

ABSTRACT

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Pre- and postseason measurements of aerobic and anaerobic power were determined for women's intercollegiate basketball players (WIBP) on the 1995-96 University of Wisconsin-La Crosse team ($N = 13$). Aerobic power was measured by a treadmill VO_{2max} test while anaerobic power was determined by the Wingate Cycle Ergometry Test. Using dependent t-tests, it was found that neither aerobic nor anaerobic power changed significantly ($p > .05$) over the season. Additionally, HR_{max} data were collected during a preseason VO_{2max} test, a team practice, a scrimmage, and an actual game and were compared using a one-way ANOVA with repeated measures. HR_{max} values for 7 of the 13 WIBP were found to be significantly ($p < .001$) higher during both the scrimmage and game than the practice and the preseason VO_{2max} test using Tukey's post hoc procedure. Similarly, HR_{max} values for 11 of the 13 WIBP were found to be significantly ($p < .001$) higher during the scrimmage than both the practice and the preseason VO_{2max} test. However, the higher HR_{max} values found during the scrimmage and game situations were not sustained due to the characteristics of competitive basketball.

PHYSIOLOGICAL RESPONSES TO

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CHAPTER I INTRODUCTION

Background

Basketball's popularity has endured for nearly a century due to its challenging nature in either recreational or competitive venues. It requires both aerobic and anaerobic energy expenditures. Games are usually 40 minutes long and at the collegiate level it consists of two 20 minute halves. This duration of an entire game accounts for the aerobic component. The additions of a 24-second shot-clock at the professional level, a 35-second shot-clock for collegiate men, and a 30-second shot-clock for collegiate women have made basketball a faster paced game. Numerous short energy bursts, such as stealing the ball and subsequently sprinting the length of the court, jumping for a rebound, and changing directions suddenly require anaerobic energy. Players at any level need to develop both aerobic and anaerobic power to be competitive.

Although women have been playing competitive basketball for many years, they have not played the entire court until the last 25 years. Two other rule changes that have affected the women's game were the smaller ball introduced in 1984 and the three point goal introduced in the 1987-88 academic year (Hult & Trekell, 1991). According to Hult and Trekell the smaller ball and three point goal made basketball faster and more exciting for both girls and women.

Developmental programs and special camps at facilities such as local schools and YMCAs now include girls in the lower elementary grades. The

addition of such programs has sparked the interest of many females across the country. National tournaments for college players and state tournaments for high school players have inspired teams and individuals to strive to be the best. The first Olympic competition for women's basketball was held in 1976 at Montreal (Lieberman-Cline & Roberts, 1996).

Training programs for women's basketball usually include running for distance and time, sprinting, repetitive drills, and weight training. Specific training in the 1960s included rope jumping, bench stepping, wall passing, push-ups, and sit-ups (Hult & Trekell, 1991). Then, as the five-player, full court game advanced, training included wind sprints, distance runs up to two miles, and stair running (Hult & Trekell, 1991). A good training program for basketball should include a balance of aerobic and anaerobic training (McArdle, Katch, & Katch, 1991). The aerobic training could include short distance runs such as one-two miles and continuous scrimmage play without stopping the clock. The anaerobic training could include wind sprints, defensive lateral running drills, jumping rope, and rebounding drills.

Need for the Study

Although a few studies have measured aerobic power of women's intercollegiate basketball players pre- and postseason (Hakkinen, 1993; McArdle, Magel, & Kyvallos, 1971; Sinning, 1973; Sinning & Adrian, 1968), the caliber of players tested, times of testing, protocols, and results have been conflicting. Sinning and Adrian (1968) found that VO_{2max} increased significantly from pre- to postseason in eight college women as measured on a cycle ergometer. In contrast, McArdle et al. (1971) found no significant changes pre- to postseason in VO_{2max} , HR_{max} , and body weight in six college

women as measured on a treadmill. In support of McArdle's findings, Coleman, Kreuzer, Friedrich, and Juvenal (1974) reported no significant changes in VO_{2max} or anaerobic power pre- to postseason in seven male college freshmen.

Even fewer studies have examined anaerobic power of women's intercollegiate basketball players pre- and postseason. Coleman et al. (1974) found no significant changes using a modified version of the Margaria test of anaerobic power in seven male college freshmen, while Hakkinen (1993) reported a significant increase pre- to postseason in ten female basketball players in the official league in Finland using a vertical jumping test to determine anaerobic power.

There is a need to study both the aerobic and anaerobic power pre- and postseason in women's intercollegiate basketball players due to conflicting findings of previous studies as well as the differences in training which have changed in recent years. What are the changes in specific physiological responses as a result of participation in a season of women's NCAA Division III intercollegiate basketball? Furthermore, how can such information assist basketball coaches who want their players to maintain and even optimize both aerobic and anaerobic power during a season?

Purpose of the Study

The purpose of this study was to determine what changes, if any, occur in aerobic and anaerobic power of women's intercollegiate basketball players over a competitive season. The independent variable was the effects of participation during a season of intercollegiate basketball. The dependent variables were aerobic and anaerobic power including selected physiological components of both. A subpurpose of this study was to monitor heart rate responses of women

intercollegiate basketball players during a practice, a scrimmage, and actual competition and compare them to the individual player's maximal heart rates obtained during a treadmill run.

Statement of the Problem

The problem of this research was to determine changes in the pre- and postseason aerobic and anaerobic power including selected physiological components of both for the 1995-96 University of Wisconsin-La Crosse (UW-L) women's basketball team.

Hypothesis

There will be no significant differences in various aerobic and anaerobic power measures of female basketball players pre- and postseason. For statistical purposes the level of significance was set at the .05 level for all variables.

Assumptions

There were three assumptions in this study:

1. It was assumed that all participants were physically able to perform all tests.
2. It was assumed that all participants exerted maximal effort during all tests.
3. It was assumed that all physiological tests measured the variables they were designed to measure.

Limitations

There were four limitations to this study:

1. There was the possibility of human and machine errors during the tests.

2. Outside activities and habits of the participants, such as diet, sleep patterns, psychological stress, and recreational activities could not be controlled and may have affected physical condition during testing.
3. The conditioning of each subject prior to testing and during the season could not be controlled.
4. The subjects were volunteers from the 1995-96 women's basketball team at UW-L.

Delimitations

There were two delimitations to this study:

1. This study was conducted using only volunteer members of the 1995-96 women's basketball team at UW-L as listed on the eligibility roster.
2. The testing procedures for aerobic and anaerobic power took place in the Human Performance Laboratory at UW-L.

Definition of Terms

Aerobic Power (VO_{2max}) - a quantitative measure of an individual's ability for aerobic energy transfer that determines one's capability to sustain high-intensity exercise for longer than 5 minutes and is expressed as one's VO_{2max} (McArdle et al., 1991). A treadmill run was used in this study.

Basketball Player - a participant on the 1995-96 UW-L women's basketball team as listed on the eligibility roster.

Fatigue Index (FI) - the rate of power decline during the 30-second Wingate cycle test and calculated as the difference between peak anaerobic power and the lowest 5-second power output divided by the peak power and expressed as a percentage (MacDougall, Wenger, & Green, 1991).

HR_{max} - the maximal heart rate as determined by a maximal treadmill test expressed in beats per minute (beats·min⁻¹).

Maximal oxygen consumption (VO_{2max}) - a point at which oxygen consumption plateaus with an additional workload as determined by the protocol described in Chapter II. It is expressed in both relative units (ml·kg⁻¹·min⁻¹) and absolute units (L·min⁻¹), and is a good measure of aerobic power (McArdle et al., 1991).

Mean Anaerobic Power (MP) - the average power output generated during the entire 30-second Wingate power test and expressed in both relative (watts·kg⁻¹) and absolute (watts) units (McArdle et al., 1991).

Peak Anaerobic Power (PP) - the highest mechanical power generated during the first 5 seconds of the 30-second Wingate power test expressed in both relative (watts·kg⁻¹) and absolute (watts) units (McArdle et al., 1991).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

There is a limited amount of research available that has reported both aerobic and anaerobic power pre- and postseason of women's intercollegiate basketball players (WIBP). A few studies have measured aerobic power (VO_{2max}) pre- and postseason of WIBP and men's intercollegiate basketball players separately. Intersport comparisons of anaerobic power have been made by a limited number of researchers, and even fewer studies with specific reference to anaerobic power of WIBP have been reported. These studies did not use the same protocols or the same modes for testing; thus, direct comparisons are difficult. Prior to 1972 college women participated under the six-player rule. Under these rules, only two members of the six members of each team were allowed to play the entire court (Sinning & Adrian, 1968), while the remaining members played half-court. Subsequently, the findings of all past studies have not set any particular trend concerning changes in aerobic or anaerobic power over the course of a season of competitive play.

The first section of this chapter will identify physical characteristics of women basketball players. The second section will explain aerobic and anaerobic metabolic processes. The third section will present methods of measurement to determine both aerobic and anaerobic power. The fourth section will examine VO_{2max} and its importance to women basketball players, while the fifth section will examine anaerobic power and its importance to women

basketball players. The sixth section will examine the importance of heart rate responses of women basketball players. Finally, the summary will review the information presented in the aforementioned sections.

Physical Characteristics of Women Basketball Players

Many factors affect VO_{2max} including height, weight, age, and training and there is tremendous biological variability among individuals competing in the same sport. Researchers who tested VO_{2max} of female college women basketball players reported mean heights of subjects ranging from 165.3 cm - 174.6 cm, mean weights ranging from 61.3 kg - 68.1 kg, and mean ages ranging from 19 years 1 month - 20 years of age (Hakkinen, 1993; McArdle et al., 1971; Sinning, 1973; Sinning & Adrian, 1968). These values are somewhat lower than data reported by Smith and Thomas (1991) on 29 Canadian women basketball players. These athletes, who were rated as one of the top five teams in the world at the time of testing had an average height of 181.8 cm, weighed 74.5 kg, and averaged 21.6 ± 1.8 years of age.

Compared to the four studies first mentioned above (Hakkinen, 1993; McArdle et al., 1971; Sinning, 1973; Sinning & Adrian, 1968), Vaccaro, Clark, & Wrenn (1979) found similar values for height, weight, and age as follows: height = 173.0 cm, weight = 68.3 kg, and age = 19.4 years. At the time of this study the subjects were considered superior due to a national ranking in the top 10 in the U.S.

Aerobic and Anaerobic Metabolic Processes

The body utilizes three energy systems to execute daily activities as well as sports activities that require higher amounts of energy for extended periods of time. The three systems are 1)ATP-CP, 2)anaerobic glycolysis, and 3)aerobic

or oxygen system. The ATP-CP system consists of high energy phosphates stored within muscles (McArdle et al., 1991). Both the ATP-CP and anaerobic glycolysis systems involve anaerobic metabolic processes. The ATP-CP system is called upon when the event is less than 10 seconds in duration, anaerobic glycolysis is called upon when the event is 2-5 minutes in duration, and the aerobic system is called upon when the event lasts 5 minutes or longer (McArdle et al., 1991).

Basketball involves all three of these systems due to the nature of the game (Stone & Steingard, 1993). For example, there are sprints up and down the court that may last less than 10 seconds or greater than 2 minutes depending on violations occurring as signified by the whistle of a referee or the sound of a buzzer indicating the end of a quarter or half of play.

Methods of Measurement

Exercise physiologists have developed different protocols utilizing different modes of testing to measure both aerobic and anaerobic power. In 1991, MacDougall and associates asserted that athletes can profit from a regular testing program. Attainment of one's VO_{2max} requires the integration of many body systems (i.e., cardiovascular, pulmonary, and neuromuscular), so maximal oxygen uptake has significant physiologic as well as metabolic meaning (McArdle et al., 1991). The traditional and most widely accepted method to measure aerobic power is directly measured VO_{2max} (American College of Sports Medicine [ACSM], 1995).

Two studies that measured VO_{2max} of WIEP pre- to postseason used discontinuous protocols (Sinning, 1973; Sinning & Adrian, 1968), while two studies used continuous protocols (Hakkinen, 1993; McArdle et al., 1971).

Certain disadvantages of discontinuous protocols exist (MacDougall et al., 1991). First, it is difficult to choose the proper workload. Secondly, it is difficult to determine whether a true VO_{2max} is achieved, because there is no stepwise plateau in VO_2 . Thirdly, using a discontinuous protocol inordinately extends testing time. Advantages to using continuous protocols are the following: a built-in warm-up; requires performance at VO_{2max} for less time than do discontinuous protocols; and, allows the workload to be adjusted progressively throughout each stage (MacDougall et al., 1991).

Equally important to the protocol selected is the mode of testing for both aerobic and anaerobic power. Two of the most common modes to test aerobic power (VO_{2max}) are the treadmill and the cycle ergometer. In the past, three studies that determined aerobic power of WIBP pre- to postseason used a cycle ergometer (Hakkinen, 1993; Sinning, 1973; Sinning & Adrian, 1968), and only one (McArdle et al., 1971) used a treadmill.

Although the majority of studies of aerobic power pre- to postseason of WIBP have used cycle ergometry, there are certain disadvantages to this mode such as a smaller muscle mass is used, localized leg fatigue may limit total testing time, and usually 5-15% lower VO_{2max} values are obtained compared to using a treadmill (McArdle et al., 1991). Advantages of treadmill testing include easier workload control and utilization of greater muscle mass eliciting higher VO_{2max} and HR_{max} values.

Different methods of testing anaerobic power of WIBP have also developed. The stair test pioneered by Margaria, Aghemo, and Rovelli (1966) was the most popular method until the Wingate test was validated (Inbar, Dotan, & Bar-Or, 1976). According to MacDougall et al. (1991), the Wingate test has

been used more than any other test in determining anaerobic performance. Although no published studies were found that measured anaerobic power of WIBP pre- to postseason, two unpublished studies were found (Earnest, 1992; Hilgenberg, 1988) which used the Wingate test. Earnest (1992) used the stair test to determine peak anaerobic power and the Wingate to determine anaerobic capacity. Hilgenberg (1988) used the Wingate test to determine peak power.

Aerobic Power and Its Importance to Women Basketball Players

Aerobic power is important to basketball for many reasons. As discussed in Chapter I, the length of a women's collegiate basketball game totals 40 minutes that is divided into two 20 minute halves. Although there are occasions in which the clock stops (i.e., time outs and violations), these breaks do not allow players to recover to a resting level of oxygen intake. Often, a series of plays can occur without any breaks in the play. According to Stone and Steingard (1993), the basketball player needs to be prepared to sustain a high level of continuous movement. Thus, the average collegiate basketball player needs to have fairly high aerobic power and needs to be able to maintain it to be competitive in games. Furthermore Stone and Steingard (1993) suggest that a high aerobic capacity of the basketball player is necessary for a rapid recovery from any anaerobic efforts.

Two studies which measured the aerobic power pre- and postseason during the 6-player rule for intercollegiate women's basketball reported conflicting results. In 1968, Sinning and Adrian found that VO_{2max} increased significantly in relative terms from 34.4 to 38.7 $ml \cdot kg^{-1} \cdot min^{-1}$ as well as in absolute terms over the course of a season for 8 subjects. In contrast, McArdle, et al., (1971) found similar values of 35.5 to 35.8 $ml \cdot kg^{-1} \cdot min^{-1}$, but there were

no significant changes pre- to postseason for 6 subjects. The average VO_{2max} values of the subjects in these two studies were lower than values reported by Hakkinen in 1993 (48.0 to 47.0 $ml \cdot kg^{-1} \cdot min^{-1}$) and Sinning in 1973 (44.8 to 42.9 $ml \cdot kg^{-1} \cdot min^{-1}$) pre- to postseason, and may have been lower due to the subjects only playing half-court basketball.

As a comparative study to the 1968 study by Sinning and Adrian, Sinning (1973) measured VO_{2max} pre- and postseason on 14 female players. One major purpose of this study was to compare conditioning effects under 6-player rules and full court 5-player rules. It was found that VO_{2max} expressed in relative terms decreased significantly over the course of the season from 44.8 to 43.0 $ml \cdot kg^{-1} \cdot min^{-1}$. One possible explanation for the decrease was that the players increased their body weight, specifically lean body weight, over the season. In addition, the players in the second study participating under the 5-player rule had significantly higher VO_{2max} values pre- and postseason than the players participating under the 6-player rule (Sinning, 1973), suggesting that initially the subjects involved in the 1973 study were in a better state of cardiorespiratory condition. This difference would be expected due to the transition from a half-court game to a full-court game, primarily because total distances any player ran in a game would be greater utilizing the entire court.

Anaerobic Power and Its Importance to Women Basketball Players

Anaerobic power is also an important attribute for basketball players. There are many occasions during a game in which the anaerobic system is called upon for quick energy (i.e., jumping for rebounds, sprinting down the court for the execution of a fast break, defensive lateral movement, etc.). Although Stone and Steingard (1993) indicate aerobic power is important, they suggest that

the major performance skills of basketball require an anaerobic energy base. These researchers also appropriately suggested that the coach can influence the overall tempo of the game. Coaches may devise a slower style of play concentrating on half-court offense and require more aerobic energy or a faster style of play with emphasis on a running, fast-breaking game requiring anaerobic energy sources. A coach could change style of play based on the ability and physique of the team as well as train the team to play a faster or slower tempo based on the difficulty of the opponents.

In a study that compared male basketball players, male football players, women ice hockey players, and a group of males termed "national athletes," basketball players were found to have the highest anaerobic power (Verma, Mohindroo, & Kansal, 1979). All of these athletes were studied at a training camp and ranged in age from 16 to 27 years. The method used for determining anaerobic power was the Margaria-Kalamen technique that consists of several trials of running up a series of steps.

Coleman et al., (1974) tested nine college freshmen male basketball players' anaerobic powers pre- and postseason. The results indicated a nonsignificant increase in mean anaerobic power, and the researchers suggested that gains in anaerobic power should have reached a plateau before the first week of competition due to 6 weeks of strenuous, preseason conditioning. The researchers state that for any further increases to occur in anaerobic power, the subjects would need to use strength and speed to move body weight more effectively (Coleman et al., 1974). One way the authors suggest to improve anaerobic power was to have the subjects take part in a heavy resistance program during the season.

In a comparative study of South Australian males competing in track, soccer, hockey, and basketball, Withers, Roberts, and Davies (1977) found that soccer and hockey players had higher relative power than either basketball or track competitors. The method used for testing in this study was the Margaria stair test; however, the tests were not performed pre- and postseason.

Similarly, Bhanot and Sidhu (1981) compared the anaerobic power of football, hockey, volleyball, and basketball players. Although the gender of the athletes was not mentioned in the study, these researchers found that volleyball players had the highest anaerobic power of all athletes followed by football, hockey, and basketball players, respectively. However, this study was not conducted pre- and postseason, and the athletes on the hockey and volleyball teams were considered "National Seniors," while the athletes on the basketball and football teams were considered "National Juniors." No specific ages were mentioned of any of the subjects involved in the study. Thus, although field sports such as football and hockey were noted to have subjects with higher anaerobic power than basketball players in this particular study, comparisons were difficult since neither age nor gender of subjects were identified.

Pankey, Bacharach, and Gaugler (1996) compared the anaerobic power, peak power, and fatigue percentage of physically active women in two age groups using the Wingate cycle test. The subjects had participated in aerobic classes three to five times per week for at least 1 hour over a period of at least 2 years. Women aged 18 to 29 did not differ significantly from women aged 30 to 42 in anaerobic power and peak power, but there was a significant difference between the groups in fatigue index. In fact, the older group attained a lower fatigue index of 39 versus 46% for the younger women which is calculated as

the difference between peak power and minimum power divided by peak power. The authors credited long-term adaptations such as retainment of muscle mass and less than normal loss of muscle strength from participation in moderate to high intensity aerobics as factors affecting the lower fatigue percentage (Pankey et al., 1996).

Earnest (1992) tested 10 NCAA Division I women's basketball players' anaerobic powers pre- and postseason and found that both peak anaerobic power and anaerobic capacity increased significantly over the season. This researcher used the method described by Margaria et al. (1966) for determining peak anaerobic power and the Wingate cycle test for determining anaerobic capacity.

Heart Rate and Its Importance to Women Basketball Players

Exercise intensity is generally expressed as a percentage of one's VO_{2max} , but an effective alternative method is to use heart rate (McArdle et al., 1991). Since there is a linear relationship between maximum heart rate and VO_{2max} , theoretically an individual should achieve their VO_{2max} at one's maximum heart rate. Since a treadmill VO_{2max} test normally lasts 10 to 12 minutes after an appropriate warm-up, the aerobic energy system is utilized in order for subjects to complete the test.

According to Shangold and Mirkin (1994), maximum heart rate is affected primarily by heredity and age, and not significantly affected by specific training. These authors state that VO_{2max} can increase with training up to 20% in most people (Shangold & Mirkin, 1994) without an increase in maximal heart rate. Moreover, a benefit of training is the gaining of lean body mass leading to a greater ability to use oxygen (ACSM, 1995).

There is a paucity of published studies that were conducted to determine heart rates of women basketball players in competition, however there were a few unpublished studies that examined this topic.

In a study involving 16 undergraduate college women radiotelemetry was used to monitor heart rates during 15 minutes of activity (Armstrong, 1964). The subjects were either in a physical education class or a recreation program on campus. There were ten basketball players involved, and these particular subjects differed in the type of basketball played. For example, three were in a basketball class, three participated in a basketball club, three played intramural basketball, and one played extramural basketball. From the heart rate data obtained, it was found that basketball was more strenuous than badminton or contemporary dance, and basketball drills produced a lower heart rate than actual games (Armstrong, 1964). The average heart rates for the ten basketball players involved was $166.5 \text{ beats} \cdot \text{min}^{-1}$ during play and ranged from 106 to 198 $\text{beats} \cdot \text{min}^{-1}$.

In an attempt to repeat Armstrong's (1964) study as well as investigate heart rate responses further, Cant (1965) studied a similar group of 19 college women. The subjects were participants in five activity classes that met for 1 hour two times per week for 10 weeks. Heart rates were monitored during the specific activity class the subjects were participating in (i.e., basketball, badminton, and contemporary dance). Cant (1965) found the mean heart rate of ten basketball players to be $168.6 \text{ beats} \cdot \text{min}^{-1}$, and as Armstrong (1964) found, basketball players had a higher heart rate response than subjects involved in badminton or contemporary dance.

Huchison (1969) studied two women's basketball starting players using radiotelemetry. In five different game settings, telemetry readings were taken during the first two minutes of play, the first two minutes of the second half, and the last two minutes of play. Heart rates during the last 5 seconds of every minute were taken throughout the game including time outs. Average heart rates for the two subjects in five separate games were as follows: 170.0, 184.5, 170.5, 191.5, and 188 beats·min⁻¹.

In addition to using radiotelemetry, verbal commentary of the game situation was provided by Huchison (1969). From this commentary, it was found that both subjects were most effective (i.e., increased scoring, rebounding, and ball stealing along with minimal violations) when maintaining a steady heart rate for two consecutive minutes or more. It was determined that the subjects reached a higher heart rate during game situations versus heart rates determined on a cycle ergometer at a heavy workload. During competition, one subject maintained a heart rate greater than 200 for 12 minutes (Huchison, 1969) compared to that obtained on the cycle test.

McArdle et al., (1971) used radiotelemetry to obtain heart rate data on six women college basketball players during home games. Recordings were taken on each player for at least one quarter but not longer than one half. These data were collected during both five-player and six-player competition. Specifically, heart rate recordings were taken at the tip-off, every 30 seconds during play, and at the beginning and end of time-outs. Heart rates during play averaged 154-195 beats·min⁻¹ which represented 81 to 95% of the subjects' maximum heart rates as measured from treadmill VO_{2max} tests.

The Spanish Olympic team that won the European Championship in 1993 participated in continuous heart rate monitoring during three international contests (Terrados et al., 1996). Heart rates during competition averaged 177 bpm and ranged between 140-203 beats·min⁻¹. The researchers concluded that the heart rates during basketball were rather high despite the fact that there were rest periods throughout the game.

Summary

Clearly basketball, as played today, is both an aerobic sport and an anaerobic sport with continuous aerobic play and frequent bursts requiring anaerobic energy (Stone & Steingard, 1993). Improvements have been rare in aerobic power over the course of a season in college women's basketball players (Earnest, 1992; Hakkinen, 1993; Hilgenberg, 1996; McArdle et al., 1971; Sinning, 1973). However, a few studies have reported significant increases in anaerobic power (Earnest, 1992; Hakkinen, 1993).

There are few studies that have investigated both aerobic and anaerobic power of women college basketball players pre- and postseason. Certain studies have determined aerobic power (Hakkinen, 1993; McArdle et al., 1971; Sinning, 1973; Sinning & Adrian, 1968; Vaccaro et al., 1979), but testing modes and protocols were different, thus, any comparisons of the findings of the aforementioned studies need to be analyzed carefully. The highest mean value reported in published studies for the VO_{2max} of a college women's basketball team was 49.6 ml·kg⁻¹·min⁻¹ (Vaccaro et al., 1979), and the highest value reported in unpublished studies was 53.9 ml·kg⁻¹·min⁻¹ (Hilgenberg, 1988).

Regarding anaerobic power, Earnest (1992) found a significant increase in peak anaerobic power in 10 NCAA Division I women's basketball players using

the stair test. To determine mean anaerobic power, they used the Wingate cycle test. It was found that there was a significant increase in mean anaerobic power (Earnest, 1992). The results of these anaerobic tests are in conflict with the findings of Hilgenberg (1988) who found that mean anaerobic power increased, but not significantly with 11 members of a NCAA Division III team.

Hakkinen (1993) found that anaerobic power increased significantly pre- to postseason for 10 female players participating in an official league in Finland. The method used for determining anaerobic power was a 30 second maximal vertical jumping test. The subjects involved were also involved in an explosive type strength training program during the season. Thus, it is difficult to conclude that increases in anaerobic power were from the effects of the season itself or from the strength training.

CHAPTER III

METHODS AND PROCEDURES

Introduction

The purpose of this study was to measure the pre- and postseason aerobic and anaerobic power of women intercollegiate basketball players (WIBP) to determine what, if any, changes occurred over the season. A subpurpose was to monitor heart rate responses of WIBP during a practice, scrimmage, and actual competition. It was hypothesized that no significant physiological changes would occur between pre- and postseason.

The procedures for this study are presented as follows: subject selection; general procedures; determination of aerobic power (VO_{2max}); determination of peak anaerobic power; heart rate monitoring; and statistics. Preseason testing was completed 3 weeks before the first game and postseason testing was completed within one and one-half weeks after the last game.

Subject Selection

A letter was submitted to the coach describing the study (see Appendix A) and after meeting personally with the coach, permission was obtained to study the team for research purposes. Verbal permission was also obtained from the Athletic Director at a special meeting with the researcher. Fourteen members of the 1995 - 96 women's basketball team at the University of Wisconsin-La Crosse (UW-L) as listed on the eligible roster began the study. Due to one team member contracting mononucleosis four weeks before completion of the season, this subject did not complete any postseason testing.

thus, 13 subjects completed the study. Prior to any practice sessions or testing, written approval was received from the Human Subject's Review Board at the UW-L. In addition, each subject was required to sign an informed consent form (see Appendix B).

General Procedures

The purpose of the study, the procedures, and the time commitment were explained at a "team meeting" and informed consent forms were signed. The entire team was encouraged to participate, and it was explained that participation would not affect the process of team selection. Subjects were shown the equipment, namely, the treadmill, the Monark cycle ergometer, Polar Vantage XL heart rate monitors, headgear, and mouthpiece prior to testing. Any subject without prior treadmill experience was required to practice on the treadmill with the appropriate testing equipment.

Determination of Aerobic Power

In order to determine changes in aerobic power during the season, VO_{2max} tests were administered to each individual pre- and postseason using a Burdick motorized treadmill (Quinton, Bothell, WA). Protocol for the treadmill test was as follows: a 5 minute warm-up at 3.5 mph and 10% grade. The grade was then decreased to 0% and the speed was increased appropriately for each subject depending on fitness level and treadmill running experience (5 or 6 mph). Thereafter the grade was increased by 2.5% every 2 minutes. The subjects were encouraged to continue throughout the test.

The subjects wore Polar Vantage XL (Polar CIC, Inc., Port Washington, NY) heart rate monitors during the VO_{2max} tests. The transmitter was moistened with distilled water, strapped around the upper torso below the breasts, and also

secured slightly under the subject's bra. The receiver was taped along the handrail of the treadmill. The subjects were weighed and this value was entered into the metabolic cart.

Once the subject was fitted with the heart rate monitor, she stood motionless on the treadmill and was fitted with a Hans-Rudolph head support (model # 2726) and a mouthpiece. The mouthpiece was connected to a Rudolph two-way valve system (model # 2700). The right side of the valve system was fitted into a flexible rubber hose which connected the subject to the Quinton Q-Plex I Cardiopulmonary Exercise System with software revision E (Quinton, Bothell, WA). The left side of the valve system was set up to take in room air. The mouthpiece fit tightly into the mouth, and the subjects were instructed to seal their lips around it. Each subject also wore a nose clip throughout the test.

The Quinton Q-Plex Cardiopulmonary Exercise System consisted of an infrared carbon dioxide gas analyzer, an oxygen analyzer, a 6.0 L mixing chamber, and a syringe volume of 3.0 L. Due to technical difficulties with the Quinton Q-Plex I at the time of posttesting, a newer model (Quinton QMC metabolic cart) was used. The Quinton QMC metabolic cart consisted of an infrared carbon dioxide analyzer, a 5.4 L mixing chamber, and a syringe volume of 3.0 L.

The Q-Plex I and QMC were turned on and allowed to warm-up for 30 minutes prior to calibration. Room conditions were obtained and entered into the metabolic cart system, thus each system was calibrated for ambient temperature and barometric pressure. The gas fractions of carbon dioxide and oxygen were also calibrated to proper percentages and target volts.

Heart rates were read continuously from the Polar Vantage XL receiver and recorded every minute and entered into the respective metabolic cart's computer. Borg's Rating of Perceived Exertion Scale (Borg, 1982) was used and values were entered into the metabolic cart at the end of each stage (see Appendix C). This scale was explained to the subjects prior to testing and they were instructed to point to the number or the word on the scale that best represented how they perceived the effort. Breath by breath recordings, as well as minute values, were obtained from the metabolic carts for the following physiological variables: ventilation (V_E); relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$); absolute VO_{2max} ($L \cdot min^{-1}$); respiratory exchange ratio (RER); and, METs. The test was considered to be a valid maximal effort when the RER reached or surpassed the value of 1.0 and when there was a plateau in oxygen consumption despite an increase in work. In addition, all subjects ran until volitional exhaustion.

Determination of Anaerobic Power

Peak anaerobic power (PP), mean anaerobic power (MP), and fatigue index (FI) were measured using a Monark cycle ergometer (Varberg, Sweden) and the computerized Wingate test (Sports Medicine Industries, Inc., St. Cloud, MN). The resistance applied was determined relative to body weight: 0.075 kg per kg of body weight. The cycle had a weight basket weighing 0.5 kg, and this was recorded and used in calculating the resistance for each subject. The subjects were weighed prior to testing, and the corresponding resistance was added to the weight basket.

The seat height of the cycle was positioned to ensure a slight angle of the knee during pedaling. The feet of each subject were secured into the toe clips on

the pedals. Each subject was required to complete a 5-minute warm-up period and during this time, instructed to execute 2-3 all out bursts of 4-8 seconds pedaling as fast as possible. This warm-up was done against moderate resistance of 2-3 kg.

When the subject was ready, she began pedaling as fast as she could. At the point when she felt she was pedaling as fast as possible, she said the command "Go" and the weights were dropped into the weight basket. Continuous verbal encouragement was provided throughout the 30 second test. At the end of the 30 second test period, most of the weights were removed leaving 1-2 kg of resistance, and the subject was instructed to continue pedaling for at least 2-3 minutes. Following the cool-down on the cycle, each subject was instructed to walk around the room to prevent dizziness and to minimize muscle cramping and stiffness.

Revolutions were sensed by a photoelectric sensor attached to the Monark cycle. Photoelectric tape was located along the circumference of the flywheel. Peak power (PP) was calculated as the highest work completed in the first 5 seconds of the test and was calculated by the following formula:

$$PP = [(Resistance\ kg)(9.8\ m/sec^2)(1.615\ m/rev)(\# revs/min)(1\ min/60\ sec)]$$

Other values calculated were mean power (MP) and fatigue index (FI). The MP was an average of the power produced in each of the six, 5-second periods and calculated in the same manner as PP. The FI was calculated according to the following formula:

$$FI = \frac{\text{Peak Power} - \text{Min Power}}{\text{Peak Power}} \times 100$$

Heart Rate Monitoring

Polar Vantage XL heart rate monitors were worn by the subjects on three different occasions. The monitors were worn during a practice, a scrimmage, and an actual nonconference game. Eleven subjects were monitored during a team practice for approximately one and one-half hours, 11 subjects were monitored during a scrimmage for approximately two and one-half to three hours, and seven players were monitored in an actual game situation.

Application of the heart rate monitors occurred before the team practice, scrimmage, and game in the locker room. The transmitters were strapped around the chest as they were during the VO_{2max} tests. The receivers were taped with athletic tape to the bra strap of the nondominant arm and set to record heart rates at minute intervals. The monitors were down-loaded to an IBM computer using a software program by Polar CIC, Inc. (Port Washington, NY) following each session; thus, heart rate data were obtained from each subject.

Since the accuracy of multiple heart rate monitors when worn in close proximity was questionable, heart rate values were considered valid when there were realistic values in the minute values preceding and following a particular value. More specifically, certain heart rate readings were excluded from the data, because they were considered erroneous, such as readings of "0" or those well above "200". These invalid readings may have occurred from the subjects being in close proximity or from a malfunction of the monitor itself.

Statistics

Data analyses were executed by the VAX SPSS mainframe computer system. In addition to standard descriptive statistics, the pre- and posttesting values of each physiological variable measured were compared using a dependent t-test with the BMDP statistical package. The level of significance was set at .05. Standard descriptive statistics were also used for the heart rate data. A one-way ANOVA with repeated measures from the BMDP statistical package was used to compare maximal heart rate responses of the practice, scrimmage, and game to the preseason HR_{max} established during the VO_{2max} tests. Additionally, the Tukey post hoc procedure was applied to the HR_{max} data.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

Thirteen members of the 1995-96 UW-L women's basketball team were studied to determine changes in both aerobic and anaerobic power as a result of a season of competitive play. The athletes were tested three weeks before the first game and within one and one-half weeks after the last game of the season. In addition to standard descriptive statistics, dependent t-tests were used to compare pre- and postseason data. The level of significance was .05.

In addition, heart rate monitoring took place during one practice, scrimmage, and nonconference game. The heart rate responses during the aforementioned situations were compared to the HR_{max} values established during the preseason VO_{2max} test. A one-way ANOVA with repeated measures was used to compare heart rate responses.

Physical Characteristics and Team Record

The 1995-96 UW-L women's basketball team posted an overall record of 9 wins and 16 losses and a conference record of 5 wins and 11 losses. The first game of the season was played on November 18, 1995 and the last game was played on February 24, 1996. The team did not compete in any postseason tournament games. The mean age of the subjects ($N = 13$) at the beginning of the study was 19.1 years and their height averaged 170.8 cm. Although body weight slightly increased from preseason (66.8 ± 8.7 kg) to postseason (67.1 ± 8.3 kg), this difference was not significant ($p > .05$).

The mean height, weight, and age of the subjects in this study were all within the ranges of these variables mentioned by previous researchers of WIBP in Chapter II. It should be noted that the team under investigation did not have any player taller than six feet. The mean height reported by Smith and Thomas in 1991 was greater than 10 cm more than the mean height of the subjects in the current study, while the mean weight was also higher than that of the current study by 5 kg. Hilgenberg (1988) did not report the mean height of subjects.

Aerobic Power

All subjects met the criteria for reaching VO_{2max} as stated in Chapter III during all tests. There were no significant ($p > .05$) changes in any physiological components of aerobic power, RPE, or total test time over the season. Although the postseason value decreased $.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, this was not significant ($p > .05$). It appears that the effects of a season of women's intercollegiate basketball for 13 members of the 1995-96 UW-L team, namely, the training during the season coupled with playing a 25 game schedule were adequate to maintain their aerobic power. Preseason aerobic conditioning consisted of 1.5 mile runs three times per week until October 1, 1995 and then aerobic workouts occurred two times per week until October 20, 1995 when official practices began (C.A. Kennedy, personal communication, November 15, 1995). The preseason mean VO_{2max} value of $50.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ indicated that the team had a good aerobic base at the start of the season. Based on norms established by Shvartz and Reibold (1990), these players' VO_{2max} would place them in the "very good" to "excellent" classification. The mean scores and standard deviations of the subjects' physiological responses to the VO_{2max} test pre- and postseason are listed in Table 1.

Table 1. Means^a and standard deviations^b of subjects' (N=13) responses to VO_{2max} test pre-postseason

Variable	Pre	Post
V _E (L·min ⁻¹)	112.0 ^a 1.9 ^b	111.0 1.8
VO _{2max} (L·min ⁻¹)	3.302 .451	3.312 .539
VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)	50.8 4.4	50.0 3.6
METS	14.5 1.3	14.2 1.0
HR _{max} (beats·min ⁻¹)	186.5 6.4	188.2 4.1
RPE	18.9 1.2	18.9 .6
Total test time (min)	17.5 1.8	17.4 2.6

The "aerobic base" necessary for basketball was mentioned by Stone and Steingard (1993) who asserted that aerobic training as a base for conditioning allows the basketball player to practice and play longer and harder and with less fatigue. Subsequently, as a result, they suggested that there would be fewer chances for injury if a good aerobic training program has occurred preseason

(Stone & Steingard, 1993). Out of 13 subjects involved in the current study, three suffered ankle sprains and one was hampered by an ankle dislocation during the season, but the subjects were able to complete all testing procedures.

Of all the studies, Hilgenberg (1988) reported the highest VO_{2max} for her 11 WIBP with pre- to postseason values of 53.9 to 53.7 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. Smith and Thomas (1991) found a value of 51.3 $ml \cdot kg^{-1} \cdot min^{-1}$, but the 31 subjects on a Canadian national team were not tested pre- to postseason. The subjects involved in the current study had similar VO_{2max} values (50.8 to 50.0 $ml \cdot kg^{-1} \cdot min^{-1}$) thus were comparable to those subjects in both Hilgenberg (1988) and Smith and Thomas (1991) studies.

It should be noted that the team at UW-L studied by Hilgenberg in 1988 played 38 games while the team in the current study competed in only 25 games. Furthermore there may have been a difference between the Hilgenberg (1988) study and the current study in the style of play (i.e., running, fast-breaking style versus a slower, more controlled style).

Considering results from previous studies which included pre- and postseason VO_{2max} values of WIBP, the findings from the current study were in agreement with the results of the majority of available literature on this topic that VO_{2max} was not significantly altered over a competitive season. Despite the fact that protocols, time of testing, and mode of testing were different, VO_{2max} testing of aerobic power for WIBP has usually remained unchanged pre- to postseason (Earnest, 1994; Hakkinen, 1993; Hilgenberg, 1988; McArdle et al., 1971).

In contrast Sinning and Adrian (1968) found that VO_{2max} of WIBP increased significantly pre- to postseason for eight subjects; however, significant

increases in selected cardiovascular and pulmonary measurements were not found. Cardiovascular variables determined were blood pressure 30 seconds after the end of the VO_{2max} tests and hemoglobin values. Pulmonary variables determined were maximal voluntary ventilation and forced expiratory volume. The authors suggested the small sample size, in addition to numerous factors affecting VO_{2max} , as explanations for lack of improvement in the cardiovascular and pulmonary measurements that would normally improve if VO_{2max} increased.

McArdle et al. (1971) attributed the lack of improvement in VO_{2max} values as a result of a season of basketball to more than one factor. One factor suggested was that the subjects were in a highly trained state prior to the start of the season. Another factor suggested was that the intensity of women's basketball at the time was not high enough to overload the oxygen transport system (McArdle et al., 1971). However, from heart rate data collected in the same study, most subjects reached HR_{max} during game situations, but practices were found to be at a "moderate" intensity.

Hakkinen (1993) suggested that the high volume of training and the competitive season constituted sufficient demands on oxidative processes which maintained the VO_{2max} values throughout the season.

Vaccaro et al., (1979) did not conduct VO_{2max} testing pre- and postseason with 15 subjects from the University of Maryland women's basketball team, but reported a team average of $49.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ which is similar to values found by researchers mentioned in Chapter II. The authors stated that an elevated VO_{2max} had not been established as a prerequisite to success for women's basketball in the U.S.A., because the game was skill-oriented emphasizing shooting, passing,

and dribbling. These authors indicated that assessing aerobic power would become increasingly important in women's basketball.

Hoffman, Tenenbaum, Maresh, and Kraemer (1996) tested 29 male NCAA Division I basketball players over a four year period. Of those 29 athletes, 15 were tested in multiple years for endurance, speed, agility, and strength. From the endurance testing, the authors suggested that although basketball players need a high aerobic base, there is no additional benefit gained with an aerobic capacity greater than those of college or professional players. The subjects completed 2,414 m runs for performance times, and the authors claimed that the results were equivalent to a VO_{2max} of $50 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. The results of the current study are in agreement with these findings. It was interesting that the NCAA Division III women's team in this investigation had similar VO_{2max} values compared to the estimated VO_{2max} values of an NCAA Division I men's team.

Anaerobic Power

Similar to the aerobic results in this study, it appears that the basketball players were able to maintain their anaerobic power over the basketball season. Preseason anaerobic training consisted of sprint training two times weekly from early September 1995 until October 1, 1995 and then three times weekly until October 20, 1995 when official practices began. Weight training varied in frequency preseason and during the season (C.A. Kennedy, personal communication, March 15, 1996). There were no significant ($p > .05$) changes in any of the power variables as a result of a season of competitive play. Peak power increased slightly from 9.1 to 9.3 $\text{watts}\cdot\text{kg}^{-1}$ pre- to postseason, but this was not significant ($p > .05$). Mean power decreased slightly from 7.0 to 6.8

watts·kg⁻¹ which also was not significant ($p > .05$). The mean scores and standard deviations of the subjects' responses to the Wingate Cycle Ergometer Test are presented in Table 2.

Table 2. Means^a and standard deviations^b of subjects' (N=13) physiological responses to the Wingate cycle ergometer test pre-postseason

Variable	Pre	Post
Peak Power (watts)	608.2 ^a 80.4 ^b	622.6 82.9
Peak Power (watts·kg ⁻¹)	9.1 .8	9.3 .7
Mean Power (watts)	463.1 62.6	457.1 71.1
Mean Power (watts·kg ⁻¹)	7.0 .7	6.8 .7
Fatigue Index (%)	43.7 7.9	45.7 8.6
Resistance (kg)	5.0 .7	5.0 .6

The subjects in the current study had peak power (PP) values above the 95th percentile for women both pre- and postseason according to norms established by Maud and Shultz (1989). Also, the team average values of 463.1

and 457.1 watts for mean power (MP) pre- to postseason were comparable to the 85th to 90th percentile range for women based on norms reported by Maud and Shultz in 1989.

Using the same Wingate testing procedure as the current study, Hilgenberg (1988) reported a nonsignificant increase in absolute PP from 618.6 watts to 651.5 watts pre- to postseason for 11 subjects, but did not report relative values for PP, MP or fatigue index (FI). Thus, the only anaerobic power variable that could be compared between the study in 1988 by Hilgenberg and the current study was absolute peak power.

In the current study absolute peak power increased from 608.2 to 622.6 watts pre- to postseason, but this increase was not significant ($p > .05$). These values are somewhat lower than those of Hilgenberg (1988), but neither study found significant changes in this variable over the season. Although not significant, Hilgenberg (1988) suggested that the increase in anaerobic power could be from an increase in anaerobic energy substrates developed over a season of play.

Hakkinen (1993) used a 30 second maximal vertical jumping test to determine the anaerobic power of 10 female basketball players from a team in an official league in England pre- to postseason. Power output was calculated for two time periods (0 to 15 seconds and 15 to 30 seconds) and for total time. Significant ($p < .05$) increases were found for the first 15 second work period and for the total work period of 30 seconds. However, these subjects participated in explosive type strength training during the season. Hakkinen (1993) suggested that it was impossible to determine if the increases in anaerobic

power were from the strength training during the season, the drills in practices, or training effects from actual games.

Earnest (1992) reported significant ($p < .05$) increases in both anaerobic power and anaerobic capacity in 10 WIBP pre- to postseason. In this study the Margaria-Kalamen stair test was used to determine anaerobic power and the Wingate test was used to determine anaerobic capacity. The pre- and postseason values of 1243.8 to 1355.9 watts for anaerobic power in the 1992 study by Earnest were much higher than both the Hilgenberg (1988) study and the current study. Earnest (1992) stated that it was surprising to find such increases in power, because these increases would be expected during an organized preseason conditioning program. Possible reasons for Earnest (1992) finding values more than twice the values found in the 1988 study by Hilgenberg and the current study include the testing protocol, the state of training of the athletes involved, and the level of competition of the subjects.

MacDougall et al., (1991) suggested that the Margaria-Kalamen stair test measures short-term anaerobic power, while the Wingate test measures intermediate anaerobic power. The women studied by Earnest in 1992 may have achieved higher results in anaerobic power, because higher results are obtained from the stair test versus the Wingate test. Higher values could be achieved from the stair test because the test measures the time it takes the subject to get from the third stair to the ninth stair and the entire body weight moves over a shorter distance than the distance covered in the Wingate test, and the test takes less than one second to complete. Furthermore, the stair test is not a continuous load test due to the fact that the feet are not always in contact with the stairs (i.e., as one is leaping from the third to ninth stair). Pedaling the cycle

ergometer for the Wingate test is a nonweight bearing activity whereas the stair test allows a running start which imparts momentum to the subject.

Heart Rate Responses

Maximal heart rate responses from the preseason VO_{2max} test, a practice, a scrimmage, and an actual game were compared using a one-way ANOVA with repeated measures. For the seven subjects that were monitored in all four situations, a significant ($p < .001$) difference was found among the HR_{max} values (see Figure 1) using the Tukey post hoc procedure.

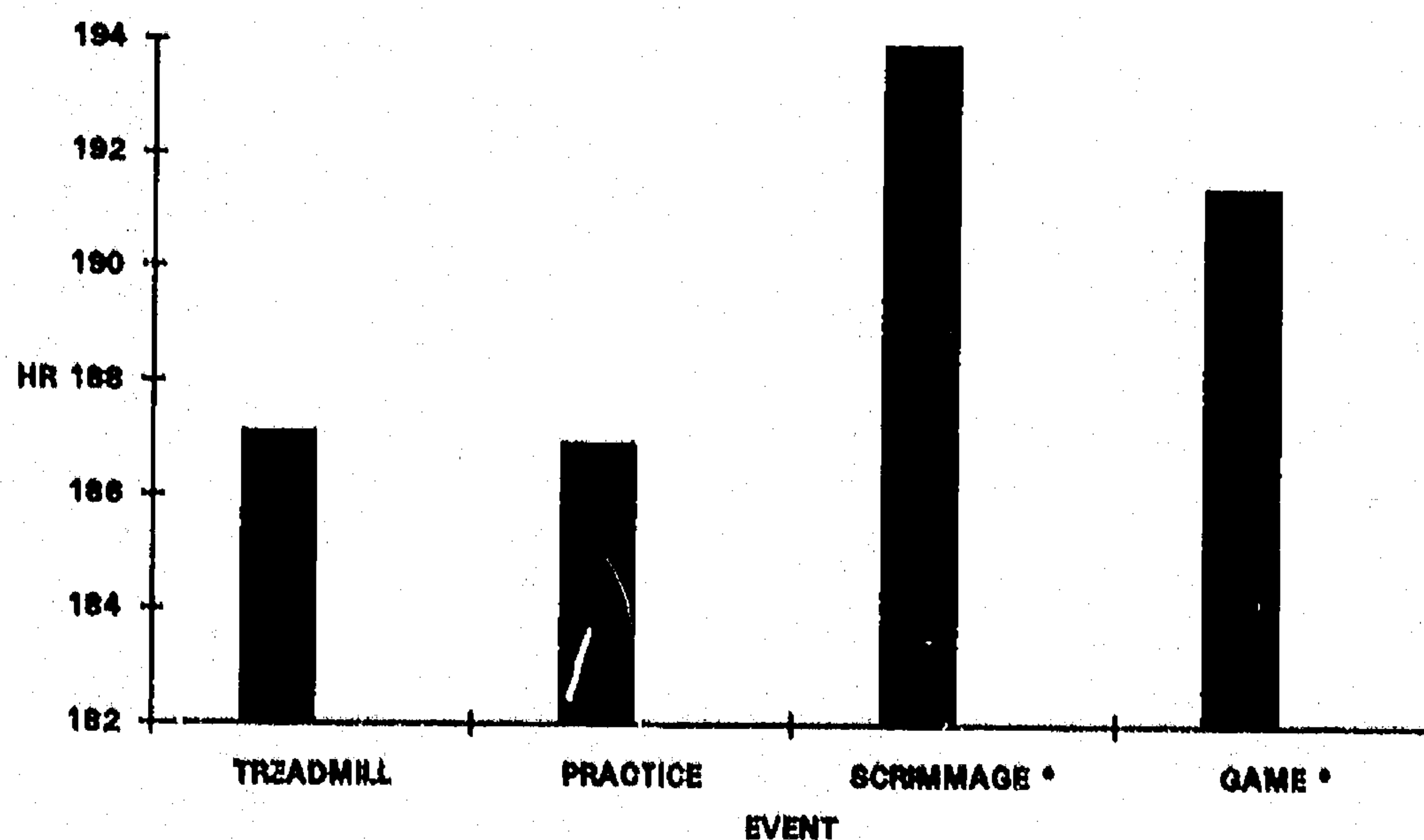


Figure 1. Mean HR_{max} values for 7 players during the preseason treadmill VO_{2max} test and practice, scrimmage, and game situations.

*significantly ($p < .001$) higher than TM and practice

HR_{max} values during the scrimmage ranged from 98 to 106% of the HR_{max} established from the preseason VO_{2max} tests, and HR_{max} values during the game ranged from 99 to 106% of the HR_{max} established from the preseason

VO_{2max} tests. Additionally, heart rate data from 11 subjects were collected from the preseason VO_{2max} test, practice, and scrimmage as shown in Figure 2.

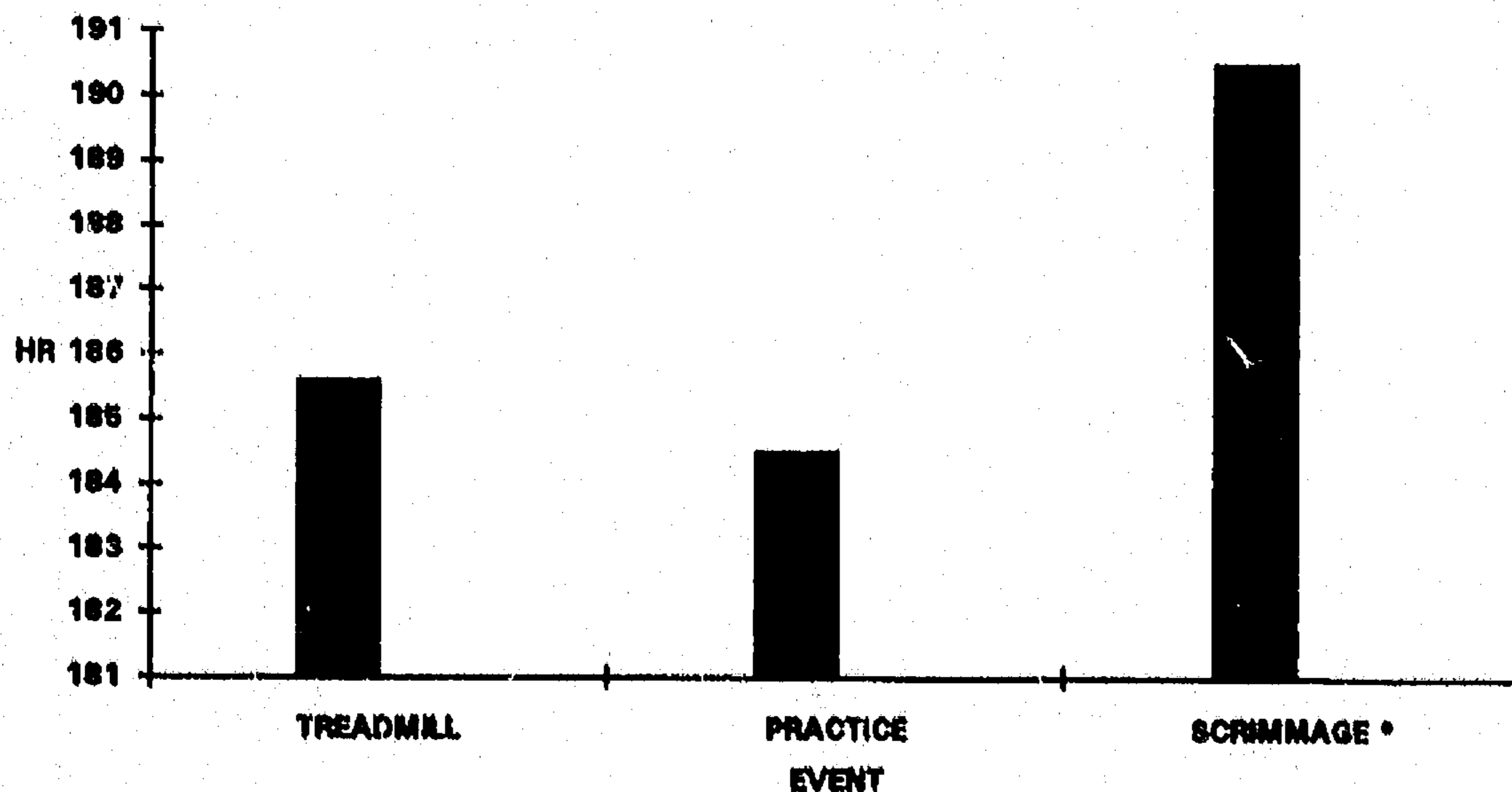


Figure 2. Mean HR_{max} values for 11 players during the preseason treadmill VO_{2max} test, and practice and scrimmage situations.

*significantly ($p < .001$) higher than TM and practice

The Tukey post hoc procedure revealed that the HR_{max} values for 11 subjects achieved at the scrimmage were significantly ($p < .001$) higher than the HR_{max} values at both the practice and the preseason VO_{2max} tests. These heart rates were taken from data that included live playing time as well as time outs and half-time, because the monitors were applied before the event started and were removed in the locker room a few minutes after the event ended.

Heart rate data were collected from one player during a practice, scrimmage, and game (see Figure 3). The preseason HR_{max} determined during the preseason VO_{2max} test was $190 \text{ beats} \cdot \text{min}^{-1}$ for this individual.

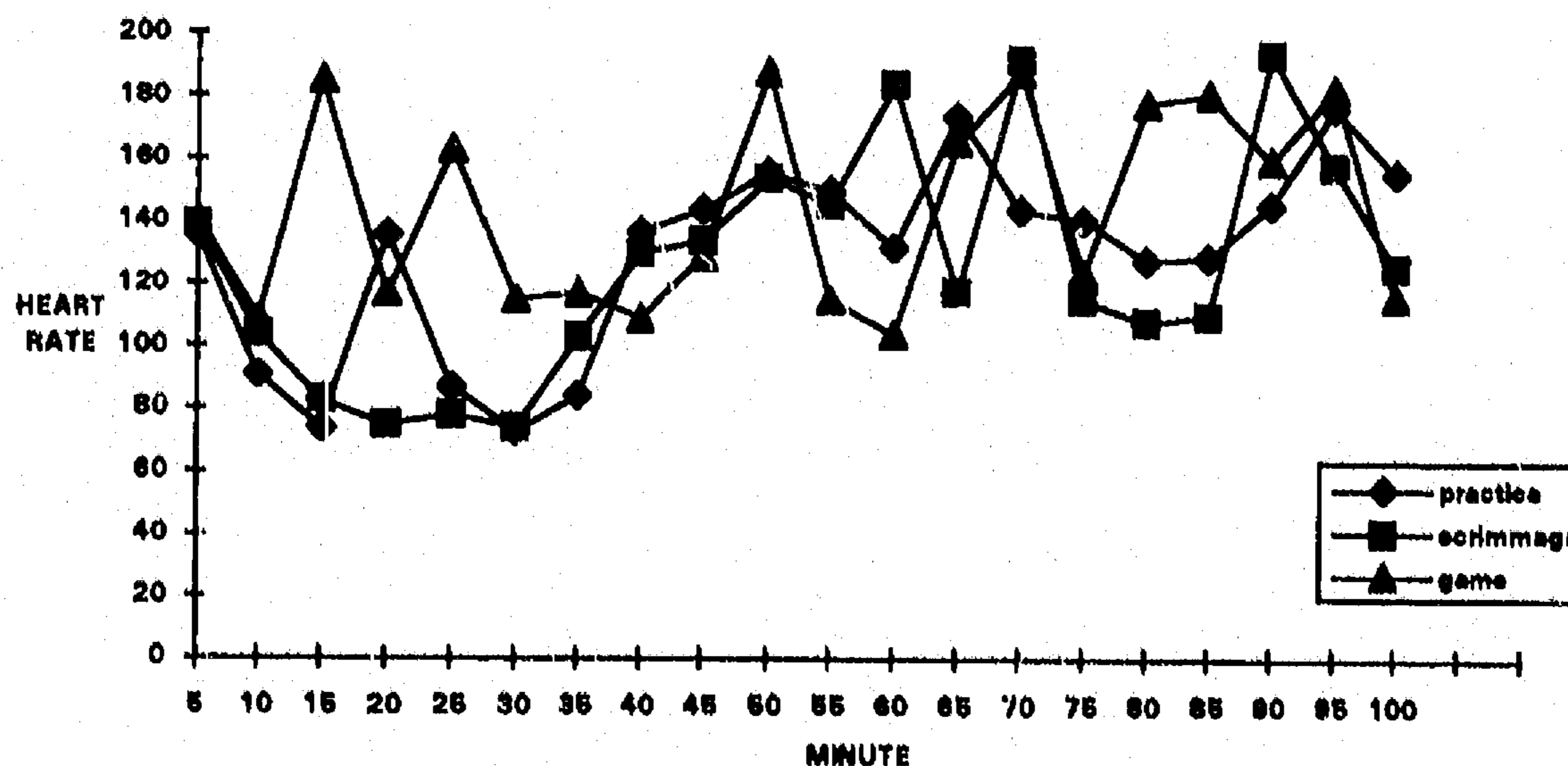


Figure 3. Example of individual player's HR responses during practice, scrimmage, and game situations.

The higher heart rates found during the scrimmage and game for seven subjects as well as for the 11 subjects during the scrimmage in this study could be from the psychological stress that players normally face in competitive situations. During the preseason treadmill VO_{2max} tests, there was not any specific situational stress. The subjects were familiar with the requirements of the treadmill test, and they were not necessarily competing as they do in a scrimmage or game situation. During practice situations, the team usually

executed drills, sprint training, and intrasquad play. The scrimmage was the first competitive situation of the season for the subjects that was not intrasquad.

Possible physiological explanations for the higher HR_{max} values during the scrimmage and game situations include increases in sympathetic stimulation and decreases in vagal tone as a result of the competition. The release of the catecholamines can cause the heart to beat more rapidly and with more strength. McArdle et al. (1991) stated that variations in one's emotional state significantly affect cardiovascular responses, and cerebral impulses also cause the heart rate to rise considerably in anticipation of exercise. The treadmill test required maximal exertion, but did not involve the same psychological or emotional demands as competition. Thus the players may have experienced more situational stress during the scrimmage and game than both the practice and treadmill test causing occasional high heart rates.

It should also be noted that the HR_{max} values for any one player were not sustained for any substantial length of time. This could indicate that during the game and scrimmage there were periods of high intensity activity, but this activity was not of sufficient duration to equal that required of a VO_{2max} test. Moreover, even though HR_{max} values during the scrimmage and game for seven subjects were higher than the preseason VO_{2max} tests, the heart rates during competition did not rise steadily as in a treadmill VO_{2max} test, since there are periods of alternating types of activity and stops in the game.

The heart rate findings of the current study are consistent with McArdle et al. (1971) who used telemetry with six WIBP to obtain heart rate data. Heart rates from actual game play and time outs ranged from 105 to 204 bpm. When time outs and other breaks in play were excluded heart rates ranged from 154 to

195 bpm. These heart rates represented 81 to 95% of the HR_{max} values established from treadmill tests. The authors mentioned that there was considerable variability in heart rates between and within subjects. Players involved in the current study also exhibited variability in heart rates with values ranging from 107 to 202 bpm.

McInnes, Carlson, Jones, and McKenna (1995) also used short-range telemetry to monitor heart rates of eight Australian male basketball players. Heart rates were recorded at 15-second intervals during game situations. The average heart rate during live time was 169 ± 9 beats·min⁻¹ which corresponded to $89 \pm 2\%$ of peak heart rates determined by laboratory testing. These researchers concluded that basketball necessitates a high energy demand due to consistently high heart rates. Even though the high heart rates could have indicated a high aerobic contribution, psychological arousal can also influence the values (McInnes et al., 1995).

Studies involving heart rate monitoring of basketball players during the 1990s (McInnes et al., 1995; Terrados et al., 1995) have found similar results to those from the 1960s and the 1970s (Armstrong, 1964; Huchison, 1969; McArdle et al., 1971; Cant, 1965). The heart rate responses found in the current study are also consistent with the previous studies involving basketball players. It appears that the WIBP studied herein compete at high intensities as indicated by high heart rate responses during a scrimmage and a game.

CHAPTER V
SUMMARY, CONCLUSIONS,
PRACTICAL APPLICATIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine what, if any, changes occurred in both aerobic and anaerobic power pre- to postseason in 13 members of the University of Wisconsin-La Crosse women's basketball team. Aerobic power was determined by treadmill VO_{2max} testing, and anaerobic power was determined by the Wingate cycle ergometry test. Aerobic responses measured included VO_{2max} expressed in both relative ($ml \cdot kg^{-1} \cdot min^{-1}$) and absolute ($L \cdot min^{-1}$) terms, HR_{max} , V_E , METs, RER, RPE, and total treadmill time. Anaerobic responses measured included both peak and mean power expressed in relative ($watts \cdot kg^{-1}$) and absolute (watts) terms, resistance, and fatigue index. A subpurpose was to monitor and compare maximal heart rate responses from the preseason VO_{2max} tests, a practice, a scrimmage, and an actual game.

Dependent t-tests from the BMDP statistical program were used to compare both aerobic and anaerobic power pre- to postseason results with a level of significance set at .05. A one-way ANOVA with repeated measures and the Tukey post hoc procedure were used to make comparisons of the HR_{max} data.

Conclusions

1. There were no significant ($p > .05$) changes in any physiological components of aerobic power pre- to postseason, so the null hypothesis was accepted.

2. There were no significant ($p > .05$) changes in any physiological components of anaerobic power pre- to postseason, so the null hypothesis was accepted.
3. For seven subjects, there was a significantly ($p < .001$) higher HR_{max} response in both the scrimmage and game situations versus both the preseason VO_{2max} tests and the practice.
4. For 11 subjects, there was a significantly ($p < .001$) higher HR_{max} response in the scrimmage versus both the preseason VO_{2max} tests and the practice.

Practical Applications

1. The results of this study indicate that the preseason training was adequate in establishing both aerobic and anaerobic power that were maintained over the season for 13 members of the 1995-96 UW-L women's basketball team.
2. The training which occurred as a result of the team practices and the games was sufficient to maintain both aerobic and anaerobic power for 13 members of the 1995-96 UW-L women's basketball team.

Recommendations

1. A longitudinal study could be done in the future on any returning participants of the 1995-96 UW-L women's basketball team to compare both aerobic and anaerobic power at different points in the subjects' and team's career.
2. A study could be done comparing both aerobic and anaerobic power of male intercollegiate basketball players to that of women players.

3. A repeated measures design study could be used to make comparisons which may occur during the season itself.
4. A study could be done pre- and postseason with high school females to compare physiological values to those at the collegiate level.
5. A study could be done on an American Olympic team to be compared with other international data.
6. Heart rate monitoring of basketball players could be done during the Wingate test and compared to heart rate responses from competition.
7. Submaximal testing of aerobic and anaerobic power could occur at various points during the season as "checkpoints" to monitor a team's fitness.

REFERENCES

American College of Sports Medicine (1995). ACSM's guidelines for exercise testing and prescription. (5th ed.). Baltimore, MD: Author.

Armstrong, J. (1964). The effects of participation in selected activities on the heart rate of college women. Unpublished master's thesis, University of Washington, Seattle.

Bhanot, J.L., & Sidhu, L.S. (1981). Maximal anaerobic power in national level Indian players. British Journal of Sports Medicine, 15, 265-268.

Borg, G.A.V. (1982). Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise, 14, 377-381.

Cant, M.V. (1965). A further investigation of the effect of participation in selected activities on the heart rate responses of college women. Unpublished master's thesis, University of Washington, Seattle.

Coleman, A.E., Kreuzer, P., Friedrich, D.W., & Juvenal, J.P. (1974). Aerobic and anaerobic responses of male college freshmen during a season of basketball. Journal of Sports Medicine, 14, 26-31.

Earnest, E.K. (1992). Seasonal changes in selected physiological variables of female basketball players. Unpublished master's thesis, Brigham Young University, Provo, Utah.

Hakkinen, K. (1993). Changes in physical fitness profile in female basketball players during the competitive season including explosive type strength training. The Journal of Sports Medicine and Physical Fitness, 33, (1) 19-26.

Hilgenberg, H. (1988). The effects of a season of intercollegiate basketball on various fitness measures of women players. Unpublished master's thesis, University of Wisconsin-La Crosse, La Crosse.

Hoffman, J.R., Tenenbaum, G., Maresh, C.M., & Kraemer, W.J. (1996). Relationship between athletic performance tests and playing time in elite college basketball players. Journal of Strength and Conditioning Research, 10, (2) 67-71.

Huchison, J. (1969). The effects of situational stress on women basketball players. Unpublished master's thesis, Illinois State University, Normal.

Hult, J.S., & Treckell, M. (Eds.). (1991). A century of women's basketball from frailty to final four. Reston, VA: American Alliance for Health, Physical Education, Recreation and Dance.

Inbar, O., Dotan, R., & Bar-Or, O. (1976). Aerobic and anaerobic components of a thirty second supramaximal cycling task [Abstract]. Medicine and Science in Sports, 8, 51.

Lieberman-Cline, N., & Roberts, R. (1996). Basketball for women: Becoming a complete player. Champaign, IL: Human Kinetics.

MacDougall, J.D., Wenger, H.A., & Green, H.J. (Eds.). (1991). Physiological testing of the high performance athlete. Champaign, IL: Human Kinetics.

Margaria, R., Aghemo, P., & Rovelli, E. (1966). Measurement of muscular power (anaerobic) in man. Journal of Applied Physiology, 21, 1662-1664.

Maud, P.J., & Shultz, B.B. (1989). Norms for the Wingate Anaerobic Test with comparison to another similar test. Research Quarterly for Exercise and Sport, 60, (2), 144-151.

McArdle, W.D., Katch, F.I., & Katch, V.L. (1991). Exercise physiology energy, nutrition, and human performance. Philadelphia: Lea & Febiger.

McArdle, W.D., Magel, J.R., & Kyvallos, L.C. (1971). Aerobic capacity, heart rate and estimated energy cost during women's competitive basketball. The Research Quarterly, 42, 178-186.

McInnes, S.E., Carlson, J.S., Jones, C.J., & McKenna, M.J. (1995). The physiological load imposed on basketball players during competition. Journal of Sport Sciences, 13, 387-397.

Pankey, R.B., Bacharach, D.W., & Gaugler, R.A. (1996). Anaerobic power differences in fit women across age. Journal of Strength and Conditioning Research, 10, (1) 62-64.

Polar CIC., Inc. (1992). Polar vantage XL heart rate monitor user's instruction manual [manual]. Port Washington, NY: Author.

Quinton Instrument Company (1989). Q-plex I cardiopulmonary exercise system operator manual [manual]. Bothell, WA: Author.

Quinton Instrument Company (1994). Quinton metabolic cart operator manual [manual]. Bothell, WA: Author.

Shangold, M., & Mirkin, G. (1994). Women and exercise: Physiology and sports medicine. Philadelphia: Davis.

Shvartz, E., & Reibold, R.C. (1990). Aerobic fitness norms for males and females aged 6 to 75 years: A review. Aviation, Space, and Environmental Medicine, 61, 3-11.

Sinning, W.E. (1973). Body composition, cardiorespiratory function, and rule changes in women's basketball. The Research Quarterly, 44, 313-321.

Sinning, W.E., & Adrian, M.J. (1968). Cardiorespiratory changes in college women due to a season of competitive basketball. Journal of Applied Physiology, 25, 720-724.

Smith, H.K., & Thomas, S.G. (1991). Physiological characteristics of elite female basketball players. Canadian Journal of Sport Science, 16, 289-295.

Sports Medicine Industries, Inc. (1991). User's software manual version 1.02 [manual]. St. Cloud, MN: Author.

Stone, W.J., & Steingard, P.M. (1993). Year-round conditioning for basketball. Clinics in Sports Medicine, 12, 173-191.

Terrados, N., Fernandez, B., Perez-Landaluce, J., Rodriguez, M., Coloma, M., & Buceta, J.M. (1995, May). Physiological aspects of women's basketball. Medicine and Science in Sports and Exercise, 26 (Suppl.), S24.

Vaccaro, P., Clarke, D.H., & Wrenn, J.P. (1979). Physiological profiles of elite women basketball players. Journal of Sports Medicine, 19, 45-54.

Verma, S.K., Mohindroo, S.R., & Kansal, D.K. (1979). The maximal anaerobic power of different categories of players. Journal of Sports Medicine, 19, 55-62.

Withers, R.T., Roberts, R.G.D., & Davies, G.J. (1977). The maximum aerobic power, anaerobic power and body composition of South Australian male representatives in athletics, basketball, field hockey and soccer. Journal of Sports Medicine, 17, 391-400.

APPENDIX A

LETTER TO COACH KENNEDY

P.O. Box 326
Fountain City, WI 54629

September 22, 1988

Ms. Cheryl Kennedy
Head Women's Basketball Coach
University of Wisconsin-La Crosse
Mitchell Hall
La Crosse, WI 54601

Dear Coach Kennedy:

I would like to study aerobic power and anaerobic power during a season of intercollegiate women's basketball competition. In this study I will measure aerobic capacity and anaerobic power pre- and postseason.

To determine aerobic capacity and anaerobic power, I would like to test the women's basketball team pre- and postseason on the treadmill for VO_{2max} and on the cycle ergometer for anaerobic power. Separate tests will be completed within two weeks of each other. Preseason measurements will be completed before your official practice begins. Postseason measurements will be completed 1-2 weeks after the season is over.

From the preseason VO_{2max} test, maximum heart rates of each player will be determined. Heart rate monitors will be used during selected practices and games to determine if maximal heart rates are reached.

I will be contacting you with the specific dates that practice sessions can occur and we can meet to determine specific dates for the testing.

Thank you,

Lori Kleinschmidt
AF/CR Graduate Student

APPENDIX B
INFORMED CONSENT

PHYSIOLOGICAL RESPONSES TO A BASKETBALL SEASON
INFORMED CONSENT

I, _____, would like to volunteer to participate in a study to determine the physiological changes that occur over a basketball season. This study will require the measuring of my maximal aerobic power (VO_{2max}) and my maximal anaerobic power pre- and postseason. In addition I may be asked to have my heart rate monitored during practice and/or an actual game.

My maximal aerobic power (VO_{2max}) will be determined on a treadmill test which will consist of walking/running to voluntary exhaustion on a motor-driven treadmill. After a 5-minute warm-up walking at 3.5 mph and 10% grade the treadmill speed will be increased to a comfortable speed. This speed will be based upon how active I am as determined through various questions. Once this comfortable speed has been determined it will remain constant throughout the test however the elevation of the treadmill will be gradually increased (2.5 % each 2 minutes) throughout the test.

During the treadmill test, my heart rate will be monitored continuously with a heart rate monitor strapped to my chest. Also I will breathe room air through a mouthpiece so that my exhaled air can be collected and analyzed. Although this test will require maximal effort I understand that I can stop the test anytime I wish. As with any exercise, there exists the possibility of adverse changes occurring (i.e., dizziness, difficulty in breathing, etc.) during the test. In addition, I will probably feel tired at the end of the test. If any abnormal observations are noted at any time, the test will be immediately terminated.

A Wingate cycle ergometer test will be given to determine my anaerobic power. This anaerobic power test will involve a short, no longer than 30 seconds, all-out effort on a cycle ergometer after an adequate warm-up period. I understand that I will be required to pedal against a resistance as fast as I can for the duration of the test. The resistance will be based on my individual body weight (i.e., the more I weigh, the greater the resistance will be). After the 30 second test I will be required to "cool-down" until I have recovered.

This power test may make my legs sore as would any high intensity, short duration activity. This soreness is usually short-lived and generally will not interfere with any other activity. I will be closely monitored after this test since

some individuals may experience nausea or become light-headed immediately after the test.

Heart rates will be measured at various times during practice and/or game situations using heart rate monitors that will be strapped around my chest. Other than the possible discomfort of this strap there should be no interference with my ability to play.

All practice sessions and testing sessions will be scheduled at my convenience. The tests and practice sessions will be supervised/conducted by Lori Kleinschmidt, a graduate student enrolled in the Adult Fitness/Cardiac Rehabilitation graduate program under the direction of N.K. Butts, Ph.D.

I consider myself to be in good health and to my knowledge I am not infected with a contagious disease or have any limiting physical conditioning or disability, especially with respect to my heart, that would preclude my participation in the tests as described above. I have read the foregoing material and I understand what is expected from me. Any questions which may have occurred to me have been answered to my satisfaction. I, therefore, voluntarily consent to participate in this test although I may withdraw at any time without any type of penalty. Furthermore I understand that neither participating in this study nor the results of these tests will influence my chance of being selected to the 1995-96 UW-La Crosse women's basketball team.

NAME: _____ DATE: _____

WITNESS: _____ DATE: _____

APPENDIX C

BORG'S RATING OF PERCEIVED EXERTION SCALE

Borg's Rating of Perceived Exertion Scale (Borg, 1982)

6	
7	Very, Very Light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very, Very Hard
20	