HEART RATE AND ESTIMATED ENERGY COST OF WOMEN'S BASKETBALL PRACTICE

by

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DEDICATION

I dedicate this work to all women participating in sports.

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Chapter I

INTRODUCTION

Women's basketball has often been critized for not being vigorous enough to allow athletes to reach their physical potentials. Lack of intensity in practice sessions and restrictive rules were the main reasons for the criticism. In the past, women's basketball rules restricted movement and added a player to make the game less vigorous than the men's version. Practice sessions, held only two or three times a week, were not designed to develop conditioning.

Today, collegiate women's basketball rules have changed and are now nearly identical to men's basketball. Five players run full court for two twenty minute halves. Coaches realize that practice sessions must be vigorous enough to enable the athletes to meet the physical demands of the revised game.

There are several ways for a coach to determine if practices are vigorous enough to increase or maintain the conditioning of the players. Heart rate is considered an excellent indicator of the intensity of an activity (1, 2, 8, 10). The heart rate increases in order to help meet the demand for increased oxygen transport caused by an activity such as basketball practice. Another way to measure the intensity of an activity is to determine how much energy it requires. Oxygen consumption and caloric cost are both measures of energy expenditure. A third way to determine the intensity of a basketball practice is to measure the amount of work being done.

Radio transmission of heart rate, or telemetry, can also be used to estimate energy cost. Heart rate is linearly related to oxygen consumption, caloric expenditure, and work load. In the laboratory, the oxygen consumption, caloric expenditure, and work load can be accurately determined for each player at various exercise heart rates. The energy used and the work being done during basketball practice can be estimated by recording practice heart rates and comparing them to the energy used and the work done during exercise heart rates in the laboratory. For example, when a player reaches a heart rate of 150 beats per minute on the bicycle ergometer, the values measured in the laboratory for oxygen consumption, caloric expenditure, and work load at that heart rate will be approximately the same as when a player reaches a heart rate of 150 beats per minute during basketball practice.

In this study, telemetry enabled the investigator to determine the intensity of basketball practice by recording heart rates of players during practice and then estimating their oxygen consumption, caloric expenditure, and work load. By determining the intensity of the practice sessions, the investigator was able to determine whether or not the practice contributed to the conditioning of the players for the game situation.

The results of this study provide needed data on the physiological response of the female athlete during participation. Research done on the physiological response of male athletes is plentiful but results cannot be directly applied to female athletes without verification.

Also, research on women's basketball needs to be updated because the rules have changed. Most of the research done on women's basketball was conducted while the rules allowed a total of six players on the court with four of the players limited to half the court. The data in this study was obtained under the new collegiate rules. The game is played with five players running full court for twenty minute halves.

Furthermore, research on women's basketball practice sessions has been neglected. The investigator hopes this study could be used in the future to provide some direction for determining a training index, based on average heart rate, for women's basketball practice. Such an index would be a valuable asset to a coach when planning the intensity of practice sessions.

Finally, due to the rapid increase of opportunities for women in all sports, research on females needs to be continuously updated. The female athletes of the present may respond differently physiologically because of their increased opportunity to participate.

STATEMENT OF THE PROBLEM

The purpose of this study was to determine how vigorous women's basketball practice was at Kansas State University. More specifically, the objectives of this study were:

1. To determine the heart rate response of players during women's basketball practice.
2. To determine heart rate, the oxygen consumption, and caloric expenditure during specific work levels for women basketball players.
3. To estimate the maximum oxygen consumption for women players during basketball practice.
4. To estimate oxygen consumption, caloric expenditure, and work load for each heart rate recorded for women participating in basketball practice.

SCOPE AND LIMITATIONS

The study was conducted in the gymnasium at Kansas State University from February 10 to February 28, 1975, which was the 18th, 19th, and 20th week of practice during a 23 week season. Five members of the Kansas State University varsity women's basketball team, ranging in age from 18 to 21, volunteered as subjects. All five had been in vigorous preseason conditioning programs from September 2 to the start of organized practice on October 15. The subjects were skilled players and played in every varsity game. Two of the subjects were guards and the other three were forwards.

Kansas State University played a 26 game schedule which included 78 practice sessions. The team practiced at

3:30 pm, Monday through Friday, but the amount of time spent daily depended on the season game schedule. Practices in the early season tended to be longer than in the late season.

The limitations which existed in the study were:

1. The investigator was only able to monitor the heart rates of one person each practice session. As a result, no comparisons were made between individuals.

2. The investigator was not able to monitor the heart rate of the subjects during games to compare to the practice sessions.

3. The recording of heart rate did include limited movement artifacts. Careful electrode placement made most of the recordings clear and easy to count.

4. Results cannot be generalized to other women unless they possessed characteristics very much like the subjects in the study.

5. The estimations of energy expenditure for basketball practice were based on a comparison of heart rate response during practice and while riding the bicycle ergometer. The muscles involved in riding the bicycle ergometer were not exactly the same muscles used when playing basketball. Due to this difference in muscular involvement, energy expenditure results for each player during practices should only be regarded as estimates.

DEFINITION OF TERMS

Individual Mean Heart Rate

The mean of the total number of heart beats per minute recorded during a practice session.

Highest Heart Rate

The greatest number of heart beats per minute recorded for a subject during one basketball practice.

Oxygen Consumption (VO_2)

The volume of oxygen extracted from inspried air at STPD[1] and is expressed in liters per minute (l/min) and milliliters per kilogram of body weight per minute (ml/kg/min). It is a measure of energy expenditure.

Respiratory Quotient (R. Q.)

The ratio of the volume of carbon dioxide expired per minute to the volume of oxygen consumed during the same time interval.

Practice Session

Conditioning, skill practice, and scrimmage of the women's varsity basketball team.

Physiological Stress

Physical activity which causes the body to make adjustments to try to maintain homeostasis. In this study, the increase in heart rate was one of the adjustments the body

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[1]Standard temperature and pressure, dry.

made in order to meet the physiological demands of playing basketball.

Vigorousness of an Activity

The amount of physiological stress placed on the body from participation in an activity. In this study, the vigorousness of basketball practice for each subject was determined by heart rate response, individual mean heart rate, and estimated oxygen consumption, caloric expenditure, and work load.

Steady State Heart Rate

A steady state heart rate was reached during a submaximal work load when the heart rate reached a constant level.

Warm Up

Unorganized individual shooting prior to the start of practice.

Chapter II

REVIEW OF LITERATURE

In this study, the investigator studied the heart rates of women basketball players during actual practice sessions and collected exercise data on the subjects in a controlled laboratory. The purpose of this chapter was to review and discuss information related to both the laboratory testing and recording heart rates using telemetry in field conditions. The chapter was divided into main topics: 1) Heart rate and the severity of an activity, 2) Factors which affect heart rate, 3) Telemetry studies, 4) Physiological studies in basketball, and 5) Summary.

HEART RATE AND THE SEVERITY OF AN ACTIVITY

Several authors have shown heart rate was an excellent indicator of the severity of an activity. (1, 2, 8, 9, 10, 14) The circulatory response to a stressful situation was generalized by Johnson (14) to include increased blood pressure and heart rate. Morse (25) also listed increased heart rate as a major cardiovascular response to sudden demand for increased oxygen transport.

Johnson (14) showed that because of its close relation to cardiac output and oxygen consumption, heart rate can be used to evaluate the stress imposed by physical activity upon the circulatory system. He found that as a single factor, heart rate quite accurately showed the cardiovascular adjustment of a subject to an aerobic activity. The fact that heart rate can be taken with limited amount of restriction of movement makes it particularly useful in field conditions. Astrand (1) agreed and stated that heart rate has been used during and after exercise to test the circulatory functional capacity.

In addition to heart rate, other measures are used to determine the severity of various activities. In Table 1, Wells (43) used R.Q., heart rate, oxygen consumption, and Calories per minute to classify activities into light, heavy, and severe categories. A heart rate between 160 and 180 beats per minute was considered severe physical activity.

TABLE 1

CLASSIFICATION OF PHYSICAL ACTIVITY

Work Classification	Heart Rate	Cal/Min	R.Q.	O_2 l/min
I. Light				
1) Mild	100	4	.85	.750
2) Moderate	120	7.5	.85	1.500
II. Heavy				
3) Optimal	140	10	.90	2.00
4) Strenuous	160	12.5	.95	2.50
III. Severe				
5) Maximal	180	15	1.00	3.00
6) Exhausting	180	15	1.00	3.00

Ricci (29) used number of calories burned per hour to classify work. He divided work into sedentary, light, moderate, heavy, and very heavy using calories burned per hour. Johnson (14) also calssified physical activity and used oxygen consumption as his criteria. All three classification systems are equivalent and all data used to establish the categories were collected on men.

Energy expenditure has been determined from heart rate on the basis of the linear relationship between heart rate and various measures denoting energy costs (7, 19, 21, 26, 36, 39, 40). Malhotra (21) collected expired air during steady state and recorded heart rates of seven male subjects doing field tests. A linear correlation was obtained between the heart rate and the oxygen consumption in all subjects. He also stated that the relationships between heart rate and oxygen consumption appears to be linear up to 180 beats per minute. Heart rates higher than 180 beats per minute seemed to underestimate the oxygen consumption. Malhotra showed that when the oxygen consumption was one liter or more per minute, the heart rate was directly related to oxygen consumption.

Several authors have recognized the linear relationship between heart rate and oxygen consumption (1, 22, 24, 40, 44) during sub-maximal work loads. Skubic (38) stated that this linear relationship made it possible to determine by extrapolation the oxygen consumption for specific heart rates found in various sports activities.

The generally accepted methods of indirect calorimetry for the determination of metabolic rate were suitable techniques for laboratory experiments but could not be used practically during athletic performance because equipment limited the movement of the players. However, the invention and refinement of miniaturized telemetry made it possible to continuously record heart rate during sports activities and provide more accurate indication of the severity of the activity. Mathews (22) showed that telemetry of heart rate allows one to estimate oxygen consumption of numerous sports activities which otherwise would have been impossible to determine. Skubic (40) concluded that in sports in which the work load was not constant and included rest periods, the average telemetry heart rate for the total game was a good indicator of the level of activity.

FACTORS WHICH AFFECT HEART RATE

Factors causing the increase of heart rate are varied. Playing basketball caused an increase in heart rate. As the muscles of the players were exercised they needed fuel, both oxygen and blood sugar. This increased demand for fuel by the muscles was met by increased blood circulation which resulted when heart rate was increased.

Another factor which affects heart rate was the emotional reaction of a subject. Rutherford (32) and Yarbrough

(45) stated that working heart rates were significantly increased by the introduction of emotional stimuli. They also reported that emotional factors produced a greater increase in heart rates when applied at lower levels of heart rate.

A third factor which affects heart rate was the environment. Brouha (3) showed that the linear relationship with oxygen consumption no longer existed in extreme temperature and humidity. Dalta (7) and Maxfield (23) also indicated the validity of the use of heart as a measure of physiological strain but only under normal conditions.

TELEMETRY STUDIES

The assessment of the severity of a sport was a problem under actual game or practice conditions. Procedures normally used in the laboratory could not be duplicated in the live situation. The development of telemetry equipment allowed investigators to record heart rate and then estimate the oxygen consumption of the activity.

Studies using telemetry have been done in several areas on men. McArdle (18) telemetered the heart rate response of men during running events. He found that longer events elicited higher peak heart rates. Hanson (11) used telemetry to observe the heart rate of little league baseball players. The heart rate of the players were high while at bat and increased slightly when playing the field. Kozar

(16) observed the response of a man's heart rate when performing gymnastic routines. Kozar later reported (17) the cardiac response of 23 adult men to badminton, bowling, handball, paddleball, tennis, and volleyball using telemetry equipment. The results indicated that the mean heart rate in handball, tennis, badminton, and paddleball did not differ significantly from each other but were greater than volleyball and bowling. Magel and others (20) used telemetry to monitor heart rates of male university swimmers prior to, during, and after competition. In events ranging from 50 to 1000 yards, the longer events elicited higher heart rates.

Norris (27) developed a system using pulse rate counts in interval training from telemetry of actual interval workouts. He monitored three groups of runners after a 440 yard interval at about 80 percent effort. He noted that the heart rate of each runner recovered a little less after each repetition of a workout.

Stockholm and Morris (42) also used telemetry to monitor the heart rate of a college freshman pitcher throughout a nine inning intercollegiate baseball game. They reported that a combination of physical and emotional stress caused the heart rate of the pitcher to exceed 180 beats per minute several times during the game.

Studies using heart rate response of females to various activities were not as numerous. Skubic (38) observed heart rates of five trained girls during actual competition in the 220 yard, 440 yard, 880 yard and mile run. She showed the peak heart rates for the four races ranged from 185 to 215 beats per minute with the mile run eliciting the highest heart rate. Skubic (39) also observed the cardiac response of females to participation in tennis, badminton, golf, archery, and bowling using telemetry. The heart rates were used to determine the relative strenuousness of the sports and classify them according to work load. Noble (26) attempted to determine energy expenditure of women gymnasts while performing routines. He used telemetered heart rates during competition to predict VO_2 using individual heart rate-VO_2 regression lines obtained in the laboratory.

PHYSIOLOGICAL STUDIES IN BASKETBALL

Skubic (40) also did a later study which involved basketball. She reported the relative energy expenditure of females participating in archery, badminton, bowling, golf, tennis, basketball, field hockey, softball, and volleyball. The results indicated that the roving player, that used to exist in basketball, and the halfback position in field hockey required the greatest energy expenditure. The roving basketball player had a mean heart rate of 185 beats per minute and an estimated oxygen uptake of 1.862 liters per minute.

Skubic (40) reported data on two college women. In basketball, Skubic telemetered the subjects in five different games. The subjects played randomly selected positions throughout the entire game. Heart rate was taken continuously during the first two minutes of the game and thereafter for the last thirty seconds of every second minute throughout the game. The subjects also performed on a treadmill in order to determine oxygen consumption and ventilation rates at various heart rates. From these data, Skubic used regression coefficients to determine the relationship of heart rate to ventilation, oxygen uptake, and VO_2 ml/kg/min. From the regression line of each subject, oxygen uptake and VO_2 ml/kg/min for the obtained heart rate in the basketball games were estimated.

McArdle (19) studied aerobic capacity, heart rate, and estimated energy costs of women's basketball. Six members of the Queen's College women's varsity basketball team served as subjects. McArdle determined the maximum oxygen uptake of each subject before the season began and after the last game. He also obtained telemetry data on each girl during one quarter of each home game. McArdle recorded heart rate every thirty seconds during play. The relationship between heart rate and oxygen consumption was determined in the laboratory on the treadmill. The laboratory data were used to estimate the oxygen consumption of the heart rates recorded during the games. For five subjects in a five player game, he reported a range of estimated oxygen uptake from 1.56 to 2.44 liters per minute. The heart rate ranged from 132 to 204 beats per minute.

Sinning (35, 36) did two studies on the maximum oxygen uptake at the beginning and end of the season on women basketball players. His first study (35) showed an average maximum oxygen uptake of 34.4 ml/kg/min with no significant difference between the start and end of the season. At this time, the subjects played under the old rules with six players and participated in seven games and twenty-five practices. Sinning concluded that the participants had not reached their potential physical condition. He stated that lack of intensity in practice sessions contributed to their inferior conditioning.

Gerber (10) had similar views about female practice sessions. She stated,

> Although it is considered an endurance activity for males, varsity basketball for girls generally has not reached the pressured stage that it has in male varsity competition, so that female practice sessions are not as intensive or extensive as those of male teams.

She observed that of those female basketball players studied, their maximum oxygen consumption was within the expected value for untrained females. Astrand (1) gave 37-40 ml/kg/min as an average for an untrained female.

McArdle (19) also stated that although girls reached near maximum heart rates during games, team practice sessions were relatively moderate in work output. He stated men's basketball practices were designed to improve both skill and fitness.

However, Sinning (36) did a later study under the present basketball rules, in which the data indicated the female basketball players were closer to the maximum oxygen consumption of trained women. The maximum oxygen consumption values in this study, an average of 44.4 ml/kg/min, were about 30 percent higher at the beginning of the season and 11 percent higher at the end of the season than those found in the previous study when six player rules were in effect. Sinning suggested that the higher demands of playing full court eliminated those not in good cardiovascular condition or encouraged those who were. He also stated that increased opportunity for women in all areas of sports could make more well conditioned athletes available.

Sinning (36) also reported that during the season there was no change in maximum oxygen uptake in liters per minute. He concluded that no training effects during the season could be attributed to the five player rules.

Campbell (4) examined the effect of a season of basketball on the resting heart rate of male college freshmen. He reported no significant difference between pre and post season resting heart rate. He stated the subjects dropped in performance in treadmill walking but exhibited a more rapid recovery rate during post season testing.

Ramsey (28) and others investigated the relationship between rest intervals and heart rate during a basketball game. Heart rate of two male university basketball players was monitored by means of telemetry during an actual game. Brief rest periods, such as time outs and foul shots, provided significant decrease in heart rate. However, when a player was shooting a foul shot, his heart rate did not show a significant decrease.

Corbin (6) used telemetry to observe the heart rate response of a male college basketball player during actual game conditions. The average heart rate while playing was 169 beats per minute. His average heart rate for the entire game, playing about half of the game, was 126 beats per minute. In the same study, Corbin also observed the heart response of the coach and a spectator to the same game.

Husman (13) also studied the heart rate of a basketball coach during competition and practice. Stress on the coach produced marked changes in heart rate. During critical periods in the basketball game, the heart rate of the coach rose as high as 152 beats per minute. Practice sessions raised the heart rate of the coach to a high of 114 beats per minute.

SUMMARY

Authors have shown that heart rate was an excellent indicator of the severity of an activity. Heart rate was considered primarily useful in field conditions because it could be taken with limited restriction of movement. An estimate of energy expenditure has been determined from heart rate and various measures denoting energy costs. Malhotra showed that a linear correlation existed between heart rate and oxygen consumption up to 180 beats per minute. Skubic stated that this linear relationship made it possible to determine by extrapolation the oxygen consumption for specific heart rates found in various sports activities. The invention of telemetry made it possible to obtain heart rates during actual participation so that estimations of energy costs could be made. Skubic also stated that in sports in which the work load was not constant and included rest periods, the average telemetry heart rate for the total game was a good indicator of the level of activity. Authors listed increased demand for fuel by the body, emotional reaction, and environment as factors which affect heart rate.

Telemetry studies were numerous but the subjects were mainly men. Studies on heart rate included track events, baseball, handball, tennis, volleyball, swimming, badminton, bowling, golf, archery, and field hockey.

Several studies were conducted on physiological factors of men's basketball. Resting heart rates were examined for pre and post season. Telemetry was used to examine the relationship between rest intervals and heart rate during a game. Coaches and spectators, monitored by telemetry, showed marked changes in heart rate.

Studies on women's basketball were conducted both with the older six player rules and the more recent five player rules. Earlier studies, with six players, indicated lack of intensity in practice sessions contributed to the inferior aerobic conditioning of the players. Later studies, with five player rules, showed significant improvement in aerobic conditioning from previous studies. Telemetry was used during the six player game and reported a mean heart rate of 185 beats per minute for the roving player and an estimated VO_2 of 1.85 l/min. Another telemetry study, conducted during a five player game, reported a heart rate range from 132 to 202 beats per minute for five subjects.

Chapter III

METHODS AND PROCEDURES

In this study, the investigator studied the heart rates of women basketball players during actual practice sessions and collected exercise data on the subjects in a controlled laboratory. The purpose of the chapter was to describe the methods that were used and then to give the procedures the investigator followed when the study was done. The chapter is divided into the following sections: 1) Selection of Subjects, 2) Methods, 3) Procedures, 4) Treatment of Data.

SELECTION OF SUBJECTS

Before the study began, a proposal was approved by the Committee on Rights and Welfare of Human Subjects of the Department of Health, Physical Education and Recreation. The committee reviewed the written proposal to insure that the investigator had made provisions for the rights and safety of the subjects.

Five varisty women basketball players at Kansas State University served as subjects in this study. Upon approval from a coach, a description of the study was presented to the women's basketball team and a request was made for volunteers. The five volunteers who played the most in varsity games were chosen as subjects. Each subject was presented a letter of informed consent which briefly outlined the purpose, procedures, and risk involved in the study.[1] The players signed and dated the letter if they wished to participate in the study.

After the informed consent form was received, each subject was scheduled to wear telemetry equipment for two basketball practice sessions and one testing session in the laboratory at the conclusion of the basketball season. All subjects were in good health when the study began. Physical examinations were required to participate in basketball.

METHODS

Telemetry During Practice

The heart rate of women basketball players were monitored by telemetry during practice. Each subject wore two electrodes and a small transmitter. The ECG signal was transmitted to an FM receiver and recorder which were placed along the side of the court. Heart rate was recorded in one minute intervals and was counted for a full minute every other minute. Heart rate was monitored during the individual shooting warm up and throughout the entire practice unless a rest period was declared by the coach. The recording was not stopped

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[1]See Appendix A.

if play was interrupted by a comment from the coach or when specific instructions were given to a player or the team. A brief description of the practice was written on the physiograph paper along with details of what the subject was doing while heart rate was recorded.

Laboratory

Each subject rode the bicycle ergometer at 50 revolutions per minute freewheeling (zero) and at work loads of 300, 600, and 900 KPM without stopping. The heart rate of each subject was continuously monitored by telemetry. The subject continued at a work load until the heart rate reached a steady state. At this time, samples of expired air were taken and the volume of air determined for the one minute sample. Following the collection of the one minute sample, the work load was changed to the next level then the gas samples were analyzed. For each one minute gas sample during a work load, the investigator recorded the steady state heart rate, percent oxygen in the gas sample, percent carbon dioxide, and ventilation volume.

Method of Estimating Oxygen Cost

An average heart rate per minute for each player and the group was found from the telemetry recording during practice. A graph showed the range and fluctuation of each subject's heart rate during the practices. In the laboratory, the oxygen consumption in VO_2 l/min, VO_2 ml/kg/min, and caloric cost at each work load on the bicycle ergometer was calculated. The steady state heart rate at each work load was the mean of the last two heart rates counted that were four beats apart. An estimation of maximal oxygen consumption was made by plotting heart rate to work load (1).

The correlation coefficients for heart rate to work load, VO_2 l/min, VO_2 ml/kg/min, and calories per minute were calculated. High correlation coefficients in the laboratory for all subjects allowed the investigator to use a regression equation to predict estimations of work load, VO_2 l/min, VO_2 ml/kg/min, and calories used per minute for basketball practice heart rates of each subject.

PROCEDURES

Applying the Electrodes and Transmitter

The careful application and placement of electrodes was emphasized by several authors (16, 18, 41). The investigator took care to apply the electrodes securely to help eliminate unnecessary movement artifact on the heart rate recording. The investigator used the method described by McArdle for the placement of the electrodes (18). One electrode was placed over the manubrium sterni and the other electrode was put over the fifth interspace on the left midaxillary line.

The transmitter was taped with athletic adhesive tape to the anterior midpoint of bra of the subject. The areas of skin where the electrodes were placed were lightly scraped with a small spatula and then cleaned with rubbing alcohol. New Skin by Johnson and Johnson was then applied to the skin to help secure the electrodes. Round double adhesive disks were attached to the electrodes then placed on the skin. The investigator was careful not to allow the bra to rub against the electrodes. Adhesive tape was placed over the electrodes to secure them further.

Instrumentation of Telemetry

The electrodes were connected to the lightweight frequency-modulated radio transmitter which was manufactured by the E&M Company. The ECG signal was transmitted to an FM receiver, and a Narco physiograph recorder which were located on the side of the basketball court. Prior to the application of the transmitter to the subject, a microphone, designed for use with the transmitter, was used to tune in the receiver to the same frequency as the transmitter.

Determination of Oxygen Consumption During Laboratory Exercise

Open-circuit calorimetry as described by Consolazio, Johnson, and Pecora (5) was used to measure metabolic rate during exercise on a Monarch bicycle ergometer. The subject did a submaximal work load on the bicycle until the heart rate no longer increased. At this point, air was expired through a two way valve into a collecting apparatus. The expired air was analyzed to determine the percentage of oxygen and carbon dioxide remaining in the air. The pulmonary ventilation was measured by passing it through a Parkinson-Cowan Ventilometer. The oxygen consumption expressed in liters per minute and milliliters per kilogram of body weight was calculated from the obtained exercise data which was adjusted for environmental conditions by converting to STPD.

Pre-testing Procedure. The carbon dioxide and oxygen analyzers were turned on by a timer one hour before the subject was scheduled. The investigator calibrated both the carbon dioxide and oxygen analyzers with a reference gas before each testing. The room thermostat was adjusted to approximately 23 degrees centigrade.

When the subject entered the laboratory, the investigator recorded on a data sheet the actual room temperature, wet bulb temperature, and barometric pressure. The data sheet also included the height, weight, and age of the subject. The investigator used the same procedure to apply the electrodes and transmitter to the subject as described for the telemetry of basketball practice. In addition to the electrodes, a nose clamp was placed on the subject to allow all air to be expired through the mouth.

The seat of the bicycle ergometer and the mouthpiece were adjusted for the comfort of the subject. All gas analyzing equipment was briefly checked to make sure connections were tight. The receiver and physiograph recorder was placed along side the bicycle ergometer. The investigator then explained the testing procedure to the subject.

Test Administration. The subject was instructed to pedal to a metronome set for 50 RPM until instructed to stop. The subject rode the bicycle continuously both freewheeling and at work loads of 300, 600, and 900 KPM. The investigator timed 30 heart beats during the last half of each minute the subject pedaled to determine heart rate per minute. The steady state heart rate at each work load was determined when the heart rate was no more than four beats apart on consecutive readings. When the steady state heart rate was reached, pulmonary ventilation was measured and expired air gas samples were collected for one minute. At the end of the minute, the work load was increased to the next level and the gas samples were analyzed on a Beckman oxygen analyzer. After the last work load was completed, the subject removed the mouthpiece and cooled down by freewheeling on the bicycle. When the heart rate of the subject was below 90 beats per minute, the electrodes were removed and the skin cleaned with alcohol. The investigator answered any questions the subject might have had about the testing.

TREATMENT OF DATA

In the laboratory, oxygen consumption in VO_2 l/min, VO_2 ml/kg/min, and Calories used per minute were calculated for freewheeling and work loads of 300, 600, and 900 KPM. A steady state heart rate for each work load was computed by averaging the last two heart rates counted that were less than four beats apart. Correlation coefficients for heart rate to work load, VO_2 l/min, VO_2 ml/kg/min, and Calories used per minute were determined. The high correlation coefficients enabled the investigator to enter the practice heart rates obtained by telemetry into a regression equation and predict estimates of a player's work load, VO_2 l/min, VO_2 ml/kg/min, and Calories used per minute during a basketball practice. A method developed by Sjostrand (37) and modified by DeVries (8) which predicted maximum oxygen consumption from the PWC 170 test was used to estimate the player's maximum oxygen consumption.

The heart rates recorded during basketball practice by telemetry were averaged for each practice session the player was monitored. Graphs showed the range and fluctuation of the heart rate and briefly described the activity that was occurring while the heart rate was being monitored. All five subjects were also considered as a group and an average heart rate and estimations of work load, VO_2 l/min, VO_2

ml/kg/min, and Calories used per minute were determined. The percentage the player's heart rate exceeded 140 beats per minute was also calculated.

Calories used per minute were calculated for an R.Q. of 1.0 with one liter of oxygen equal to 5.047 Calories and an R.Q. of .82 with one liter of oxygen equal to 4.825 Calories. This was done to enable the investigator to compare the estimations of calories used in basketball practice to a study by McArdle (19) in which he estimated calories used in a college women's basketball game.

Chapter IV

RESULTS AND DISCUSSION

This chapter was divided into two major divisions, results and discussion. The results were further subdivided into practice session data and laboratory data. The discussion was subdivided into the specific objectives of the study.

RESULTS

Practice Session Data

Heart rate was continuously recorded during basketball practice. The only time the recording was stopped was if the coach declared a rest period. The investigator then counted the recorded heart rates of the players every other minute for a full minute. As shown in Table 2, the individual mean heart rate ranged from 134 to 159 beats per minute and the grand mean for all subjects was 150 beats per minute. The initial warm up heart rate was shown along with the range of the practice heart rates. The lower bound of all practice heart rates was 80 beats per minute and the upper bound was 204 beats per minute. The percentage of heart rates which were above 140 beats per minute and the range of the estimated oxygen consumptions predicted by the regression equations,

TABLE 2

PRACTICE HEART RATES AND ESTIMATED O_2 CONSUMPTION

Subject	Initial Warm-up HR	Mean HR	% of HR Above 140	Range HR	Est. VO_2 (1/min) Range
1	83	134	43	106 - 164	1.36 - 1.90
1	71	146	72	80 - 184	.82 - 2.03
2	83	152	61	88 - 204	.45 - 3.24
2	92	154	74	103 - 185	.79 - 2.78
3	91	151	92	138 - 189	1.50 - 2.72
3	91	155	77	120 - 173	1.12 - 2.35
4	97	159	84	128 - 178	1.21 - 2.27
4	110	159	86	128 - 195	1.21 - 2.63
5	95	143	53	98 - 172	.82 - 2.73
5	108	146	70	110 - 182	1.03 - 2.99
GRAND MEANS*	92	150	71		

* N = 10

were also given for each subject. According to a work classification system by Wells (43), heart rates above 140 are considered strenuous and likely to result in a training effect if continued for more than five minutes. For the ten practice sessions, heart rate was above 140 beats per minute 71 percent of the time. Subject number two had the widest range in heart rate and estimated oxygen consumption with values of 88 to 204 beats per minute and .45 to 3.24 liters per minute, respectively.

Figures 1 through 5 showed the variation of the heart rates of the players during specific activities of practice. Shooting freethrows and talks by the coach seemed to cause heart rate to drop the most. Wind sprints elicited the highest heart rate at the conclusion of practice. Full court scrimmages frequently showed heart rates of 180 beats per minute or higher. Half court play allowed for more rest periods due mainly to comments and explanations from the coach and generally resulted in lower heart rates.

Table 3 showed the estimated individual mean energy requirements for each practice. The estimates were taken from the computer data presented in Appendix A for the equivalent work load, VO_2 ml/kg/min, VO_2 l/min, and Calories used per minute that were predicted by a regression equation using the monitored practice heart rates. The mean estimation of oxygen consumption for all ten practice sessions was 1.90 l/min

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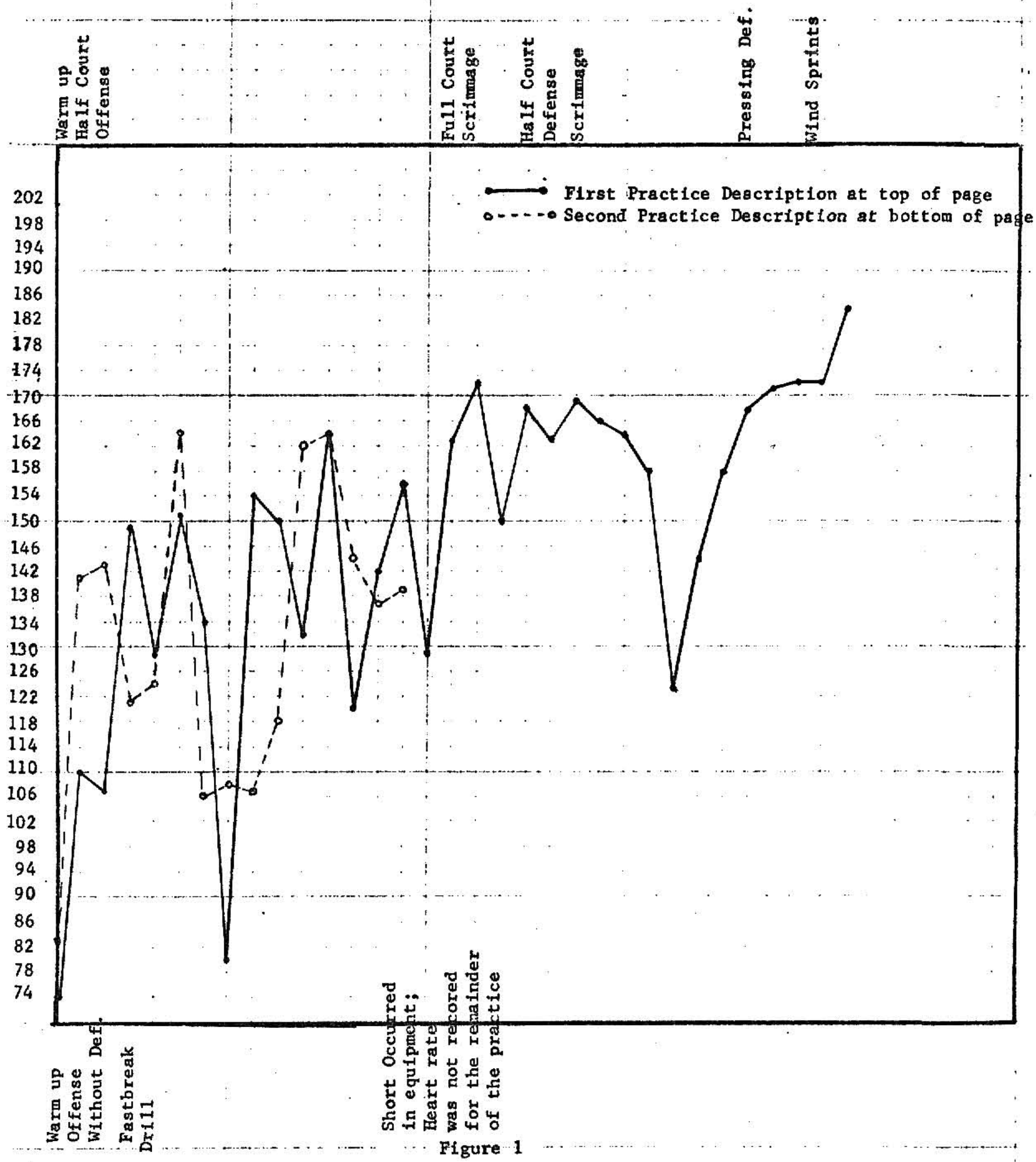

Figure 1

Practice Heart Rates for Subject One

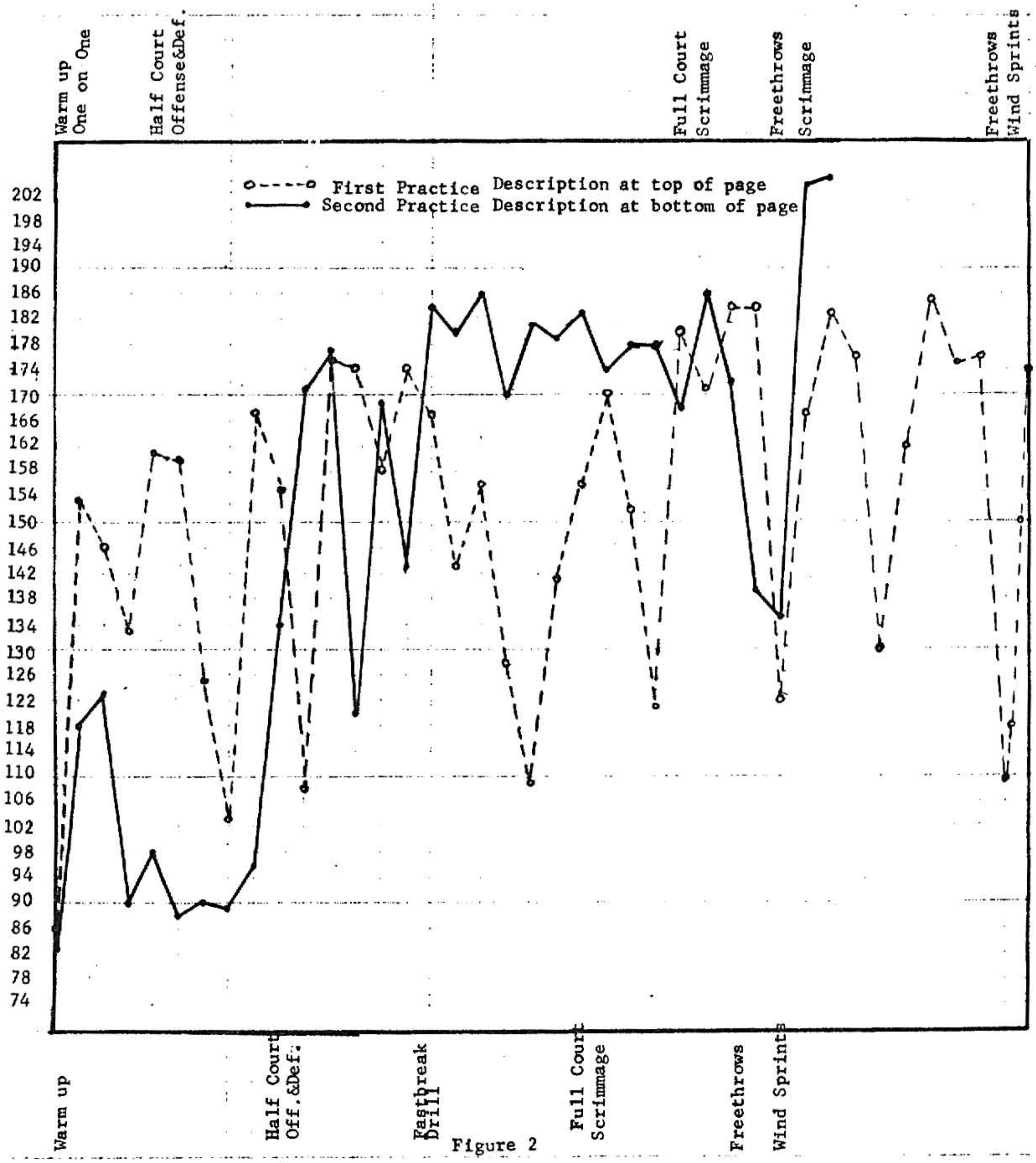

Figure 2

Practice Heart Rates for Subject Two

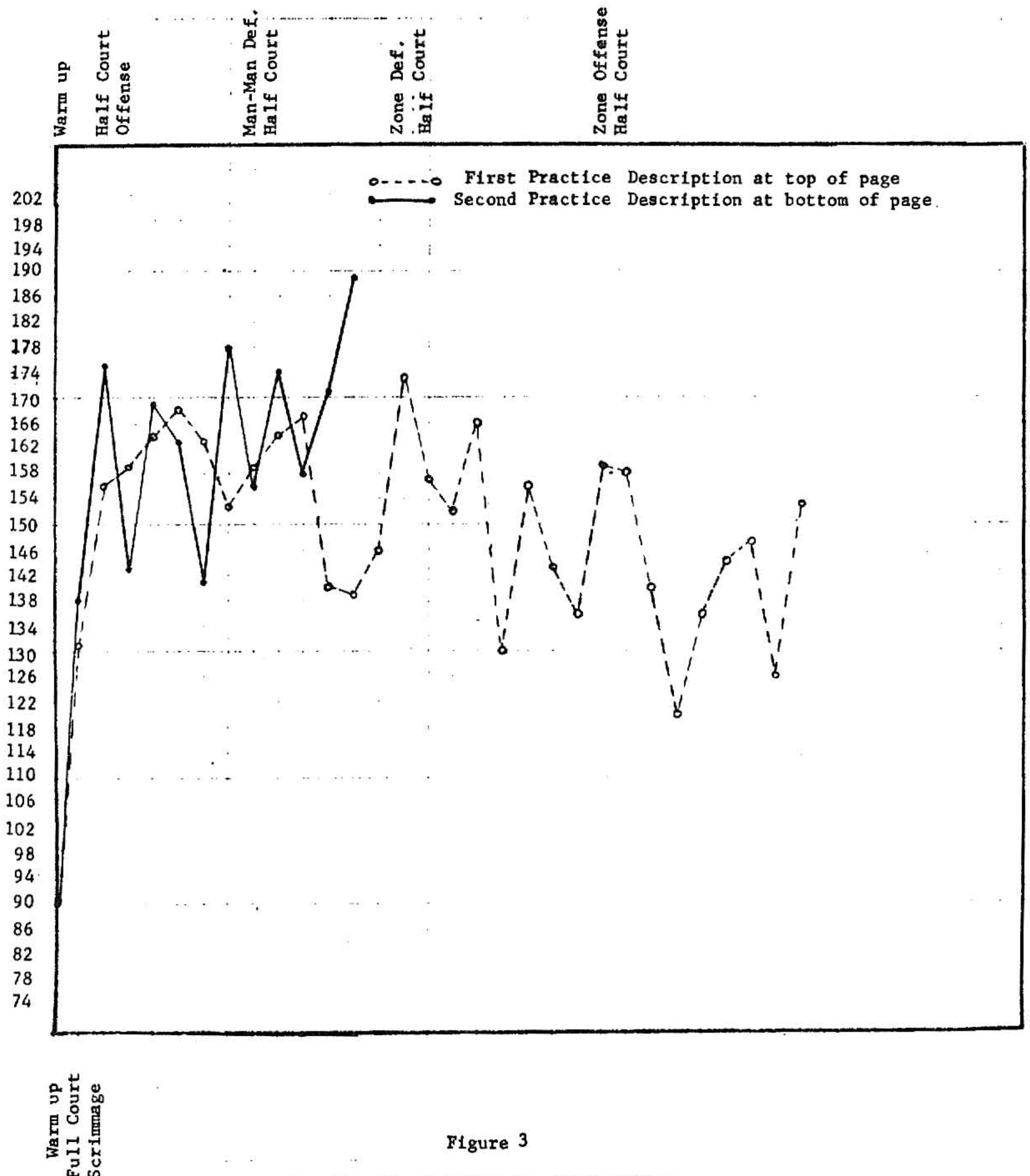

Figure 3

Practice Heart Rates for Subject Three

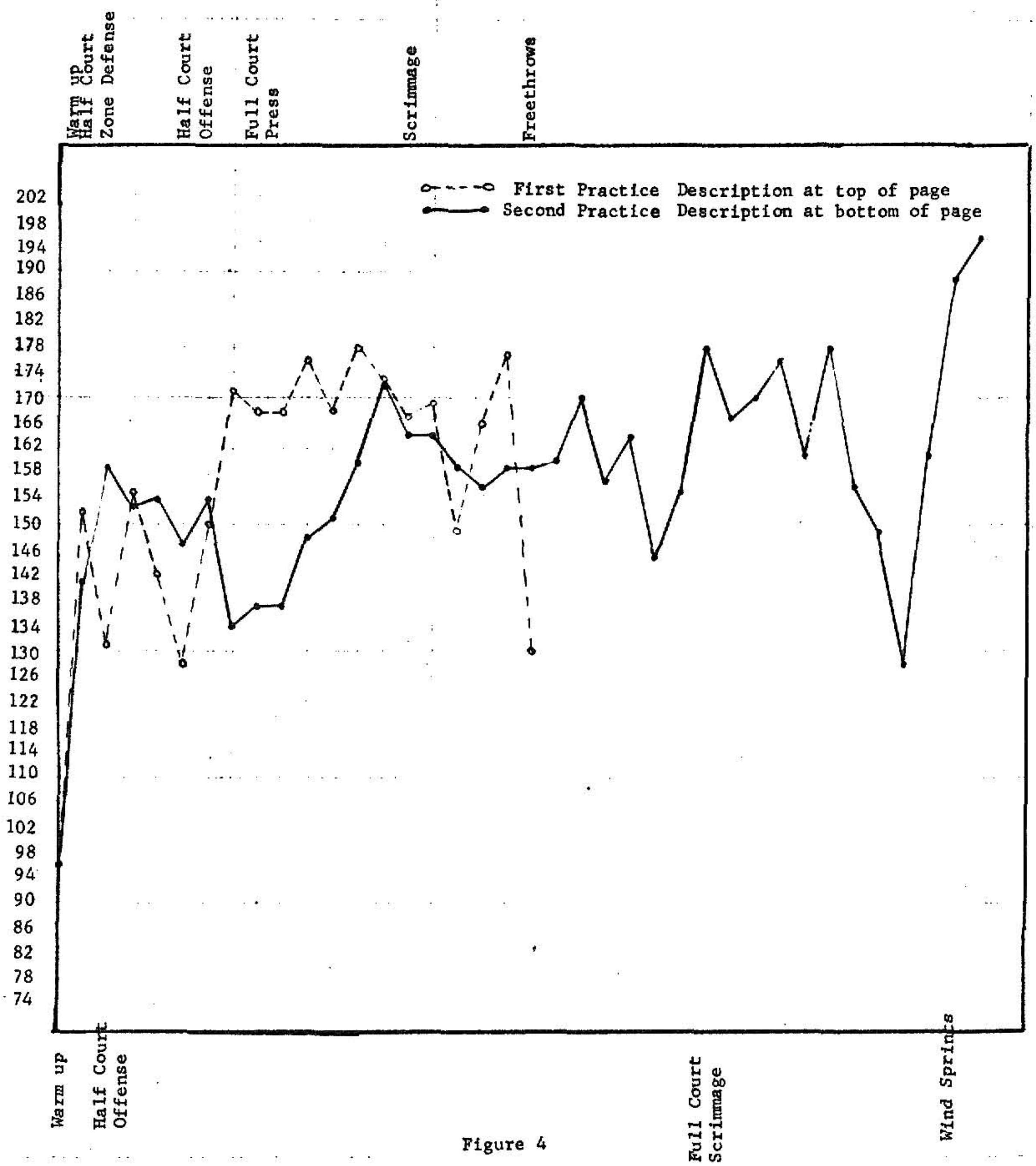

Figure 4

Practice Heart Rates for Subject Four

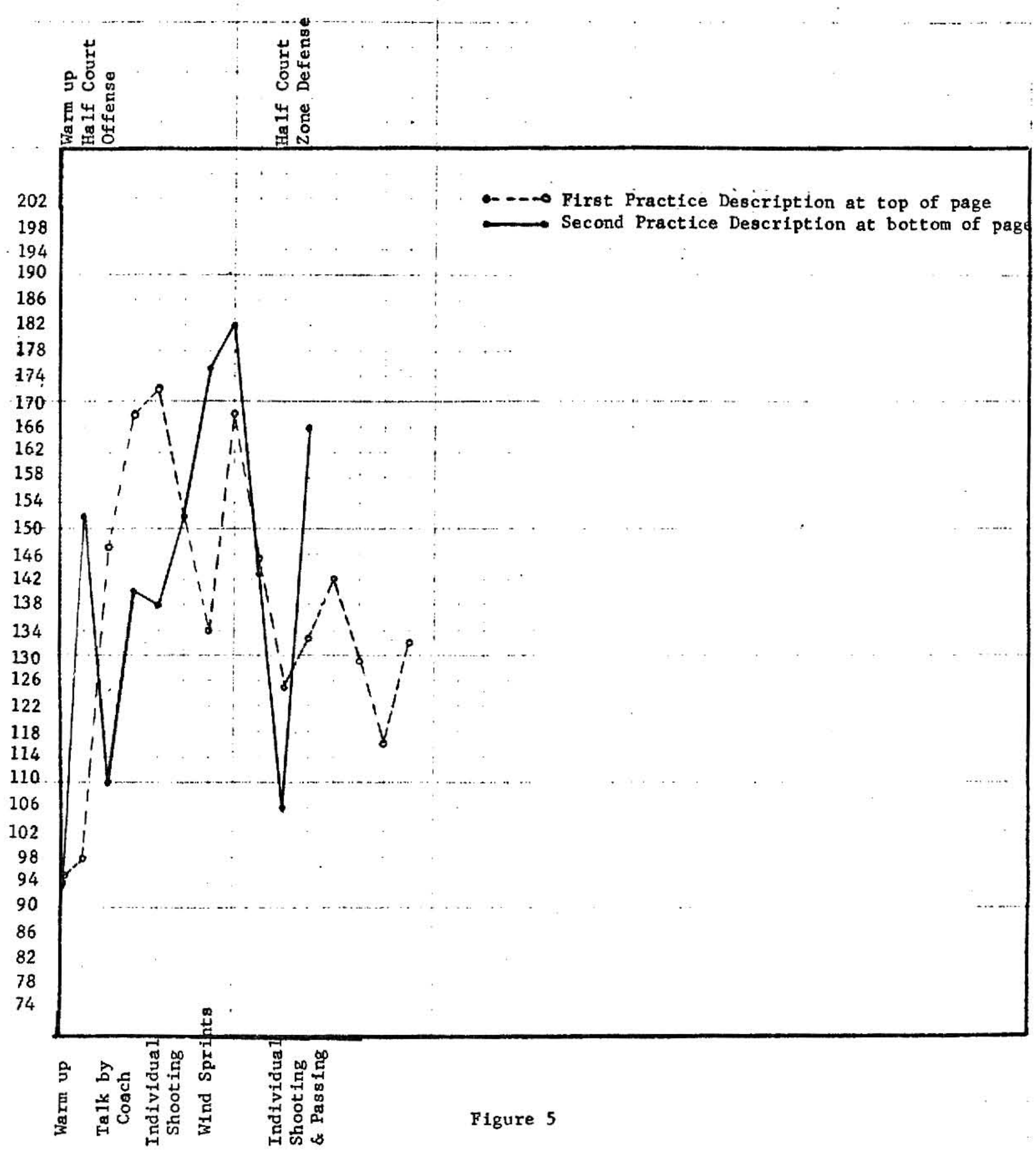

Figure 5

Practice Heart Rates for Subject Five

TABLE 3

ESTIMATED INDIVIDUAL MEAN ENERGY REQUIREMENTS FOR PRACTICES

Subject	Heart Rate	Equivalent Work Load (KPM)	VO_2 l/min	VO_2 ml/kg/min
1	134	764	1.67	24
1	146	878	1.77	25
2	152	914	1.98	30
2	154	944	2.03	31
3	151	690	1.87	33
3	155	735	1.95	35
4	159	788	1.86	27
4	159	788	1.86	27
5	143	816	1.98	32
5	146	858	2.06	33
GRAND MEANS*	150	818	1.90	30

* N = 10

and 30 ml/kg/min. The grand mean for the equivalent work load was 818 KPM.

Table 4 showed the estimated caloric expenditure for each practice. Calories used per minute were shown with one liter of oxygen equal to 5.047 Calories per minute (R.Q. = 1.0) and 4.825 Calories (R.Q. = .82). The mean for all practices was 9.6 Calories per minute when oxygen equalled 5.047 Calories and 9.2 Calories per minute when oxygen equalled 4.825 Calories per minute. According to the work classification system of Wells, Balke, and Van Fossan (43), the practices ranged from moderate-heavy, for one subject, to heavy physical activity.

Table 5 showed the estimated maximum VO_2 ml/kg/min and the individual estimated practice mean VO_2 ml/kg/min for each subject. The individual mean VO_2 ml/kg/min for practice ranged from 49 to 66 percent of the players estimated maximum VO_2 ml/kg/min.

Laboratory Data

The five subjects rode the bicycle ergometer free-wheeling, and at work loads of 300, 600, 900 KPM. The subject continued to ride at each level until their heart rate reached a steady state. The investigator considered the subject to be in a steady state when the heart rate no longer increased. Table 6 showed the results of the laboratory exercise. The steady state heart rates were the means of

TABLE 4

TWO ESTIMATIONS OF INDIVIDUAL MEANS OF CALORIC EXPENDITURE FOR PRACTICE

Subject	Heart Rate	Cal/min R.Q.=1.0	Cal/min R.Q.=.82	Work Classification
1	134	8.4	8.0	Moderate-Heavy
1	146	8.9	8.5	Moderate-Heavy
2	152	10.0	9.5	Heavy
2	154	10.2	9.7	Heavy
3	151	9.4	9.0	Heavy
3	155	9.9	9.4	Heavy
4	159	9.4	9.0	Heavy
4	159	9.4	9.0	Heavy
5	143	10.0	9.5	Heavy
5	146	10.4	10.0	Heavy
GRAND MEANS*	150	9.6	9.2	Heavy

* N = 10

TABLE 5

ESTIMATED OXYGEN CONSUMPTION AT MAXIMUM AND DURING BASKETBALL PRACTICE

Subject	Estimated Maximum VO_2 ml/kg/min	Estimated Individual Practice Mean VO_2 ml/kg/min*	Percentage Practice Mean of Max. VO_2
1	49	24	49
1		25	51
2	54	30	55
2		31	57
3	53	33	62
3		35	66
4	43	27	63
4		27	63
5	56	32	57
5		33	59

* Estimated from mean practice heart rate

TABLE 6

ENERGY EXPENDITURE AND HEART RATE AT VARIOUS WORK LOADS AS OBTAINED ON THE BICYCLE ERGOMETER

Subject	Work Load	Steady State Heart Rate	VO_2 l/min	VO_2 ml/kg/min	Calories per min
1	Freewheeling	72	.70	10.3	3.6
Ht. 67 in.	300	92	.97	14.0	4.9
Wt. 151 lbs.	600	118	1.56	22.8	7.9
	900	149	1.78	25.9	9.0
2	Freewheeling	92	.51	7.9	2.6
Ht. 68 in.	300	107	.88	13.6	4.5
Wt. 145 lbs.	600	129	1.50	23.0	7.6
	900	153	1.96	30.0	9.9
3	Freewheeling	92	.54	9.7	2.7
Ht. 67 in.	300	117	1.07	19.0	5.4
Wt. 124 lbs.	600	151	1.64	29.1	8.3
	900	166	2.32	41.1	11.7
4	Freewheeling	81	.35	5.1	1.8
Ht. 69 in.	300	110	.81	11.9	4.1
Wt. 150 lbs.	600	144	1.32	19.4	6.7
	900	168	2.19	32.2	11.0

TABLE 6 (Con't.)

Subject	Work Load	Steady State Heart Rate	VO_2 l/min	VO_2 ml/kg/min	Calories per min
5	Freewheeling	82	.40	6.4	2.0
Ht. 65 in.	300	102	.88	14.2	4.4
Wt. 137 lbs.	600	123	1.63	26.3	8.2
	900	152	2.12	34.2	10.7
GRAND MEAN	Freewheeling	84	.50	7.9	2.5
	300	106	.92	11.7	4.6
(N = 5)	600	133	1.54	24.1	7.7
	900	158	2.06	32.7	10.4

the last two heart rates recorded for each work level. Subject number four had a steady state heart rate of 168 beats per minute for 900 KPM. This was the highest heart rate recorded for all the subjects. The mean steady state heart rates for all the subjects were 84, 106, 133, 158 beats per minute for the four work levels.

The investigator collected a one minute sample of expired air at each steady state heart rate. The oxygen consumption was calculated from the air sample for each work load in liters per minute and milliliters per minute per kilogram of body weight. The highest oxygen consumption was 2.32 l/min and 41 ml/kg/min by subject number three.

Calories used per minute were calculated assuming an R.Q. of 1.0 with one liter of oxygen equal to 5.047 Calories per minute. Subject three used 11.7 Calories per minute at 900 KPM which was the highest among the subjects. The mean caloric expenditures for the group at each work level were 2.5, 4.6, 7.7, and 10.4 Calories per minute.

There was a linear relationship between each subject's heart rate and the work load on the bicycle. This relationship was used to predict an estimation of the maximum oxygen consumption for each subject by estimating the subject's maximum heart rate at 220 minus the subject's age (8). The estimated maximum oxygen consumptions, shown in Table 7, ranged from 49 to 56 ml/kg/min. The grand mean was 51

TABLE 7

ESTIMATED MAXIMUM OXYGEN CONSUMPTION AND PHYSICAL CHARACTERISTICS OF THE SUBJECTS

Subject	Age	Height (in)	Weight (lbs)	Estimated VO_2 l/min	Estimated VO_2 ml/kg/min
1	21	67	151	3.4	49
2	19	68	145	3.5	54
3	18	67	124	3.0	53
4	21	69	150	2.9	43
5	20	65	137	3.5	56
GRAND MEANS*	20	67	141	3.3	51

* N = 5

ml/kg/min and 3.3 l/min. The mean estimated maximum heart rate for the subjects was 200 beats per minute. Table 7 also included the age, height, and weight of each subject.

DISCUSSION

The purpose of this study was to determine how vigorous women's basketball practice was at Kansas State University. Comments on the specific objectives of this study are presented in the following section.

Heart Rate Response During Practice

The first objective of this study was to determine the heart rate of players during women's basketball practice. The individuality of each subject, the amount of time practiced, and the variety of activity during practice made each player's heart respond uniquely to the stress of basketball practice. Individual mean heart rate for the practices ranged from 134 to 159 beats per minute. In a study by McArdle (19), in which telemetry was used to record heart rate during a five player college women's game, he reported individual mean heart rates ranging from 159 to 195 beats per minute. However, the heart rate was measured from six R spikes from the electrocardiogram and then extrapolated to beats per minute. He recorded the heart rate every 30 seconds the subject was in the game. In this study, the heart rate was measured by counting a full minute of R spikes every other minute of practice. Even though different methods were used to measure heart rate, the investigator felt that the results of McArdle's study and this study could be generally compared.

The individual mean heart rate recorded during a game would be expected to be higher than a mean practice heart rate. Practice sessions allowed more rest periods due to explanations by coaches. When time outs were included in McArdle's study, the heart rates of the five subjects in a game ranged from 132 to 201 beats per minute. In this study, heart rate ranged from 80 to 204 beats per minute. The lower bound of practice heart rates was considerably lower than the lowest game heart rate in McArdle's study. However, in the ten practice sessions in which the heart rate of the five subjects was monitored, the heart rate exceeded 140 beats per minute 71 percent of the time. It would seem that the practice heart rates recorded in this study indicate that practice sessions include activity that was as vigorous as a game situation. Furthermore, it has been generally accepted that activities that increase the heart rate above 140 beats per minute provide enough physical stress to improve the functioning of the cardiovascular system (1) (9). The practice sessions in this study would also be contributing to the improvement of the cardiovascular system.

Determination of Heart Rate, Oxygen Consumption, and Calories Used Per Minute and the Estimation of Maximum Oxygen Consumption

The second and third objectives of this study were to determine the heart rate, the oxygen consumption, and Calories used per minute during specific work levels for women and to estimate the maximum oxygen consumption for women basketball players. Figure 1 showed the estimated linear relationship between heart rate and work load for all the subjects. It also provided an estimation of the players' maximum oxygen consumption by estimating their maximum heart rate. All the subjects responded similarly to the work loads on the bicycle ergometer. Estimations of oxygen consumption placed all the players in the excellent category for college women.

The laboratory data on the bicycle ergometer was done a week after the season had ended. The investigator felt that this level of fitness could not be maintained without daily vigorous exercise. Daily basketball practice along with competition seems to have contributed to either maintaining or improving the high state of aerobic fitness of the five subjects.

Furthermore, the subjects in this study were estimated to be in better condition than women basketball players in previous studies by McArdle (19) and Sinning and Adrian (35). They reported mean maximum oxygen consumption of 35.75 ml/kg/min and 34.4 ml/kg/min, respectively. These values were only slightly higher than values reported for non-athletic college women and well below the highly trained athletes in this country (10) (12). McArdle thought that the low maximum oxygen consumption might be a result of lack of sufficient intensity in practice sessions. The estimated grand mean for maximum oxygen consumption of 51 ml/kg/min in the present study indicates a trained athlete. The results of this study indicated that practice sessions were vigorous and of sufficient intensity to increase aerobic capacity.

The investigator felt that the basketball players in the present study ranked with top athletes in this country and were well above the average nonathletic college woman in aerobic fitness. The athletes in this study probably differed from women in previous studies because they have been given more opportunity to develop to their potentials. Lack of quality coaching, limited use of facilities for practice, and inhibition from negative attitudes toward women athletes did not allow women to develop the skill level or physical conditioning that they might have been capable of. For example, in a study by Sinning and Adrian (35) on women's basketball players, the subjects had participated in seven games and 25 practices. In this study, the team played 26 games and had 78 practice sessions. The large difference in the number of practices and games indicates the increase in opportunity for female athletes.

Estimation of Energy Cost During Practice

The fourth objective of this study was to estimate the energy used when women participate in basketball practice in terms of oxygen consumption, Calories used per minute, and an equivalent work load of playing. The use of regression equations developed from laboratory exercise values for heart rate and oxygen consumption to predict energy expenditure from heart rate monitored during live competition seems to be a practical research tool. In sports such as basketball, soccer, and team handball which involve large muscle groups of the lower body and in which direct measurement of oxygen consumption would be impractical, this technique of estimating energy expenditure seems to be quite appropriate.

The investigator realized that a subject's heart rate response to a live basketball practice and to riding a bicycle in the laboratory would not be identical. Muscular involvement, emotional factors, and environment would be different in the two situations. The investigator could not determine how much emotion affected the player's heart rate during practice or on the bicycle. The environment could not be strictly controlled in the gymnasium as it could be in the laboratory. However, extremes in temperature and humidity were not encountered in practice sessions that would cause a change in the linear relationship between heart rate and energy expenditure. The muscles used when riding the bicycle were not exactly the same muscles used to play basketball although major muscle groups were involved in both activities. Riding the bicycle provided a stress similar to basketball practice. Furthermore, this enabled the investigator to predict an estimate of a work load on the bicycle that would be equivalent to the stress of a basketball practice. The knowledge of an equivalent work load on the bicycle might be useful to a player in case of an injury that prevented running. Working on the bicycle until the injury healed could prevent the player from falling behind the other players in conditioning.

The estimated caloric expenditure in Table 4 showed that basketball practice, in all but one case, was classified as a heavy activity. According to Wells, Balke, and Van Fossan (43), 7.5 to 12.5 Calories used per minute is considered heavy activity and would improve the functioning of the cardiovascular system. The estimate of caloric cost further suggests that women's basketball practice is a vigorous activity.

Chapter V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to determine how vigorous women's basketball practice was at Kansas State University. More specifically, the objectives of this study were to determine the heart rate response of players during women's basketball practice; to determine heart rate, oxygen consumption, and caloric expenditure during specific work levels for women players; to estimate the maximum oxygen consumption for women basketball players; and to estimate oxygen consumption, caloric expenditure, and work load for each heart rate recorded for women participating in basketball practice.

Five varsity basketball players participated in the study. The heart rate of each subject was monitored by radio telemetry for two practice sessions. The heart rate was recorded for a full minute every other minute of the practice session. The subjects were also tested in the laboratory on the bicycle ergometer. The players rode freewheeling and at work loads of 300, 600, 900 KPM while the investigator determined heart rate, pulmonary ventilation, VO_2 l/min, VO_2 ml/kg/min, and calories per minute at each work load. An estimation of maximal oxygen consumption was also made by plotting heart rate to work load.

From the data collected in the laboratory, the investigator determined an individual relationship for each subject between heart rate and four measures of energy expenditure. Correlation coefficients were calculated to determine the relationship between heart rate to work load, heart rate to VO_2 l/min and VO_2 ml/kg/min, and heart rate to calories used per minute. High correlation coefficients between heart rate and all four measures of energy expenditure allowed the investigator to use basketball practice heart rates, monitored by telemetry, to predict four different estimations of the energy used in basketball practice. A regression equation was used to predict estimations of work load, VO_2 l/min, VO_2 ml/kg/min, and calories per minute for each heart rate recorded during basketball practice.

The investigator also determined an individual mean practice heart rate for each practice the player's heart rate was monitored. The range and fluctuations of the heart rate of the subjects were shown by graphs. A grand mean was determined for heart rate and the four estimations of energy expenditure for the ten practice sessions studied.

CONCLUSIONS

On the basis of the data obtained and within the limitations of this study the following conclusions appear warranted:

1. Heart rates achieved during basketball practices seem to be of sufficient intensity to improve or maintain the high level of conditioning of the players.

2. Women's basketball practice sessions frequently include near maximum effort by players.

3. A wide range of heart rates exists during a practice session.

4. Estimations of oxygen consumption, work load, and caloric expenditure can be determined from the heart rate of players participating in basketball practice.

RECOMMENDATIONS

Based on the results and interpretations of this study, more research needs to be done on the physiological effects of women's basketball. For future study, the investigator suggests that:

1. Telemetry equipment be used to determine the heart rate response of players during competition.

2. Maximum oxygen consumption be directly determined, rather than estimated, for women basketball players for both the pre and post season.

3. Telemetry equipment be used on five players simultaneously to determine differences in heart rate response between positions during a game.

4. Telemetry equipment be used to study the recovery rate of the players after practice and games.

5. A training index be developed to be used to check the intensity of basketball practice. It could be based on heart rate prior to practice, five minutes after the end of practice, and the resting heart rate the following morning.

6. Direct measure of VO_2 using Max Plank Meter (back pack unit).

Furthermore, the investigator suggests the following to coaches and players:

1. Practice sessions should include full court scrimmage sessions for conditioning.

2. Explanations by the coach should be brief and concise so that conditioning is not lost due to more rest than activity.

3. Half court play can contribute to conditioning as long as play is continuous and not interrupted frequently.

4. Free throws should be used after a strenuous part of practice as a brief recovery period for players.

5. The intensity of a practice session is more important for conditioning than the total amount of time practiced.

6. Coaches should be aware that due to individual differences each player can be affected differently by the same practice session. A practice session might be considered vigorous to one player but not another.

7. The estimations of equivalent work load, VO_2 l/min, VO_2 ml/kg/min, and caloric cost of practices can only be applied to the subjects in this study. Similar estimations for other players can be obtained with the use of telemetry equipment and an exercise physiology laboratory.

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APPENDIX A

LETTER OF INFORMED CONSENT

LETTER OF INFORMED CONSENT

The purpose of this study is to measure the severity of women's basketball practices at Kansas State. It has been suggested by researchers that practice sessions of women do not seem vigorous enough to improve the players' conditioning. For this study, five players' heart rates will be monitored by telemetry during practice sessions for about three weeks. After the completion of the season, the same subjects will do a progressive bicycle ergometer test. Heart rate and expired air will be recorded during the test. The subject will work at 300, 600, 900 KPM and it will not be a maximal test. From the results of the test, a graph of work load to heart rate to VO_2 will be plotted and compared to the heart rates found during basketball practice sessions. The final results and conclusions of the study will be reported to the subjects at their request.

I have read the above explanation and understand the nature of the study and the extent of my participation as a subject. By signing this form I give my informed consent to participate as a subject. However, I realize that I may withdraw from this research at any time if I choose to do so.

Signed ______________________

Date ______________________

APPENDIX B

CORRELATION COEFFICIENT DURING LABORATORY EXERCISE

CORRELATION COEFFICIENTS DURING LABORATORY EXERCISE

Subject	Heart Rate (HR)	Work Load (WL)	VO_2 l/min ($VO_{2.1}$)	VO_2 ml/kg/min ($VO_{2.2}$)	Calories per min (Cal/min)
1					
HR	1.00				
WL	.99	1.00			
$VO_{2.1}$	.99	.99	1.00		
$VO_{2.2}$	.99	.99	1.00	1.00	
Cal/min	.99	.99	1.00	1.00	1.00
2					
HR	1.00				
WL	.99	1.00			
$VO_{2.1}$	.98	.99	1.00		
$VO_{2.2}$	.98	.99	1.00	1.00	
Cal/min	.98	.99	1.00	1.00	1.00
3					
HR	1.00				
WL	.99	1.00			
$VO_{2.1}$	.98	.99	1.00		
$VO_{2.2}$	.98	.99	1.00	1.00	
Cal/min	.98	.99	1.00	1.00	1.00
4					
HR	1.00				
WL	.99	1.00			
$VO_{2.1}$	.99	.99	1.00		
$VO_{2.2}$	.99	.99	1.00	1.00	
Cal/min	.99	.99	1.00	1.00	1.00
5					
HR	1.00				
WL	.99	1.00			
$VO_{2.1}$	.99	.99	1.00		
$VO_{2.2}$	.99	.99	1.00	1.00	
Cal/min	.99	.99	1.00	1.00	1.00

APPENDIX C

INDIVIDUAL LABORATORY DATA

INDIVIDUAL LABORATORY DATA SHEET

Subject Number 1 Ht. 67 in. Wt. 151 lbs. 68 kg Age 21 months 2 Date April 2, 1975

Barometer 701.6 mm

Temperature
Wet bulb 15 Dry bulb 24

Partial Presure of O_2 7.2

HEART RATES

					Steady State
Freewheel	72	72			72
300 KPM	85	94	90		92
600 KPM	110	118	118		118
900 KPM	137	143	150	149	149

Work Load	$\%O_2$	$\%CO_2$	STPD	Ve(air)	Ve	R.Q.	VO_2 l/min	VO_2 ml/kg/min	Cal/min
Freewheel	16.58	4.33	.8398	19.5	16.34	.97	.70	10.3	3.6
300 KPM	16.47	4.44	.8398	25.9	21.07	.97	.96	14.1	4.5
600 KPM	16.07	4.84	.8398	38.5	32.26	.97	1.56	22.7	7.9
900 KPM	15.96	4.95	.8398	42.8	35.87	.97	1.78	25.9	9.0

INDIVIDUAL LABORATORY DATA SHEET

Subject Number 3 Ht. 67 in. Wt. 124 lbs. 56 kg Age 18 months 0 Date April 4, 1975

HEART RATES

					Steady State
Freewheel	91	92			92
300 KPM	113	118	116		117
600 KPM	150	151	151		151
900 KPM	164	165	167		166

Barometer 705.1 mm

Temperature
Wet bulb 16 Dry bulb 22

Partial Presure of O_2 9.9

Work Load	$\%O_2$	$\%CO_2$	STPD	Ve (air)	Ve	R.Q.	VO_2 1/min	VO_2 ml/kg/min	Cal/min
Freewheel	16.14	4.77	.8465	13.5	11.40	.97	.54	9.7	2.7
300 KPM	15.92	4.99	.8465	25.4	21.45	.97	1.07	19.0	5.4
600 KPM	16.06	4.85	.8465	40.0	33.79	.97	1.64	29.1	8.3
900 KPM	16 62	4.29	.8465	63 8	53 89	97	2.32	41.1	11.7

INDIVIDUAL LABORATORY DATA SHEET

Subject Number 4 Ht. 69 in. Wt. 150 lbs. 68 kg Age 21 months 7 Date April 9, 1975

HEART RATES

					Steady State
Freewheel	78	81			81
300 KPM	103	108	113		110
600 KPM	144	145			144
900 KPM	155	167	170		168

Barometer 699.9 mm

Temperature
Wet bulb 18.3 Dry bulb 24.1

Partial Presure of O_2 12.1

Work Load	$\%O_2$	$\%CO_2$	STPD	Ve (air)	Ve	R.Q.	VO_2 1/min	VO_2 ml/kg/min	Cal/min
Freewheel	17.77	3.2	.83158	13.4	11.12	.98	.35	5.1	1.8
300 KPM	16.80	3.7	.83158	23.1	19.17	.85	.80	11.8	4.1
600 KPM	16.52	4.4	.83158	36.2	30.04	.98	1.32	19.4	6.7
900 KPM	16.09	4.7	.83158	54.3	45.06	.94	2.18	32.17	11.4

INDIVIDUAL LABORATORY DATA SHEET

Subject Number 5 Ht. 65 in. Wt. 137 lbs. 62 kg Age 20 months 6 Date April 9, 1975

HEART RATES

					Steady State
Freewheel	93	83	81		82
300 KPM	101	103			102
600 KPM	122	124			123
900 KPM	150	154			152

Barometer 703.7 mm

Temperature
Wet bulb 18 Dry bulb 25

Partial Presure of O_2 11.1

Work Load	$\%O_2$	$\%CO_2$	STPD	Ve(air)	Ve	R.Q.	VO_2 l/min	VO_2 ml/kg/min	Cal/min
Freewheel	17.86	2.8	.83485	15.3	12.74	.86	.40	6.4	2.0
300 KPM	16.97	3.4	.83485	26.0	21.66	.81	.88	14.2	4.4
600 KPM	16.58	4.0	.83485	44.3	36.90	.87	1.62	26.3	8.2
900 KPM	16.20	4.3	.83485	53.5	44.6	.87	2.11	34.2	10.7

INDIVIDUAL LABORATORY DATA SHEET

Subject Number 2 Ht. 68 in. Wt. 145 lbs. 65 kg Age 19 months 10 Date April 3, 1975

HEART RATES

					Steady State
Freewheel	95	92			92
300 KPM	98	110	105		107
600 KPM	129	129			129
900 KPM	151	151	154		153

Barometer 705.7 mm

Temperature
Wet bulb 16 Dry bulb 22

Partial Presure of O_2 9.9

Work Load	$\%O_2$	$\%CO_2$	STPD	Ve(air)	Ve	R.Q.	VO_2 1/min	VO_2 ml/kg/min	Cal/min
Freewheel	16.73	4.18	.8472	14.5	12.26	.97	.51	7.8	2.6
300 KPM	15.98	5.02	.8472	20.8	17.58	.97	.88	13.6	4.5
600 KPM	15.47	5.44	.8472	32.6	27.56	.97	1.50	23.0	7.6
900 KPM	15.46	5.45	8472	42.4	35.85	.98	1.96	30.0	9.9

APPENDIX D

COMPUTER PRINT OUT OF PREDICTIONS OF WORK LOAD
VO_2 l/min, VO_2 ml/kg/min, AND CALORIES
USED PER MINUTE

SUBJECT 1

HEART RATE	WORKLOAD	VO_2 1/min	VO_2 1/kg/min	CALORIES
110.	516.5227762	1.4184600	0.0206259	7.1606900
107.	482.4861171	1.3795895	0.0200605	6.9643219
148.	894.6165357	1.7910269	0.0260451	9.0425485
127.	696.3122345	1.6066686	0.0233636	8.1113973
151.	921.2486526	1.8144385	0.0263857	9.1607896
134.	764.9347070	1.6726922	0.0243240	8.4448770
80.	129.7104584	0.8298272	0.0120603	4.1852387
154.	947.5108179	1.8372610	0.0267176	9.2760547
150.	912.4131571	1.8067019	0.0262731	9.1217160
132.	745.6084749	1.6543630	0.0240574	8.3522989
164.	1032.5648938	1.9095161	0.0277685	9.6409730
120.	624.7387052	1.5347209	0.0223171	7.7479804
142.	840.1768887	1.7422740	0.0253360	8.7963165
152.	930.0430512	1.8221096	0.0264972	9.1995327
129.	716.2037321	1.6260828	0.0236460	8.2094578
163.	1024.2227748	1.9025351	0.0276670	9.6057162
172.	1098.0905131	1.9636135	0.0285553	9.9141817
150.	912.4131571	1.8067019	0.0262731	9.1217160
168.	1065.5914438	1.9369425	0.0281674	9.7794855
163.	1024.2227748	1.9025351	0.0276670	9.6057162
169.	1073.7646722	1.9436790	0.0282654	9.8135070
166.	1049.1457123	1.9233271	0.0279694	9.7107232
164.	1032.5648938	1.9095161	0.0277685	9.6409730
158.	981.9773432	1.8668360	0.0271478	9.4254216
123.	655.7990669	1.5663668	0.0227774	7.9078296
144.	858.5035869	1.7588262	0.0255768	8.8799158
158.	981.9773432	1.8668360	0.0271478	9.4254216
168.	1065.5914438	1.9369425	0.0281674	9.7794855
171.	1090.0138246	1.9570137	0.0284594	9.8808512
172.	1098.0905131	1.9636135	0.0285553	9.9141817
172.	1098.0905131	1.9636135	0.0285553	9.9141817
184.	1192.6587748	2.0395685	0.0296601	10.2977722
83.	174.2935288	0.9281960	0.0134925	4.6829228
141.	830.9435857	1.7338786	0.0252139	8.7539142
143.	849.3633202	1.7505892	0.0254570	8.8383138
121.	635.1589622	1.5454139	0.0224726	7.8019929
124.	666.0214437	1.5766362	0.0229268	7.9597019
164.	1032.5648938	1.9095161	0.0277685	9.6409730
106.	470.9618526	1.3661333	0.0198647	6.8963414
108.	493.9196322	1.3927881	0.0202525	7.0310004
107.	482.4861171	1.3795895	0.0200605	6.9643219
118.	603.6911446	1.5128763	0.0219993	7.6376366
162.	1015.8456037	1.8955024	0.0275647	9.5701987
164.	1032.5648938	1.9095161	0.0277685	9.6409730
144.	858.5035869	1.7588262	0.0255768	8.8799158
137.	793.5268747	1.6994554	0.0247132	8.5800522
139.	812.3334471	1.7168395	0.0249661	8.6678550

SUBJECT 2

HEART RATE	WORKLOAD	VO_2 1/min	VO_2 1/kg/min	CALORIES
83.	-95.1266056	0.3132024	0.0048031	1.5807369
118.	417.0935783	1.1601387	0.0177925	5.8551856
123.	490.2678903	1.2811295	0.0196481	6.4658211
90.	7.3174312	0.4825897	0.0074010	2.4356266
98.	124.3963304	0.6761751	0.0103700	3.4126435
88.	-21.9522936	0.4341933	0.0066587	2.1913724
90.	7.3174312	0.4825897	0.0074010	2.4356266
89.	-7.3174312	0.4583915	0.0070299	2.3134995
96.	95.1266056	0.6277787	0.0096277	3.1683893
134.	651.2513767	1.5473095	0.0237305	7.8092193
171.	1192.7412854	2.4426421	0.0374621	12.3279222
177.	1280.5504598	2.5878312	0.0396888	13.0606848
120.	446.3633031	1.2085350	0.0185347	6.0994398
169.	1163.4715607	2.3942458	0.0367198	12.0836680
143.	782.9651383	1.7650931	0.0270706	8.9083632
184.	1382.9944966	2.7572185	0.0422867	13.9155745
180.	1324.4550470	2.6604257	0.0408022	13.4270661
186.	1412.2642214	2.8056148	0.0430289	14.1598287
170.	1178.1064230	2.4184439	0.0370909	12.2057951
181.	1339.0899094	2.6846239	0.0411733	13.5491932
179.	1309.8201846	2.6362276	0.0404310	13.3049390
183.	1368.3596342	2.7330203	0.0419155	13.7934474
174.	1236.6458726	2.5152367	0.0385754	12.6943035
178.	1295.1853222	2.6120294	0.0400599	13.1828119
178.	1295.1853222	2.6120294	0.0400599	13.1828119
168.	1148.8366983	2.3700476	0.0363487	11.9615408
186.	1412.2642214	2.8056148	0.0430289	14.1598287
172.	1207.3761478	2.4668403	0.0378332	12.4500493
139.	724.4256887	1.6683004	0.0255861	8.4198548
135.	665.8862391	1.5715077	0.0241016	7.9313464
203.	1661.0568822	3.2169838	0.0493380	16.2359895
204.	1675.6917446	3.2411820	0.0497092	16.3581166
153.	929.3137623	2.0070749	0.0307818	10.1296343
146.	826.8697255	1.8376877	0.0281839	9.2747445
133.	636.6165143	1.5231113	0.0233593	7.6870922
161.	1046.3926615	2.2006603	0.0337508	11.1066511
160.	1031.7577991	2.1764622	0.0333797	10.9845240
125.	519.5376151	1.3295259	0.0203903	6.7100753
103.	197.5706424	0.7971660	0.0122256	4.0232790
167.	1134.2018359	2.3458494	0.0359776	11.8394137
155.	958.5834871	2.0554713	0.0315241	10.3738885
108.	270.7449544	0.9181569	0.0140812	4.6339145
172.	1207.3761478	2.4668403	0.0378332	12.4500493
174.	1236.6458726	2.5152367	0.0385754	12.6943035
158.	1002.4880743	2.1280658	0.0326374	10.7402698
174.	1236.6458726	2.5152367	0.0385754	12.6943035
167.	1134.2018359	2.3458494	0.0359776	11.8394137
143.	782.9651383	1.7650931	0.0270706	8.9083632
156.	973.2183495	2.0796694	0.0318952	10.4960156
128.	563.4422023	1.4021204	0.0215037	7.0764566
109.	285.3798168	0.9423550	0.0144523	4.7560416
141.	753.6954135	1.7166968	0.0263283	8.6641090
156.	973.2183495	2.0796694	0.0318952	10.4960156
170.	1178.1064230	2.4184439	0.0370909	12.2057951
152.	914.6788999	1.9828767	0.0304107	10.0075072
121.	460.9981655	1.2327332	0.0189058	6.2215669

SUBJECT 2

HEART RATE	WORKLOAD	VO_2 1/min	VO_2 1/kg/min	CALORIES
180.	1324.4550470	2.6604257	0.0408022	13.4270661
171.	1192.7412854	2.4426421	0.0374621	12.3279222
184.	1382.9944966	2.7572185	0.0422867	13.9155745
184.	1382.9944966	2.7572185	0.0422867	13.9155745
122.	475.6330279	1.2569314	0.0192770	6.3436940
167.	1134.2018359	2.3458494	0.0359776	11.8394137
183.	1368.3596342	2.7330203	0.0419155	13.7934474
176.	1265.9155974	2.5636330	0.0393177	12.9385577
130.	592.7119271	1.4505168	0.0222460	7.3207108
162.	1061.0275239	2.2248585	0.0341219	11.2287782
185.	1397.6293590	2.7814166	0.0426578	14.0377016
175.	1251.2807350	2.5394348	0.0389465	12.8164306
176.	1265.9155974	2.5636330	0.0393177	12.9385577
109.	285.3798168	0.9423550	0.0144523	4.7560416
117.	402.4587159	1.1359405	0.0174213	5.7330585
151.	900.0440375	1.9586786	0.0300396	9.8853801
172.	1207.3761478	2.4668403	0.0378332	12.4500493
174.	1236.6458726	2.5152367	0.0385754	12.6943035

SUBJECT 3

HEART RATE	WORKLOAD	VO_2 l/min	VO_2 l/kg/min	CALORIES
138.	526.1922995	1.5456723	0.2741427	7.7982375
175.	959.8029394	2.4046870	0.4265560	12.1321502
143.	584.7883319	1.6617554	0.2947391	8.3839013
169.	889.4877005	2.2653873	0.4018403	11.4293535
163.	819.1724616	2.1260877	0.3771246	10.7265569
141.	561.3499190	1.6153221	0.2865005	8.1496358
178.	994.9605588	2.4743369	0.4389138	12.4835485
156.	737.1380162	1.9635714	0.3482897	9.9066274
174.	948.0837329	2.3814704	0.4224367	12.0150174
158.	760.5764292	2.0100046	0.3565282	10.1408930
171.	912.9261134	2.3118206	0.4100789	11.6636191
189.	1123.8718301	2.7297196	0.4842259	13.7720090
91.	-24.6104051	0.4544914	0.0805365	2.2929970
131.	444.1578541	1.3831560	0.2453077	6.9783080
156.	737.1380162	1.9635714	0.3482897	9.9066274
159.	772.2956357	2.0332212	0.3606475	10.2580258
164.	830.8916681	2.1493043	0.3812439	10.8436896
168.	877.7684940	2.2421707	0.3977210	11.3122207
163.	819.1724616	2.1260877	0.3771246	10.7265569
153.	701.9803968	1.8939215	0.3359319	9.5552291
159.	772.2956357	2.0332212	0.3606475	10.2580258
164.	830.8916681	2.1493043	0.3812439	10.8436896
167.	866.0492875	2.2189541	0.3936018	11.1950880
140.	549.6307125	1.5921055	0.2823812	8.0325030
139.	537.9115060	1.5688889	0.2782619	7.9153702
146.	619.9459514	1.7314052	0.3070969	8.7352997
173.	936.3645264	2.3582538	0.4183174	11.8978846
157.	748.8572227	1.9867880	0.3524090	10.0237602
152.	690.2611903	1.8707049	0.3318126	9.4380963
166.	854.3300810	2.1957375	0.3894825	11.0779552
130.	432.4386477	1.3599394	0.2411884	6.8611753
156.	737.1380162	1.9635714	0.3482897	9.9066274
143.	584.7883319	1.6617554	0.2947391	8.3839013
136.	502.7538866	1.4992391	0.2659041	7.5639719
159.	772.2956357	2.0332212	0.3606475	10.2580258
158.	760.5764292	2.0100046	0.3565282	10.1408930
140.	549.6307125	1.5921055	0.2823812	8.0325030
120.	315.2465828	1.1277732	0.1999556	5.6898475
136.	502.7538866	1.4992391	0.2659041	7.5639719
144.	596.5075384	1.6849720	0.2988583	8.5010341
147.	631.6651579	1.7546218	0.3112162	8.8524324
126.	385.5618217	1.2670729	0.2247113	6.3926442
153.	701.9803968	1.8939215	0.3359319	9.5552291

SUBJECT 4

HEART RATE	WORKLOAD	VO_2 1/min	VO_2 1/kg/min	CALORIES
141.	605.1051292	1.4885912	0.0218875	7.5129431
159.	788.1621430	1.8690598	0.0274823	9.4331212
153.	727.1431384	1.7422369	0.0256173	8.7930619
154.	737.3129725	1.7633741	0.0259282	8.8997384
147.	666.1241338	1.6154141	0.0237524	8.1530025
154.	737.3129725	1.7633741	0.0259282	8.8997384
134.	533.9162904	1.3406313	0.0197118	6.7662072
137.	564.4257927	1.4040427	0.0206442	7.0862368
137.	564.4257927	1.4040427	0.0206442	7.0862368
148.	676.2939679	1.6365512	0.0240632	8.2596790
151.	706.8034702	1.6999627	0.0249957	8.5797087
160.	798.3319771	1.8901969	0.0277931	9.5397978
172.	920.3699864	2.1438426	0.0315229	10.8199166
164.	839.0113135	1.9747455	0.0290364	9.9665041
164.	839.0113135	1.9747455	0.0290364	9.9665041
159.	788.1621430	1.8690598	0.0274823	9.4331212
156.	757.6526407	1.8056484	0.0265498	9.1130915
159.	788.1621430	1.8690598	0.0274823	9.4331212
159.	788.1621430	1.8690598	0.0274823	9.4331212
160.	798.3319771	1.8901969	0.0277931	9.5397978
170.	900.0303182	2.1015683	0.0309013	10.6065634
157.	767.8224748	1.8267855	0.0268606	9.2197681
164.	839.0113135	1.9747455	0.0290364	9.9665041
145.	645.7844656	1.5731398	0.0231308	7.9396493
155.	747.4828066	1.7845112	0.0262390	9.0064150
178.	981.3889910	2.2706654	0.0333878	11.4599759
167.	869.5208159	2.0381569	0.0299688	10.2865337
170.	900.0303182	2.1015683	0.0309013	10.6065634
176.	961.0493228	2.2283912	0.0327662	11.2466228
161.	808.5018112	1.9113341	0.0281039	9.6464744
178.	981.3889910	2.2706654	0.0333878	11.4599759
156.	757.6526407	1.8056484	0.0265498	9.1130915
149.	686.4638020	1.6576884	0.0243741	8.3663556
128.	472.8972858	1.2138084	0.0178468	6.1261478
161.	808.5018112	1.9113341	0.0281039	9.6464744
189.	1093.2571661	2.5031740	0.0368069	12.6334181
195.	1154.2761708	2.6299968	0.0386718	13.2734775
152.	716.9733043	1.7210998	0.0253065	8.6863853
131.	503.4067881	1.2772198	0.0187793	6.4461775
155.	747.4828066	1.7845112	0.0262390	9.0064150
142.	615.2749633	1.5097284	0.0221983	7.6196197
128.	472.8972858	1.2138084	0.0178468	6.1261478
150.	696.6336361	1.6788255	0.0246849	8.4730322
171.	910.2001523	2.1227055	0.0312121	10.7132400
168.	879.6906500	2.0592940	0.0302796	10.3932103
168.	879.6906500	2.0592940	0.0302796	10.3932103
176.	961.0493228	2.2283912	0.0327662	11.2466228
168.	879.6906500	2.0592940	0.0302796	10.3932103
178.	981.3889910	2.2706654	0.0333878	11.4599759
173.	930.5398205	2.1649797	0.0318337	10.9265931
167.	869.5208159	2.0381569	0.0299688	10.2865337
169.	889.8604841	2.0804312	0.0305905	10.4998869
149.	686.4638020	1.6576884	0.0243741	8.3663556
166.	859.3509818	2.0170198	0.0296580	10.1798572
177.	971.2191569	2.2495283	0.0330770	11.3532994
130.	493.2369540	1.2560827	0.0184685	6.3395009

SUBJECT 5

HEART RATE	WORKLOAD	VO_2 1/min	VO_2 1/kg/min	CALORIES
152.	933.7658885	2.2195219	0.0357932	11.2151782
110.	388.3114984	1.1335290	0.0182793	5.7339817
140.	777.9217771	1.9092382	0.0307892	9.6491221
138.	751.9477585	1.8575243	0.0299552	9.3881127
152.	933.7658885	2.2195219	0.0357932	11.2151782
175.	1232.4671021	2.8142323	0.0453841	14.2167859
182.	1323.3761671	2.9952311	0.0483031	15.1303186
143.	816.8828049	1.9868091	0.0320402	10.0406361
106.	336.3634613	1.0301011	0.0166113	5.2119629
166.	1115.5840185	2.5815195	0.0416311	13.0422437
95.	193.5063591	0.7456744	0.0120243	3.7764115
98.	232.4673870	0.8232453	0.0132753	4.1679255
147.	868.8308421	2.0902370	0.0337082	10.5626548
168.	1141.5580371	2.6332335	0.0424651	13.3032531
172.	1193.5060743	2.7366614	0.0441331	13.8252718
152.	933.7658885	2.2195219	0.0357932	11.2151782
134.	699.9997213	1.7540964	0.0282872	8.8660940
168.	1141.5580371	2.6332335	0.0424651	13.3032531
145.	842.8568235	2.0385231	0.0328742	10.3016455
125.	583.1166377	1.5213836	0.0245342	7.6915519
133.	687.0127120	1.7282394	0.0278702	8.7355893
142.	803.8957956	1.9609522	0.0316232	9.9101314
129.	635.0646749	1.6248115	0.0262022	8.2135706
116.	466.2335542	1.2886708	0.0207812	6.5170097
132.	674.0257028	1.7023824	0.0274532	8.6050846

HEART RATE AND ESTIMATED ENERGY COST OF WOMEN'S BASKETBALL PRACTICE

BY

MARY PHYL DWIGHT

B. S., Southwest Missouri State University, 1974

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Health, Physical Education and Recreation

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1975

The purpose of this study was to determine how vigorous women's basketball practice was at Kansas State University. More specifically, the objectives of this study were to determine the heart rate response of players during women's basketball practice; to determine heart rate, oxygen consumption, and caloric expenditure during specific work levels for women players; to estimate the maximum oxygen consumption for women basketball players; and to estimate oxygen consumption, caloric expenditure, and work load for each heart rate recorded for women participating in basketball practice.

Five varsity basketball players participated in the study in which the heart rate of each subject was monitored by radio telemetry for two practice sessions. The heart rate was recorded continuously throughout practice. The R spikes from the ECG recordings were counted for a full minute every other minute of practice. The subjects were also tested in the laboratory on the bicycle ergometer. The players rode freewheeling and at work loads of 300, 600, 900 KPM while the investigator determined heart rate, pulmonary ventilation, VO_2 l/min, VO_2 ml/kg/min, and caloric cost at each work load. An estimation of maximal oxygen consumption was also made by plotting heart rate to work load.

From the data collected in the laboratory, the investigator determined an individual relationship for each subject between heart rate and work load, heart rate and VO_2 l/min, heart rate and VO_2 ml/kg/min, and heart rate and Calories used per minute. High correlation coefficients for all subjects between these relationships allowed the investigator to develop regression equations for each individual to be used to predict work load, VO_2 l/min, VO_2 ml/kg/min, and Calories used per minute. The investigator used basketball practice heart rates, monitored by telemetry, and the individual regressions equations to predict an equivalent work load, VO_2 l/min, VO_2 ml/kg/min, and caloric cost for basketball practice.

The investigator also determined an individual mean heart rate for each practice in which the player's heart rate was monitored. The range and fluctuations of the heart rate of the subjects were shown by graphs. A grand mean was determined for heart rate and the estimated equivalent work load, VO_2 l/min, VO_2 ml/kg/min, and caloric cost for the ten practice sessions studied.

The general conclusion reached was that women's basketball practice at Kansas State was quite vigorous and provided the players the opportunity to approach their potential in physical conditioning.