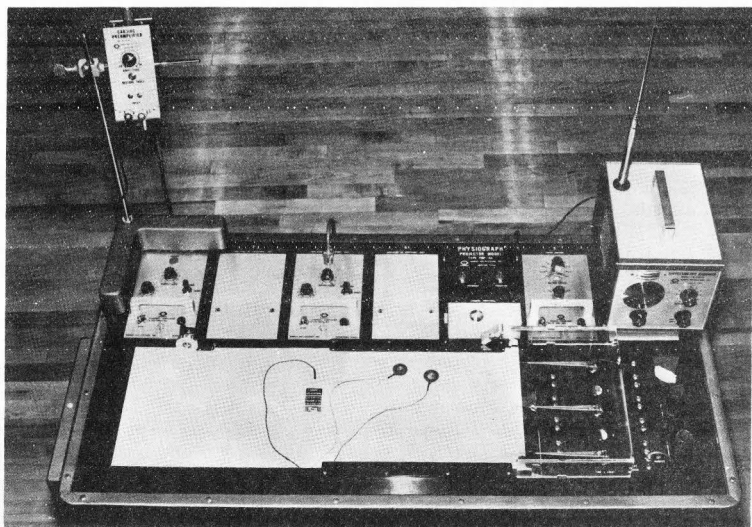
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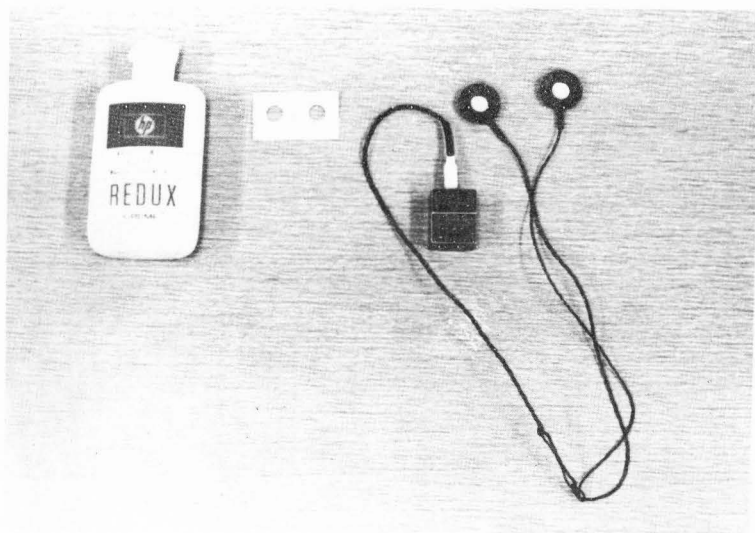
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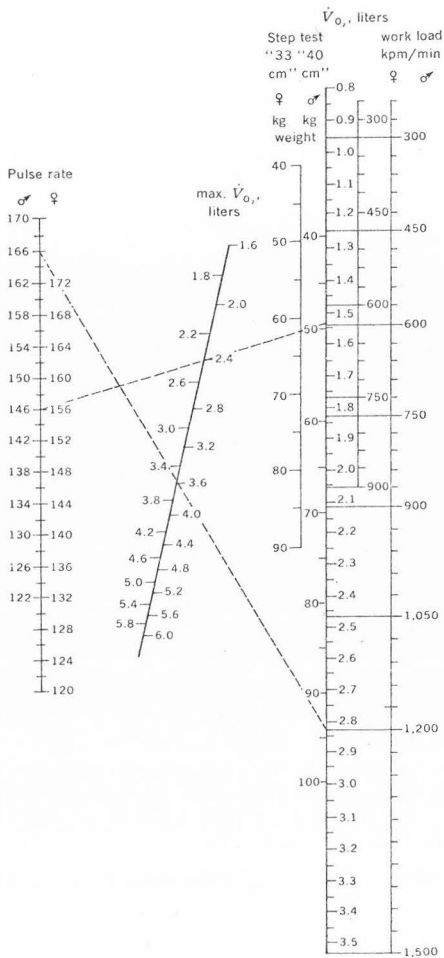
APPENDIXES

Appendix A

Appendix B

Appendix C

Appendix D



VITA

C. David Leo

Candidate for the Degree of

Master of Science

Thesis: A Comparison of the Heart Rates and Workload Levels of Selected Male Freshman Basketball Players at Utah State University During Actual Game Competition

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Helper Junior High School, 1960-63.
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College of Eastern Utah, 1966-68, A.S. Degree.
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