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THE EFFECTS OF A SEASON OF COMPETITION AND TRAINING ON SELECTED PHYSIOLOGICAL PARAMETERS OF AN INTERCOLLEGIATE WOMEN'S BASKETBALL TEAM

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Theodore G. Kurowski, Jr.

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By

Theodore G. Kurowski, Jr.

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ABSTRACT

THE EFFECTS OF A SEASON OF COMPETITION AND TRAINING ON SELECTED PHYSIOLOGICAL PARAMETERS OF AN INTERCOLLEGIATE WOMEN'S BASKETBALL TEAM

By

Theodore G. Kurowski, Jr.

The purpose of this study was to examine the effects of a season of competition and training on oxygen uptake, heart rate response, and lactate accumulation. Twelve members of an intercollegiate women's basketball team were evaluated three times during the season using a progressive, intermittent treadmill test. Repeated-measures analysis of variance revealed no significant changes in any of the parameters measured over the course of the season. When analyzed nonparametrically using the Sign test, significant differences were found in heart rate response and lactate accumulation. It was concluded that the subjects have not reached their full aerobic potential. It appears that the training program was not intense enough to greatly improve the fitness level of the subjects in this study.

To my parents, Ted and Virginia,

and my brothers, Tom and Dave.

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CHAPTER I

INTRODUCTION

Women of all ages have become more involved in sports and physical activity programs in recent years. This increased participation has become evident in improved performances in both competitive situations and research laboratories. There have been an increasing number of studies describing the cardiorespiratory characteristics of female athletes involved in individual sports such as running (4, 14, 27, 44, 45) and cross-country skiing (4, 31, 32, 33, 42, 44) and in team sports such as field hockey (3, 11, 24, 47, 48) and volleyball (19, 24, 28, 40).

There have also been studies investigating the responses of women to various types and intensities of training (2, 6, 10, 12, 13 15, 18, 22, 23, 28, 32, 46). These studies have clearly indicated that significant increases in cardiorespiratory function, as measured by maximal oxygen uptake (max $\dot{V}O_2$) in milliliters O_2 per kilogram of body weight per minute ($ml \cdot kg^{-1} \cdot min^{-1}$), are possible in untrained and trained women involved in training programs. Maximal oxygen uptake can be defined as the highest volume of oxygen an individual can extract from inspired air during exercise involving large muscle groups (1).

One area of research that has not been thoroughly examined is the effects of a season of competition and training on female athletic teams. The results of the studies that have been done in this area have been inconclusive. There have been studies that have shown significant improvement in performance (35, 39), while other studies have shown no change (3, 25), and at least one study has shown a significant decrease in performance (38). Although there are many factors that can contribute to these results, including the pretest fitness level and the training intensity, there appears to be a need for further examination of the effects of training and competition on female sports team members.

Purpose of the Study

This study was undertaken to determine the changes that occur in the cardiorespiratory parameters of intercollegiate female basketball players as a result of a season of competition and training. The parameters examined were oxygen uptake, heart rate, and blood lactate concentration.

Significance

The data obtained from this study will provide descriptive information pertaining to the effects of a competitive season on female basketball players. The results should also be useful in evaluating the basketball team's current training program and developing a more effective program if needed.

Limitations

1. The study involved only one female athletic team (basketball) with a small number of members (N = 12).

2. There was no control over the subjects' fitness level before the first test session.

3. There is no way to be certain that each test was an exhaustive test.

4. A limited number of parameters was measured.

CHAPTER II

REVIEW OF LITERATURE

In 1967, Saltin and Astrand (33) studied 95 males and 38 females who were members of various Swedish National Teams. The conclusions that the investigators drew were that there is an upper limit to the degree maximal oxygen uptake can be improved and that natural endowment is of major importance. Zeldis, Morganroth, and Rubler (48) investigated the effects of athletic conditioning on cardiac structure. They found no significant structural differences between college athletes and world-class athletes. This led to the conclusion that maximal performance is related to many factors, including peripheral oxygen extraction, aerobic and anaerobic energy metabolism, muscular strength, and psychological motivation.

Summary data from various descriptive studies found in the literature are reported in Tables 1 and 2. Table 1 contains data concerned with female athletes participating in individual sports such as running and swimming. Cross-country skiers, as a group, demonstrated the highest max $\dot{V}O_2$ values (mean = 58.1 $ml \cdot kg^{-1} \cdot min^{-1}$) although runners (mean = 56.8 $ml \cdot kg^{-1} \cdot min^{-1}$) also exhibited good aerobic power. Table 2 contains data from studies of female athletes involved in team sports. This table includes data from studies in which subjects were

Table 1.--Characteristics of female athletes involved in individual sports.[a]

Sport	N	Age (Years)	Weight (kg)	Body Fat (%)	max $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	max HR (bpm)	Type of Work
Running							
Cross-country (44)	6	12.6	42.6	16.6	52.5	194	Treadmill
Middle distance (27)	8	18.8	52.7	16.8	54.0	179	Bicycle ergometer
Distance (4)	9	20.3	50.6	--	59.0	191	Treadmill
Endurance (14)	7	28.0	53.7	19.0	59.3	175	Treadmill
Distance (45)	11	32.4	57.2	15.2	59.1	180	Treadmill
Cross-country skiing (44)	6	16.5	52.7	23.5	50.2	--	Treadmill
Cross-country skiing (4)	11	16.5	60.5	--	57.9	203	Treadmill
Cross-country skiing (31)	5	24.3	59.1	21.8	68.2	195	Treadmill
Cross-country skiing[b] (4)	10	28.2	59.5	--	52.0	193	Treadmill
Cross-country skiing (42)	14	--	--	--	56.4	--	Treadmill
Skiing (33)	5	25.0	58.7	--	63.6	194	Treadmill
Swimming (27)	8	14.6	48.2	17.0	51.4	181	Bicycle ergometer
Swimming (4)	16	18.2	59.1	--	50.6	190	Treadmill
Swimming (33)	2	15.5	58.9	--	59.3	200	Treadmill
Pentathalon (4)	9	20.7	64.3	--	52.0	194	Treadmill
Pentathalon (20)	9	21.5	65.4	11.0	45.9	185	Treadmill
Rowing (4)	14	18.9	64.0	--	49.3	194	Treadmill
Gymnastics (27)	10	14.3	46.1	14.6	41.6	176	Bicycle ergometer
Ballet (7)	4	23.7	49.5	--	43.7	185	Treadmill
Orienteering (33)	3	24.3	58.0	--	60.1	192	Treadmill
Untrained (26)	30	19.4	57.9	--	29.8	184	Bicycle ergometer
Untrained (41)	34	20.3	57.3	22.3	35.7	195	Treadmill

[a]All values are group means.

[b]Amateurs.

Table 2.--Characteristics of female athletes involved in team sports.[a]

Sport	N	Age (Years)	Weight (kg)	Body Fat (%)	max $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	max HR (bpm)	Type of Work
Basketball (34)	21	23.0	--	--	42.2	176	Bicycle ergometer
Basketball (43)	15	19.4	68.3	20.8	49.6	186	Treadmill
Basketball (30)	20	21.5	62.1	15.8	50.1	190	Treadmill
Field hockey (48)	10	20.1	58.1	--	51.7	185	Treadmill
Field hockey (47)	11	22.4	62.9	25.3	50.2	191	Treadmill
Field hockey/lacrosse (10)	18	19.2	60.0	20.9	49.8	--	Bicycle ergometer
Volleyball (19)	19	19.9	64.1	21.3	56.0	195	Treadmill
Volleyball (40)	15	23.3	67.2	--	43.2	180	Treadmill
Volleyball (29)	14	21.6	70.5	17.9	50.6	179	Treadmill
Softball (47)	13	21.4	64.0	26.9	45.4	194	Treadmill
Mixed[b] (24)	26	19.7	62.2	19.4	41.0	195	Treadmill
Field hockey	10	--	--	--	42.9	--	--
Volleyball	11	--	--	--	39.2	--	--
Basketball	3	--	--	--	40.8	--	--

[a]All values are group means.

[b]Group also included two swimmers.

measured once during their season. As a group, field hockey players obtained the highest maximal oxygen uptake value (mean = 48.7 $ml \cdot kg^{-1} \cdot min^{-1}$) while also carrying the highest percentage of body fat (mean = 23.1). Studies involving individual sports participants demonstrated higher maximal oxygen uptake values than investigations of team sports participants. The nature of the sports in which the subjects are involved and the specificity of the test administered to each group of subjects may be relevant factors in explaining this observation.

In 1981, Berg and Keul (4) examined the physiological responses to exercise of 69 female athletes involved in various sports. Parameters investigated included oxygen uptake, lactic acid, glucose, urea, free fatty acids, and various muscle enzymes. The investigators concluded that males and females exhibit similar responses to "long-lasting exercise" and that males do not have any advantage over females in regard to physiological responses to this type of exercise.

Rusko and Rahkila (32) drew a similar conclusion in a 1981 study involving 15 well-conditioned female cross-country skiers divided into three different training groups. The first group increased the amount of intensive training and emphasized interval work, while the second group decreased the amount of intensive work but increased their total amount of training by using more low-intensity, distance work. The third group continued their normal training programs. Intensive training was defined as training at a heart rate 0-15 beats per minute less than an individual's maximum heart rate. All three groups trained for 4 months. The investigators found a significant increase of 6.1% in max $\dot{V}O_2$ in all three groups combined (51.9 to 55.1 $ml \cdot kg^{-1} \cdot min^{-1}$). Both the interval work group and the distance work group exhibited significant increases in maximal oxygen uptake, while the normal work group produced a nonsignificant increase. Rusko and Rahkila concluded that male and female athletes respond similarly to endurance training. The investigators also concluded that improvement in oxygen consumption of athletes is related to frequency and quantity of high-intensity training.

In trying to maximize training effects, various methods for determining training intensity have been examined. In 1977, Burke (6) investigated the effects of an 8-week progressive interval running program at an intensity 75 to 85% of maximum heart rate. The subjects were untrained females (mean age = 18.9 years). The program involved 1/2 mile runs separated by 1/4 mile walks. Total distance run progressed from 1 mile at the beginning of the study to 2-1/2 miles at the end. The subjects exhibited a significant increase in mean max $\dot{V}O_2$ (31.7 to 39.3 $ml \cdot kg^{-1} \cdot min^{-1}$), which was attributed to training effect.

Lortie et al. (22) demonstrated a significant increase of 35% in mean maximal oxygen uptake (33.0 to 44.0 $ml \cdot kg^{-1} \cdot min^{-1}$) after a 20-week endurance training program. Sedentary women (mean age = 24 years) trained at 60 to 85% of their heart rate reserve (HR reserve = HR_{max} - HR_{rest}) (17). Kearney et al. (18) also based the intensity of their training program on heart rate reserve. Two groups of sedentary women (mean age = 17.5 years) trained on a treadmill at either 50% or 65% of their heart rate reserve for 9 weeks. Each training session was terminated when 1,000 heart beats over resting heart rate had been recorded. Both groups showed significant increases in mean max $\dot{V}O_2$. the 50% group produced an increase of approximately 5 $ml \cdot kg^{-1} \cdot min^{-1}$, while the 65% group increased their max $\dot{V}O_2$ by approximately 9 $ml \cdot kg^{-1} \cdot min^{-1}$. The investigators concluded that:

> Even when an attempt was made to control the amount of exercise stress (as determined by number of exercise heart beats in the present study), there still appeared to be a trend in favor of the more vigorous intensity period despite the fact that the training session for the higher intensity was somewhat shorter.

In 1978, Pederson and Jorgensen (28) studied the responses of six untrained women (mean age = 23.0 years) as part of a study investigating the effects of training, detraining, and retraining. The training consisted of 30 minutes of cycling on a bicycle ergometer twice a week for 7 weeks. The load was calculated to maintain the subjects' heart rate at 170 beats per minute. The subjects showed a significant increase in mean maximal oxygen uptake of 13.8% (41.5 to 46.7 $ml \cdot kg^{-1} \cdot min^{-1}$) after the 7-week training period. The investigators determined that the average weekly increase in max $\dot{V}O_2$ was 1.4 to 2.0%.

Gibbons et al. (15) varied training intensity according to heart rate at anaerobic threshold (ATHR) as determined on a treadmill. Untrained women were divided into three groups. The first group trained at an intensity that kept their heart rates at ATHR. The second group trained at an intensity that maintained their heart rates at ATHR plus 40% of the difference between heart rate at max $\dot{V}O_2$ and ATHR. The third group trained at a heart rate of ATHR minus 40% of the difference between heart rate at max $\dot{V}O^2$ and ATHR. Training was conducted on a treadmill four times a week for 20 minutes at the target heart rate per session. All three groups demonstrated a significant increase in maximum oxygen uptake of approximately 5 $ml \cdot kg^{-1} \cdot min^{-1}$ after an 8-week program. No significant differences were found between the three training intensities.

Atomi and Miyashita (2) employed a progressive training program based on max $\dot{V}O_2$ in their three-phase study of seven sedentary women (mean age = 31.7 years). The first phase of the study involved training at 60% of the subjects' initial max $\dot{V}O_2$ (mean = 29.4 $ml \cdot kg^{-1} \cdot min^{-1}$). This continued for 13 weeks, after which the subjects exhibited a significant improvement in mean max $\dot{V}O_2$ to 34.2 $ml \cdot kg^{-1} \cdot min^{-1}$. For the next 18 weeks, subjects trained at 75% of their max $\dot{V}O_2$. At the end of this period, the subjects showed a mean improvement to 36.1 $ml \cdot kg^{-1} \cdot min^{-1}$. This increase was not significant. During the final 13 weeks, training intensity was increased to 90% of the subjects' max $\dot{V}O_2$. This resulted in a mean improvement in maximum oxygen uptake to 39.4 $ml \cdot kg^{-1} \cdot min^{-1}$. It should be noted that all training and testing were done on a bicycle ergometer, and the individual training loads were adjusted every 2 to 4 weeks based on new determinations of max $\dot{V}O_2$. The investigators did not speculate as to the cause of the lack of significant increase in the second phase of the study.

In 1977, Eddy et al. (12) investigated the differences in training effects between interval and continuous training. Two groups of untrained college women underwent 7-week bicycle training programs. The continuous training program consisted of bicycle ergometer training at 70% of the subject's max $\dot{V}O_2$, while the interval program involved training at 100% of the subject's max $\dot{V}O_2$. Both groups trained four times a week. Each training session was completed when a set amount of work was accomplished. The target amount of work was started at 10,000 KPM (kilopond meters) and increased 3,000 KPM ever week. The continuous training program produced a 15.2% increase in max $\dot{V}O_2$, and the interval program produced a similar increase of 14.3%. There was no significant difference between the two training groups in regard to pretest or posttest max $\dot{V}O_2$. The investigators attributed the similarity in training effects between the two programs to the equal total work loads per session.

In 1975, Eisenman and Golding (13) investigated effects of a 14-week training program on untrained women (mean age = 19.6 years) and girls (mean age = 12.7 years). The program involved three 30-minute workouts a week. By the end of the training period, the subjects jogged approximately 1.8 miles and did 150 steps on an 18-inch bench each session. The investigators found significant increases in mean maximum oxygen uptake in both groups. The women showed an increase from 38.1 to 44.8 $ml \cdot kg^{-1} \cdot min^{-1}$, while the girls increased their mean max VO_2 from 42.7 to 49.6 $ml \cdot kg^{-1} \cdot min^{-1}$.

Daniels et al. (10) investigated the responses of female cadets to the first 6 weeks of the training program that all cadets undergo at the U.S. Military Academy (West Point). The program was similar to the basic training program administered to enlisted personnel and consisted of calisthenics and running five to six times per week. Even though the female cadets had started the program "in a fairly high state of fitness" (mean max $\dot{V}O_2$ = 44.2 $ml\cdot kg^{-1}\cdot min^{-1}$), they exhibited a significant increase in max VO_2 (mean = 48.8 $ml\cdot kg^{-1}\cdot min^{-1}$) following the program. A similar group of enlisted women had a mean max $\dot{V}O_2$ of 39.3 $ml\cdot kg^{-1}\cdot min^{-1}$ after the 6-week basic training program.

Withers (46) investigated the effects of a 3-month preseason conditioning program on members of the Australian National Women's Lacrosse Team (mean age = 23.0 years). The training program involved two sessions per day, 6 days per week. Team members performed circuit-weight training 5 days per week and ran 6 days per week. The running program was continuous initially but gradually shifted to interval work. Approximately half of the 10 hours per week the preseason program encompassed was allotted to development of lacrosse skills and game strategy. The initial mean maximum oxygen uptake value was 44.0 $ml\cdot kg^{-1}\cdot min^{-1}$. After the first month of training, this was significantly increased to 48.6 $ml\cdot kg^{-1}\cdot min^{-1}$. The second month of training produced a significant increase to 52.3 $ml\cdot kg^{-1}\cdot min^{-1}$. The third training month did not produce a significant increase in max $\dot{V}O_2$ (52.9 $ml\cdot kg^{-1}\cdot min^{-1}$). The authors concluded that a long preseason training program is necessary in light of the plateau in max $\dot{V}O_2$ after 2 months of training. This will allow a good aerobic base to be built, upon which specific anaerobic game skills can be developed.

In 1983, MacDonald (23) demonstrated a significant increase in predicted maximum oxygen uptake following 6 weeks of circuit weight training. Each session consisted of 20 seconds of maximal work on each of five weight machines with 10-second rest intervals after each exercise. The loads and number of circuits completed each session were gradually increased until all subjects completed 12 circuits in 30 minutes. Each subject participated in two sessions per week. Heart rate was kept at 60 to 80% of maximum heart rate during each session. Predicted max $\dot{V}O_2$ increased approximately 20% after the 6-week program. The investigator concluded that even relatively infrequent circuit training can improve aerobic fitness.

Table 3 contains summary data concerning preseason-postseason studies involving female athletes participating in team sports. McArdle, Magel, and Kyvallos (25) found no change in maximal oxygen uptake due to a season of women's collegiate basketball. The investigators attributed the lack of improvement to low-intensity workouts throughout the season, although the actual games were played at a high intensity as determined by telemetered heart rates.

In 1968, Sinning and Adrian (39) found a significant increase in maximal oxygen consumption due to training and competition during a season of women's collegiate basketball. Based on comparisons with data from the available literature, the investigators concluded that the athletes in their study did not reach the limits of their physical-conditioning capacity. Sinning and Adrian attributed this to a less-than-strenuous workout schedule.

In 1973, Sinning (38) duplicated the 1968 study to assess the effects of a 1971 rule change in women's collegiate basketball. The

Table 3.--Summary data of preseason-postseason studies involving female sports teams.[a]

Sport	N	Age at Start	Weight (kg)		Body Fat (%)		max $\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$		max HR (bpm)		Length of Season	Type of Work
			Pre	Post	Pre	Post	Pre	Post	Pre	Post		
Basketball (39)	7	20.8	61.3	--	--	--	34.4	38.7*	187	185	3 months	Bicycle ergometer
Basketball (25)	6	20.0	61.5	61.0	--	--	35.5	35.8	196	191	4 months	Treadmill
Basketball (38)	14	19.1	62.0	62.6*	21.0	20.8	44.8	43.0*	188	186*	4 months	Bicycle ergometer
Lacrosse (35)	17	20.0	58.6	61.8	21.6	19.5*	41.9	46.0*	189	185*	15 weeks[b]	Treadmill
Field hockey (3)	14	18.2	59.5	60.7	25.1	26.5	47.7	49.2	196	191*	3 months	Treadmill

*Significance reported in study.

[a]All values are group means.

[b]Six-week season was preceded by 9-week training program.

rule change transformed the game from a six-players-per-team game in which only two players from each team could play on the full court to a five-players-per-team game in which all players played on the full court. Sinning found a significant decrease in mean max $\dot{V}O_2$ (44.8 to 42.9 $ml \cdot kg^{-1} \cdot min^{-1}$) over the course of the season. The investigator concluded that because there was no significant change in max $\dot{V}O_2$ when expressed in $liters \cdot minute^{-1}$, the decrease in max $\dot{V}O_2$ when expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ may be due to changes in body weight and composition. In comparing data from this study with data from the previous study, Sinning found that players under the five-players rule had higher maximal oxygen uptake values than those who played under the six-players rule. This was true in both the preseason test session (30% difference) and in the postseason session (11%). Sinning concluded that this was not attributable to the training effects due to the season but speculated that the difference could be due to women with poor aerobic conditioning being selected out of the five-player, full court game in favor of better-conditioned athletes. Another possibility was that the team members were better prepared or were in better aerobic condition as a result of the increased opportunities allotted women since the rule change.

Finally, Wilmore and Brown (45) concluded in their 1974 study of female distance runners that "with further training, better coaching, better equipment and facilities and a greater emphasis on women in sport," women can continue to improve their cardiovascular performance and close the performance gap between men and women.

Conclusion

It is clear that both female athletes and nonathletes can increase their cardiorespiratory fitness by engaging in strenuous training programs. It is also evident that female athletes involved in team sports have not reached their full potential. There is an obvious need for more research exploring the effects of a season of competition and especially training on members of female sports teams.

CHAPTER III

METHODS

Oxygen uptake is a parameter most commonly measured when evaluating human performance. The most common method of determining oxygen uptake involves progressive treadmill or bicycle ergometer tests. Other parameters including heart rate, blood pressure, and lactate can also be monitored when appropriate. Pretest resting and posttest recovery values can be obtained if desired. A standardized test protocol allows comparisons between different groups of subjects and between different points in time during one subject's training. This study was designed to examine the changes that occur in various physiological parameters of a women's intercollegiate basketball team as a result of a season of competition and training.

Subjects

Twelve members of the 1983-84 Michigan State University women's basketball team participated in this study. Test sessions occurred before the start of preseason practice, at midseason, and immediately following the season. All subjects received medical clearance and signed informed consent forms before participating in the study.

Training

The 1983-84 season lasted from October 15 until March 10 and consisted of 27 games. Preseason practice, which lasted approximately 6 weeks, involved 3-hour practices 5 to 6 days per week. Conditioning was emphasized, with some time devoted to skills development. Players also participated in a weight-training program 2 days per week and a running program 3 days per week.

The second part of the season consisted of eight nonconference games and lasted approximately 1 month. The team practiced 2 to 2-1/2 hours each day, an average of 4 days per week. Practices emphasized skills development and game strategies and ended with sprint work. The players continued the weight-training program 2 days per week but reduced the number of sets in each exercise.

The final part of the season lasted 9 weeks and included 19 Big Ten Conference games (an average of two per week). Practices were held 4 days per week and were up to 2 hours in duration. Emphasis was placed on skills improvement and game strategies. Weight training was continued 2 days per week.

Off-season training involved a weight-training program similar to the preseason program 3 days per week and a running program on alternate days. The running program consisted of 1-mile runs progressing up to 3 to 5 miles by the fourth month. Sprint training was incorporated into the program during the fifth month.

Body Composition

Each subject was hydrostatically weighed as part of the test battery in each session. Underwater weight was measured continuously using a strain gauge and chart recorder. Residual volume was determined underwater utilizing a nitrogen rebreathing procedure immediately following the underwater-weight measurement. Body density was determined using the method of Brozek (5), and percentage fat was estimated using the Siri formula (37).

Treadmill Protocol

All subjects were tested using a progressive, intermittent treadmill protocol. The test consisted of 3-minute work levels interrupted by 1-1/2 minute rest periods, during which the subject was seated. The first work level was a 6 mph run at 0% grade. After the 90-second rest period, treadmill speed remained at 6 mph but the treadmill grade increased to 5%. Each subsequent level involved an increase of 1 mph in speed and 1% in grade. Subjects ran to voluntary exhaustion. A 15-minute seated recovery period followed termination of the test.

A low-resistance, modified Douglas bag method was incorporated to collect expired gases. Before a test, the subject was fitted with a headpiece containing a Daniels valve. The mouthpiece was connected to a low-resistance gas-collection system via a 20-inch long, 1-1/4 inch inner-diameter hose. Nose clips were used to ensure collection of all expired gas. All subjects were previously familiarized with all protocols, procedures, and equipment involved in the test, including running on a treadmill.

Gas collection was fractioned into 1-minute bags during the work intervals and 30-second bags during the rest intervals. Expired air was also collected for 15 minutes during recovery. The recovery gas was fractioned into five 1-minute bags, two 2-minute bags, and two 3-minute bags. Collected gas was then analyzed for oxygen content by sampling directly from the bag using an Applied Electrochemistry Oxygen Analyzer model S-3A and for carbon dioxide content by an Applied Electrochemistry Medical Gas Analyzer model CD-30. Volumes were determined by a Singer model DTM-115 gas meter. Oxygen uptake was calculated by the method of Consolazio et al. (9), using the Michigan State GASAN computer program.[1]

Heart rate was monitored continuously using a CM-5 lead configuration and a Cambridge Electrocardiograph model 3030, verified by a pulse counter.[2] Heart rates were recorded during the last 10 seconds of each work minute and every 30 seconds of the rest periods. A resting heart rate was recorded before the test, and recovery heart rates were recorded for 10 seconds at the end of minutes 1, 2, 3, 4, 5, 7, 9, 12, and 15 posttest.

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[1]The Michigan State GASAN computer program, developed by Robert Wells and Fred Brunyate, which uses an IBM 9000 computer, is unpublished at this writing.

[2]A beat-by-beat counter developed by Robert Wells, laboratory engineer at the Center for the Study of Human Performance, Michigan State University.

Lactate concentration was determined in 20 μl arterialized blood samples taken from a prewarmed fingertip. Samples were taken before the start of the test, immediately following each work level, and at 1, 5, 10, and 15 minutes of recovery. The blood samples were immediately analyzed for lactate concentration using a Roche Lactate Analyzer model 640.[3]

Blood pressure was also monitored by ausculation throughout each test. Measurements were taken before the test, during the first 45 seconds following each work level, and at 1, 5, 10, and 15 minutes of recovery.

Statistical Analysis

Descriptive statistics were used to describe each parameter investigated. A repeated-measures analysis of variance test utilizing the SPSS subprogram MANOVA (16) was used to make comparisons of data between test sessions. The Sign Test (36) was used to determine the significance of the data nonparametrically.

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[3] U.S. distributor: Wolverine Medical, 7132 Kettle Lake Drive, Alto, Michigan 49302.

CHAPTER IV

RESULTS AND DISCUSSION

This study examined the effects of a season of competition and training on selected physiological parameters of members of the 1983-84 Michigan State University women's basketball team. Subjects were evaluated before the start of preseason practice, at midseason, and immediately following the season. Summary data from the three test sessions can be found in Table 4. Due to injuries during the season, five players were unable to complete all three test sessions and were dropped from the repeated-measures analysis of variance procedure. Summary data from the seven subjects who completed all three test sessions can be found in Table 5. The parameters discussed in this chapter are oxygen uptake, heart rate response, and lactate accumulation. Unless otherwise indicated, all values discussed are mean values taken from the data of the seven subjects who completed all three tests.

Oxygen Uptake

A graph of the three test mean oxygen uptake data can be found in Figure 1. These data were taken from all the subjects. The differences between submaximal values among the three test sessions were not large enough to warrant a separate graph for each test session's data.

Table 4.--Summary data from three test sessions.

	Preseason			Midseason			Postseason		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Age (months)	233.6	10.1	12	237.5	10.4	11	239.8	10.3	12
Weight (kg)	68.0	6.7	12	67.6	7.1	11	67.9	6.7	12
Body fat (%)	25.2	4.0	11	19.1	4.0	10	19.9	3.5	12
Lean body weight (kg)	51.2	4.9	11	53.7	4.6	10	54.2	4.2	12
$\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$)	51.9	4.6	8	53.1	3.1	9	52.3	3.1	10
15-min gross recovery O_2 (ℓ)	10.20	1.09	7	10.26	1.22	8	9.73	1.12	10
HR max (bpm)	194	8	7	194	11	7	197	8	9
Peak lactate (mM)	15.15	2.08	7	12.77	4.41	9	12.17	1.78	10
RQ at $\dot{V}O_2$ max	1.02	0.06	8	1.05	0.06	9	1.03	0.05	10

Table 5.--Summary data from seven subjects who completed all three test sessions.

	Preseason		Midseason		Postseason	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	68.4	8.7	67.9	8.1	68.3	7.6
Fat (%)	24.9	4.2	20.0	4.7	20.5	3.5
$\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$)	51.2	4.6	53.1	3.3	52.3	3.5
15-min gross recovery O_2 (ℓ)	9.93	0.91	9.86	0.85	9.86	1.50
HR max (bpm)	199	10	194	11	197	8
Peak lactate (mM)	15.38	2.13	13.67	3.22	13.05	1.92

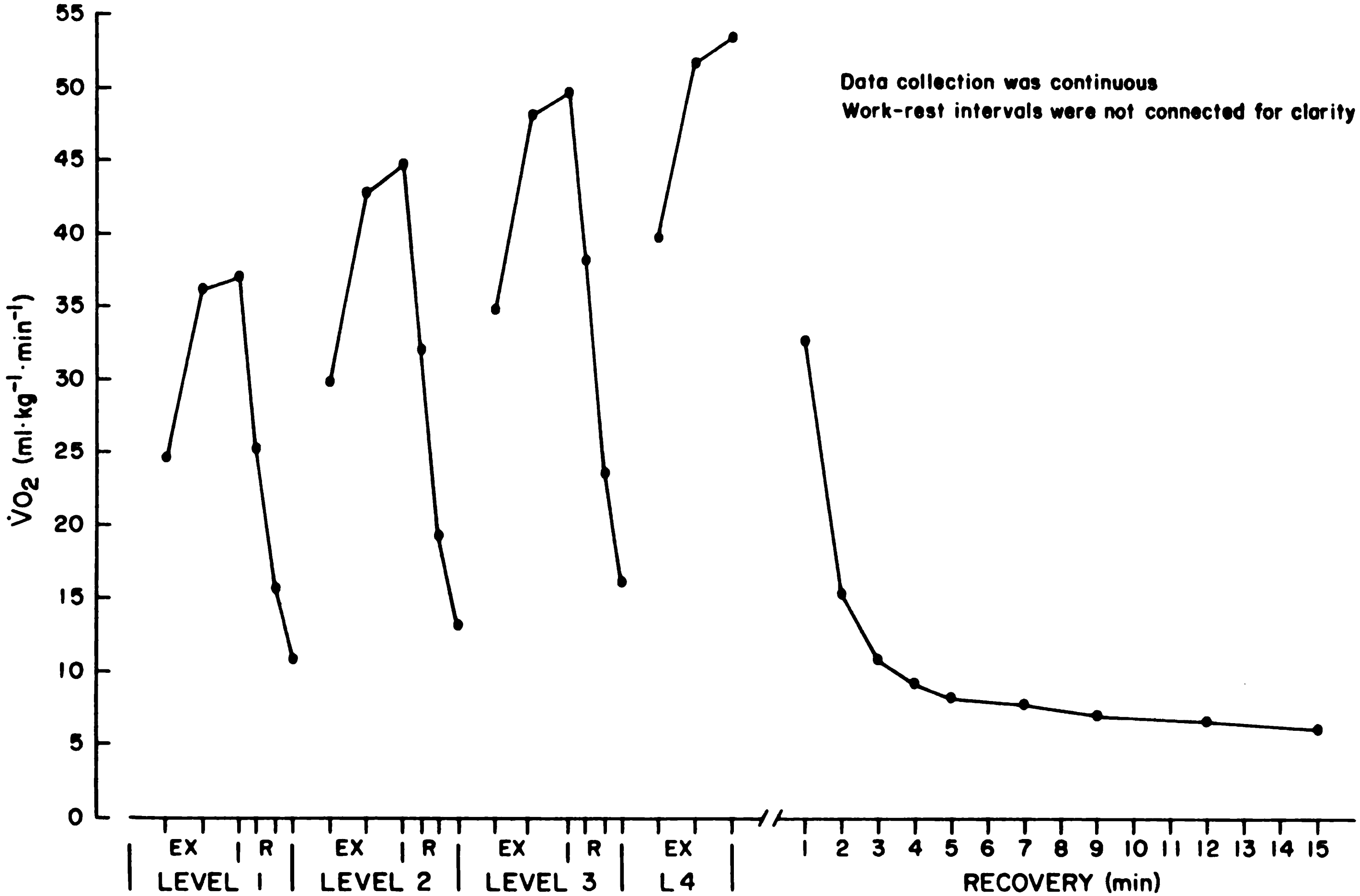

Figure 1.--Mean team oxygen uptake during a progressive intermittent treadmill test for three test sessions.

Although there was a slight increase in maximal oxygen uptake preseason to midseason and a slight decrease midseason to postseason, there were no significant changes in max $\dot{V}O_2$ over the three test sessions. The midseason value, 53.1 $ml \cdot kg^{-1} \cdot min^{-1}$, is comparable to the value 51.7 $ml \cdot kg^{-1} \cdot min^{-1}$ Zeldis et al. (48) reported for a field hockey team. The value is also similar to values reported for cross-country (44) and middle distance (27) runners, amateur cross-country skiers (4), swimmers (23), and pentathletes (4). The max $\dot{V}O_2$ reported in this study was lower than that of the volleyball team (56.0 $ml \cdot kg^{-1} \cdot min^{-1}$) reported by Kovaleski et al. (19). The basketball team's 53.1 $ml \cdot kg^{-1} \cdot min^{-1}$ was also lower than values reported for runners (4, 14, 45), cross-country skiers (4, 31, 33, 42), swimmers (33), and orienteers (33). The maximal oxygen uptake of the basketball team was higher than reported values for field hockey teams (11, 24, 47, 48), volleyball teams (24, 29, 40), and a softball team (47). The max $\dot{V}O_2$ in the present study was also higher than 50.1 $ml \cdot kg^{-1} \cdot min^{-1}$ reported by Riezbos et al. (30) for a similar team. The value is also higher than 42.2 $ml \cdot kg^{-1} \cdot min^{-1}$ reported by Samek and Cermak (34) and 49.6 $ml \cdot kg^{-1} \cdot min^{-1}$ reported by Vaccaro, Clarke, and Wrenn (43) for basketball teams.

Sinning and Adrian (39) reported a significant increase in maximal oxygen uptake in a basketball team over the course of a season, while Schmidt, Gray, and Tyler (35) reported a similar increase in a lacrosse team in response to a preseason training program. Babcock (3) and McArdle, Magel, and Kyvallos (25) reported no significant changes in preseason to postseason max $\dot{V}O_2$ in their studies of field hockey and basketball teams, respectively.

Heart Rate Responses

The heart rate data of the basketball team in this study show a decrease in mean maximal heart rate (HR_{max}) from preseason to midseason and an increase from midseason to postseason. These changes, 199 to 194 beats per minute (bpm) and 194 to 197 bpm, are not significant. The 194 bpm recorded at midseason (when team members are presumably most fit) falls into the upper end of the range of maximum heart rates attained by athletes involved in individual sports (see Table 1). Only cross-country skiers (4, 31) and swimmers (33) had higher reported values. The basketball players' HR_{max} was comparable to values reported for a volleyball team (19), a softball team (47), and a mixed group of athletes (24). In data concerning preseason and postseason studies, McArdle, Magel, and Kyvallos (25) and Sinning and Adrian (39) reported a nonsignificant decrease in maximal heart rate over the course of a basketball season. Babcock (3) found a significant decrease in the mean HR_{max} preseason to postseason of a field hockey team, while Schmidt, Grey, and Tyler (35) reported a similar decrease in HR_{max} of a lacrosse team. Sinning (30) also reported a significant decrease in the same parameter for a basketball team over the course of a season.

The heart rate data (Figure 2) were also examined nonparametrically using the Sign test (36). Significant decreases ($p < .01$) in submaximal heart rates were found between preseason and midseason and

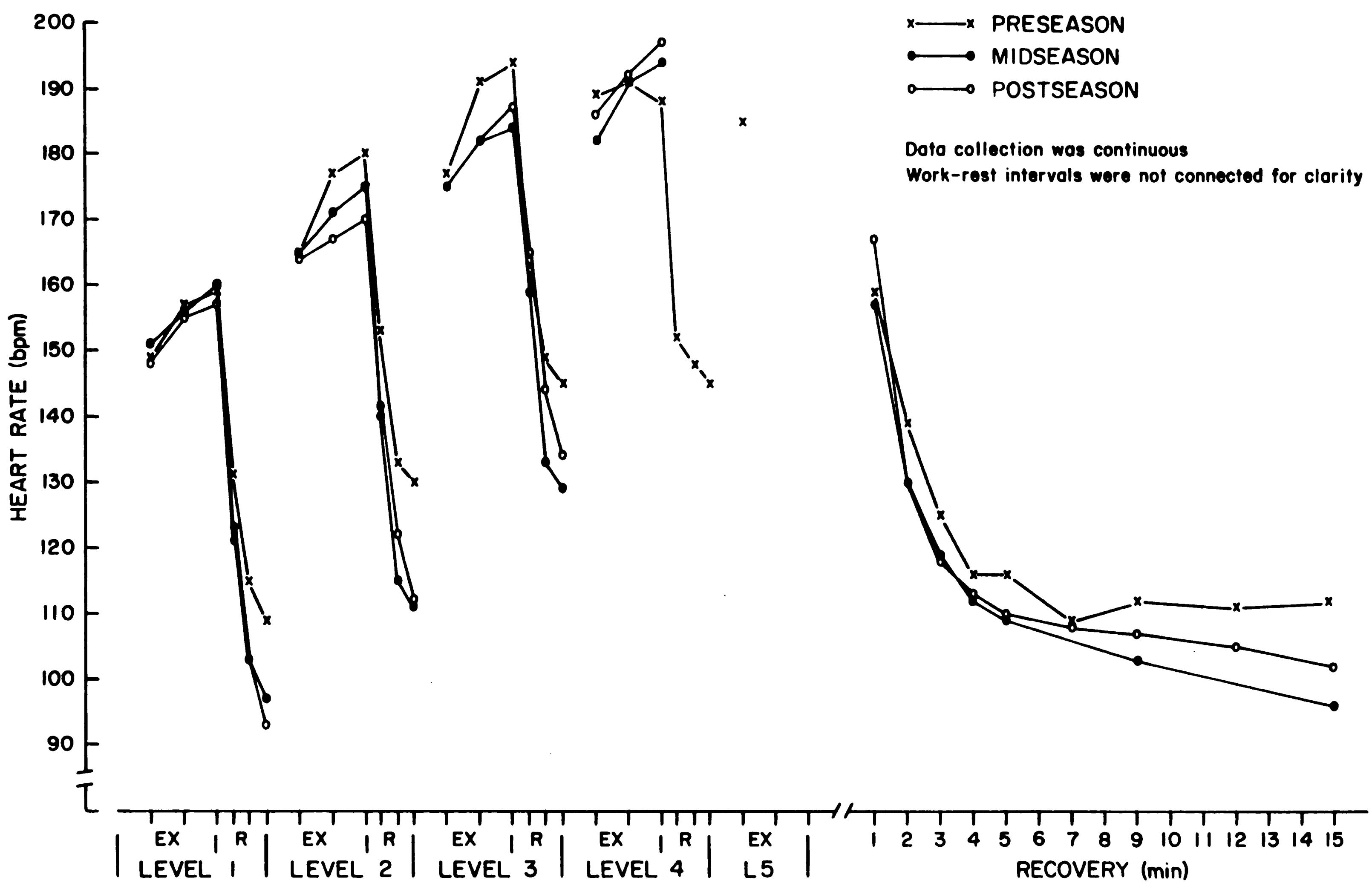

Figure 2.--Team heart rate response to a progressive intermittent treadmill test.

between preseason and postseason. No significant differences were found between midseason and postseason.

Lactate Accumulation

Lactate values generally decreased at every level across the three test sessions (Figure 3), although these changes were not significant when examined using the repeated measures analysis of variance. When examined nonparametrically using the Sign test, a significant decrease was found from preseason to midseason. No significant differences were found midseason to postseason. The peak values obtained in this study, 15.38 millimoles (mM) during the preseason test, 13.67 mM midseason, and 13.05 mM postseason, were not significantly different. The values were generally higher than those reported in the limited number of studies available in the literature in which lactate was sampled following a maximal aerobic test. Puhl et al. (29) report a mean peak value of 8.2 mM for a group of volleyball players, while Berg and Keul (4) report a mean peak value of 13.0 mM for a group of cross-country skiers. Berg and Keul also report peak values ranging from 8.9 to 11.0 mM for swimmers, runners, pentathletes, and rowers. In a preseason-postseason study, Babcock (3) reports values of 13.3 mM preseason and 12.3 mM postseason for a field hockey team. This decrease was not significant.

Discussion

The 1983-84 Michigan State University women's basketball team did show slight improvement from preseason to midseason in the

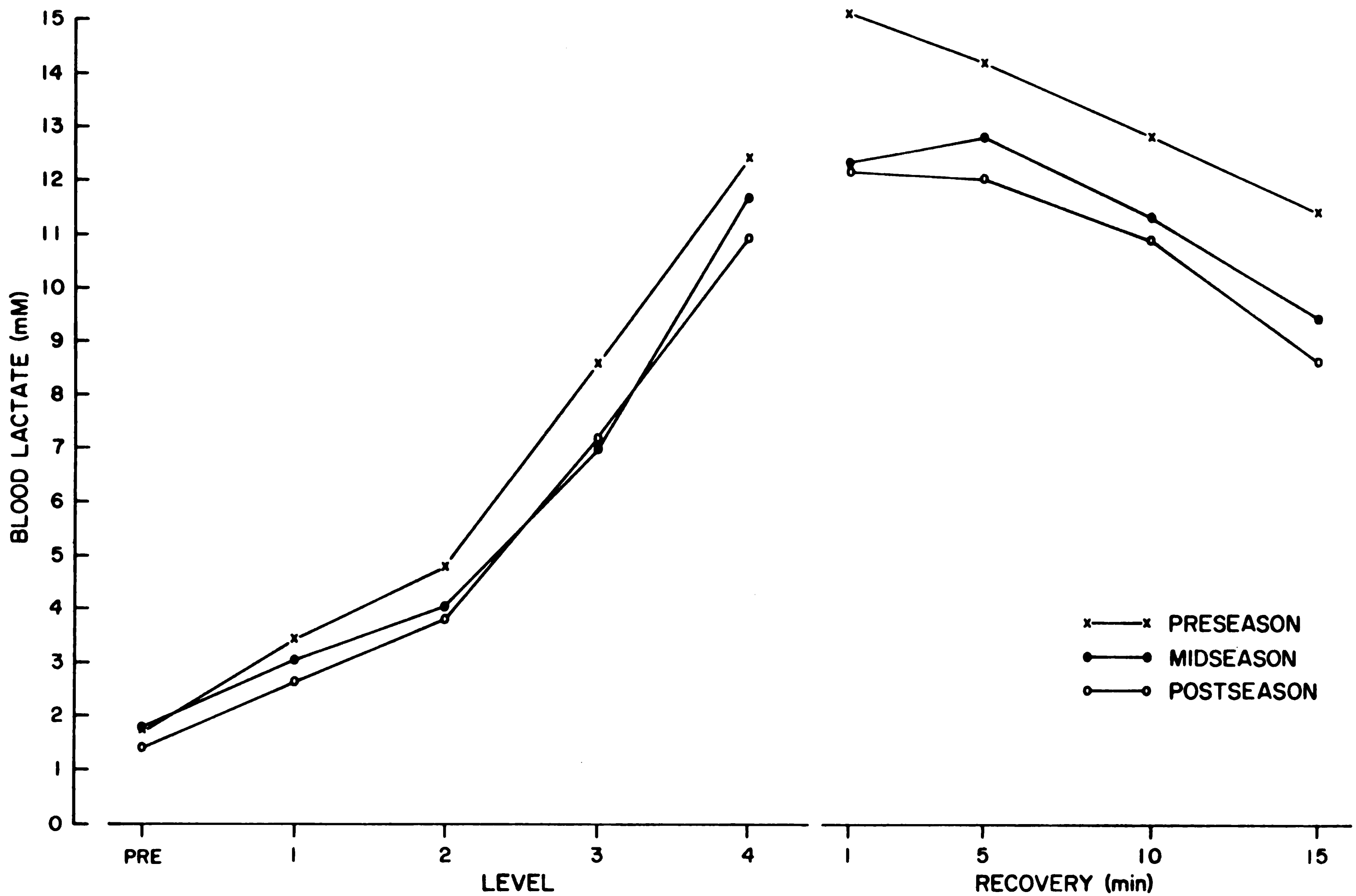

Figure 3.--Team lactate response to a progressive intermittent treadmill test.

physiological parameters measured in this study, but the team also showed a slight loss of improvement from midseason to postseason. Although none of the changes that did occur over the course of the season was significant, there appears to be a trend toward improved work efficiency, peaking at midseason. Even though the oxygen uptake values during submaximal work levels and rest periods are similar in each test, the corresponding heart rates are lower during midseason compared to preseason. This may indicate that the players are responding to a given level of exercise stress more efficiently during the midseason test session. The improved efficiency is also evident in the lactate accumulation curves. Midseason lactate values are lower than the preseason values at each work level, and the postseason values are lower than the midseason values, with one exception. Lower concentrations of lactate, a byproduct of anaerobic glycolysis (21), at a given level of work indicate the subject is performing more aerobically and thus possibly more efficiently.

A likely explanation for the lack of a significant change in oxygen uptake over the course of the season is that the training program and practices were not at an intensity level high enough to produce any significant improvement. The training program may have served only to maintain the level of fitness already achieved. If improved cardiovascular fitness is the goal of the training program, the program must be more intense, combining endurance and interval work.

Another possible explanation for the lack of significant improvement across the three test sessions is that the players were in relatively good physical condition at the start of preseason practice. The total team's preseason mean maximal oxygen uptake value of 51.9 $ml \cdot kg^{-1} \cdot min^{-1}$ is higher than the values for all the various athletic teams reported in Tables 2 and 3 except one volleyball team (19). Although the highest pooled team mean value of 53.1 $ml \cdot kg^{-1} \cdot min^{-1}$ (midseason) can be considered somewhat "average," the highest individual max $\dot{V}O_2$ attained by a subject in this study was 57.4 $ml \cdot kg^{-1} \cdot min^{-1}$ recorded at midseason. This value compares favorably with values reported for athletes involved in individual sports (Table 1). But this value falls somewhat below the highest max $\dot{V}O_2$ for a woman reported in the literature to date--77.0 $ml \cdot kg^{-1} \cdot min^{-1}$ for a cross-country skier (1). The highest value reported for a man was 94.0 $ml \cdot kg^{-1} \cdot min^{-1}$, also achieved by a cross-country skier (1).

It is unlikely that team sports participants will reach the levels of cardiorespiratory fitness that elite cross-country skiers and endurance runners have attained. It is clear, however, that the basketball players in this study have not reached their capacity for aerobic fitness. Although the team began the season at a higher level of fitness than most other teams reported in the literature, it is apparent there is need for improvement. It is also evident that further research is needed to examine the effects of team sports participation and training on female athletes.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Twelve members of the 1983-84 Michigan State University women's basketball team were examined to investigate the effects of a season of training and competition on various cardiorespiratory parameters, including oxygen uptake, heart rate, and lactate accumulation. The players were evaluated three times over the course of the season--before the start of preseason practice, at midseason, and immediately following the season. Each session involved a progressive, intermittent treadmill test to exhaustion. Only data from the seven subjects who participated in all three test sessions were included in the repeated-measures analysis of variance (AOV) used to analyze the data. Significance was also determined nonparametrically using the sign test. No significant changes were found in any of the parameters when analyzed using the repeated-measures AOV. There was a significant decrease ($p < .01$) in submaximal heart rates across the three test sessions and in lactate accumulation preseason to midseason when data were analyzed using the Sign test.

Although the players had higher max $\dot{V}O_2$ values than most other teams, it was concluded the players had not reached their maximal aerobic potential. It appears, based on the results of this study, that the training program was not specific enough to aerobic capacity to produce improvements in osygen uptake.

Conclusions

The following conclusions were drawn from this study:

1. The season of training and competition did not produce any significant changes in oxygen uptake, heart rate response, or lactate accumulation in this study of an intercollegiate women's basketball team when evaluated using the repeated measures analysis of variance.

2. The preseason to postseason heart rates and preseason to midseason lactate values were significantly different when all points were evaluated using the Sign test. There was a significant training effect, with the postseason values significantly lower.

3. The nonsignificant change in max $\dot{V}O_2$, and the significant changes in heart rate response and lactate accumulation, indicate the team performed slightly more efficiently at midseason, although the values regressed back toward preseason levels by the end of the season.

4. The subjects in this study have not attained their maximal aerobic capacity.

Recommendations

Based on the results of this study, the following recommendations are made:

1. A more intense, more specific training program needs to be implemented if the basketball team is to improve their aerobic capacity.

2. Further investigation is necessary regarding the responses of female athletes to team sports participation and training.

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