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PHYSIOLOGICAL RESPONSES OF FEMALE COLLEGIATE FIELD HOCKEY PLAYERS TO A SEASON OF COMPETITION

presented by

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PHYSIOLOGICAL RESPONSES OF FEMALE COLLEGIATE FIELD HOCKEY PLAYERS TO A SEASON OF COMPETITION

By

Teresa Irene Babcock

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ABSTRACT

PHYSIOLOGICAL RESPONSES OF FEMALE COLLEGIATE FIELD HOCKEY PLAYERS TO A SEASON OF COMPETITION

By

Teresa Irene Babcock

Fourteen members of a women's collegiate field hockey team were tested pre- and post-season for max $\dot{V}_{O_2}$, ventilation, heart rate, blood pressure, and blood lactate using a maximal intermittent treadmill test. Test results indicate a significant reduction in heart rates and a significant increase in blood pressures post-season. Ventilation rates and blood lactate concentrations were lower post-season but the difference was not significant. Oxygen uptake remained unchanged. Data from this study indicate that while the women performed at the same oxygen uptake post-season as pre-season, the combination of lower ventilation rates, lower lactates, and lower heart rates suggest that the women were performing more efficiently post-season. The increase in blood pressures is not a typical aerobic response and cannot be classified at this time. It would appear that the data reflect a specific adaptation to field hockey training.

Dedicated

To my Mom, Dad, and

sister, Carla.

ACKNOWLEDGMENTS

My sincerest appreciation belongs to my family, who have offered me strength and encouragement throughout my education and who have been with me every step along the way to my graduate degree.

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TABLE OF CONTENTS

CHAPTER | Page

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND SYMBOLS

N	number of subjects
yr	years
kg	kilograms
cm	centimeters
max $\dot{V}_{O_2}$	maximum oxygen uptake
l/min	liters per minute
ml/kg/min	milliliters per kilogram per minute
bpm	beats per minute
$\dot{V}_E$	rate of ventilation
mM	millimoles
mph	miles per hour
km/h	kilometers per hour
rpm	revolutions per minute
kpm	kilopond meters
mmHg	millimeters mercury

CHAPTER I

INTRODUCTION TO THE PROBLEM

Due to the passage of title IX, the number of women involved in intercollegiate athletic programs has dramatically increased. In recent years the sports performance standards among females have shown marked improvements. However, limited scientific data are available on the physiological capacities of the female as a member of a team sport (2, 6, 13, 15, 20, 22, 23, 27, 28, 32, 36, 37). While some data does exist concerning the female team athlete, few investigators have attempted to assign characteristics inherent to a given team sport.

Much of the physiological data which exists for women team sports members comes from the sports of basketball (6, 15, 27, 28, 32) and volleyball (6, 13, 20, 30). Basketball players have been found to exhibit aerobic capacities comparable to non-athletes upon exhaustive exercise tests. The aerobic capacities of volleyball players measured have been found to be considerably higher than those of the basketball players. Few studies, however, have drawn descriptive data from other intercollegiate sports, such as field hockey (2, 15, 37). Among the studies involving field hockey players, there is some disagreement regarding the physiologic capacities of the athletes. This suggests that further examination of this sport is necessary to establish descriptive data which may be inherent to it.

Statement of the Problem

Due to the relative lack of information regarding female athletes involved in team sports, this study was undertaken to determine selected cardiorespiratory changes that occur in female athletes as a result of a season of competition in field hockey. Data were obtained on aerobic capacity, heart rates, and blood lactate concentrations.

Purpose of the Study

1. To examine the changes in aerobic capacity which occur in women collegiate field hockey players during a season of competition.
2. To establish procedures for testing female athletes.

Significance of the Study

Information regarding the physiological characteristics of female collegiate field hockey players should be provided by this study. Few studies have shown the significance of maximum exercise testing on female athletes. This study will provide information regarding the changes in the physiological capacities of a specific group of female athletes resulting from a season of competition.

Limitations

1. The study was limited to one group of female athletes (field hockey).
2. Only the physiological parameters related to aerobic capacity were examined (i.e., oxygen uptake, heart rate response, blood lactate concentration).
3. Only pre-season/post-season comparisons were made. The season was limited to a duration of two months.

CHAPTER II

REVIEW OF THE LITERATURE

There is relatively little specific information available concerning the physiological changes which occur in women due to the physical conditioning that develops as a result of participation in a sports training and conditioning program. Åstrand (1) in 1960 concluded that women generally respond to physical conditioning in the same manner as men. This same viewpoint is supported by Roskamm (21), who determined that no difference existed between men and women in their physiological response to conditioning programs in which the intensity of exercise was controlled on the basis of the heart rate response to exercise. Several studies exist in which the physiological characteristics of female athletes have been examined. However, relatively few studies have attempted to determine the physiological characteristics of female athletes involved in team sport competition.

Parameters such as oxygen uptake, heart rate response, and lactic acid accumulation have been examined in an attempt to determine the physiological characteristics inherent to female athletes. However, a review of the literature reveals that there may not be a set of characteristics shared by all female athletes, but rather there exists a separate set of normative data that can be determined for a particular sport. This review of literature is primarily focused

on the physiological characteristics of female athletes involved in team sports.

Cardiorespiratory endurance has long been recognized as one of the fundamental components of physical fitness and as a key factor in the performance of many athletic activities. It has been defined as the ability to perform large-muscle, whole-body exercise at moderate to high intensities for extended periods of time (1). An individual's level of cardiorespiratory endurance is principally a reflection of the exercise intensity that can be sustained for an extended period of time (19). Components that determine the duration of an exercise bout include body size and weight, body composition, heart rate response, cardiac output, aerobic power, and lactic acid accumulation. Of these, aerobic power, defined as the greatest rate at which oxygen can be consumed at sea level (19), is generally considered to be the most important determinant of cardiorespiratory endurance. Maximal aerobic power (max $\dot{V}O_2$) is a key determinant of cardiorespiratory endurance since it constitutes the absolute upper limit for the range of oxygen uptake rates in a given individual.

Cardiorespiratory endurance has been extensively examined regarding women involved in individual sports such as running and cross-country skiing (11, 23, 24, 35). Relatively little information exists in this area for women participating in team athletics. Female athletes involved in endurance sports have been found to have high oxygen uptakes when compared to females involved in team sports (6, 11, 13, 15, 19, 27, 28, 35, 36, 37). A comparison of the cardio-respiratory data reported for females involved in individual sports

with that reported for female team athletes will establish the need for further study in the area of team sports.

Individual Sports

Studies of both outstanding and average athletes have shown that their physical and physiological characteristics are different from those of the general population (11, 23, 24) and that certain characteristics are unique to certain sports. Such studies have increased our knowledge of the physiology of exercise and its application to conditioning and improving performance. Athletic profiles have been developed which characterize traits commonly found among females involved in individual sports. These results can be used to establish the physiologic capacities of the female as an athlete.

Several studies have attempted to establish the physical and physiological characteristics inherent in female athletes. Table 1 presents the physical and physiological characteristics found in some of these studies of females involved in individual sports.

Saltin and Åstrand (24) determined the maximal oxygen uptake of 38 female athletes and 95 male athletes belonging to Swedish National Teams. All subjects initially performed at a submaximal load for 6-7 minutes on a bicycle ergometer. To select a suitable starting speed and inclination of the treadmill for the maximal run, the subject's maximal oxygen uptake was first predicted from heart rate and work load in the bicycle egrometer test (1). The starting speed and inclination were chosen based on the individual's predicted max $\dot{V}_{O_2}$ such that they could run no longer than seven minutes. During this

Table 1. Physiological Characteristics of Female Athletes Involved in Individual Sports

Sport	N	Type of Work	Age yr	Weight kg	Height cm	% Fat	Maximal Values: Oxygen Uptake l/min	Maximal Values: Oxygen Uptake ml/kg/min	Maximal Values: Heart Rate bpm	Maximal Values: $\dot{V}_E$ l/min	Maximal Values: Lactate mM
Various (24)	10	Treadmill	22.9	55.8	164.3	--	3.61	61.8	194.8	111.8	--
Cross-country skiing (11)	9	Treadmill	25.2	60.5	165.7	--	3.44	56.9	191.1	106.4	11.1
Running 400-1500 m (11)	5	Treadmill	21.4	58.6	170.2	--	3.36	57.5	197.6	102.5	10.8
Running marathon (35)	11	Treadmill	32.4	57.2	169.4	15.2	3.35	59.1	180.4	108.9	--
Cross-country skiing (23)	5	Treadmill	24.3	59.1	163.0	--	4.03	68.2	195.0	--	--

time, the inclination of the treadmill was increased 2.67 percent every third minute. Mean maximal oxygen uptake in liters/min and ml/kg/min for the different female athletes can be found in Table 2. The maximal oxygen uptakes for the females were significantly lower than the males when compared by sport. The authors noted that the women who exhibited the highest max $\dot{V}_{O_2}$ were involved in sports that required proper technique along with a high aerobic power (i.e., cross-country skiing, orienteering, swimming). The authors concluded that the female athletes involved in this study had aerobic capacities significantly lower than their male counterparts and that training programs must be developed to improve the endurance capacity of females.

Hermansen (11) examined the physiologic capacities of 38 female athletes who were members of the Norwegian National Teams. The athletes were tested for maximal oxygen consumption on the treadmill using the Froelicher et al. (10) protocol. The cross-country skiers and the runners had comparable maximal oxygen uptakes (Table 1). They also exhibited the greatest aerobic power among the group of female athletes. Maximum heart rates, maximum pulmonary ventilation, and maximum blood lactate showed no significant difference. The gymnasts and speed skaters exhibited significantly lower maximal oxygen uptakes, and similar maximum heart rates and ventilation rates. Blood lactate values were comparable for the speed skaters but were significantly higher for the gymnasts. Hermansen concluded that "those athletes involved in endurance sports, such as running and cross-country skiing, had a greater aerobic capacity than those involved in short term/high intensity sports."

Table 2. Average Maximal Oxygen Uptake in l/min and ml/kg/min for the Female Swedish National Team in Different Sports (24)

		Max $\dot{V}_{O_2}$	
Sport	N	l/min	ml/kg/min
Cross-country skiing	5	3.8	64.7
Orienteering	5	3.4	58.9
Swimming	5	3.2	57.6
Running 400-800 m	3	3.1	55.4
Speed skating	6	3.1	54.2
Alpine skiing	5	3.1	51.1
Table tennis	3	2.4	44.8
Fencing	3	2.4	43.9
Archery	3	2.3	40.6
Housewives[a]	8	2.2	38.9

[a]The data on housewives are from Åstrand's study (1).

Wilmore and Brown (35) investigated cardiovascular endurance capacity in highly trained female endurance athletes at various ages up to and including the fourth decade of life. Eleven subjects of national and international caliber were selected from a population of female distance runners. Each subject had been training for long-distance competition (2 miles or greater) for a minimum of three years. Maximal oxygen uptake was determined using a continuous treadmill test to exhaustion, with either grade or speed being increased each minute to attain the endpoint of exercise within an 8-10 minute period. The authors reported that the mean max $\dot{V}_{O_2}$ for the female athletes in this study was "considerably greater than that found for the average female and for other groups of female athletes." The authors concluded that these females were physiologically superior to other groups of female athletes (27, 28, 32), but that there was "room for improvement when comparisons are drawn with their male counterparts."

Rusko et al. (23) tested a group of world-class athletes (male and female), which included five women cross-country skiers. The athletes were tested on a treadmill to determine max $\dot{V}_{O_2}$. After a 10-minute warmup and a short rest, the inclination of the treadmill was increased by one degree every second minute until exhaustion occurred. The treadmill speed was selected so that the subjects were able to run about 8 to 12 minutes. The best athletes were able to run at 16 to 17 km/h with the slope of seven degrees. In some groups whose athletic specialty involved extensive use of the arms, max $\dot{V}_{O_2}$ was also measured while cranking a bicycle with the hands and

arms. After 10 minutes of warming-up and a short rest, the subject began to crank the bicycle at 50 rpm and the work load was increased by 150 kpm/min every second minute. The first load was selected so that the subjects were exhausted after about 8 to 12 minutes. The female cross-country skiers were found to have a lower max $\dot{V}_{O_2}$ than the male cross-country skiers, but higher than the male distance runners and speed skaters.

In arm work, the female cross-country skiers had a max $\dot{V}_{O_2}$ value similar to the male subjects. It has been found that, in general, the peak oxygen intake developed during arm work is only about 70 percent of that achieved during uphill treadmill running. However, if a large crank is operated by the back, arm, and shoulder muscles, the peak $\dot{V}_{O_2}$ max may closely approach the treadmill result (17). The authors concluded that the physiological capacities allowed them to excel in their sport and be world-class performers. It was also concluded that the female athletes in the study trained at levels which allowed them to attain physiologic capacities comparable to top class male athletes.

Team Sports

While several studies exist that examine the physiological capacities of females involved in individual sports, relatively few studies exist which consider the effects of team sport competition on females. Studies which do exist have looked at the female athlete prior to the season, after the season, and after a training period. Very few studies have reported on the changes which occur over the course of a competitive season.

Pre-Season Studies

A summary of the studies that have examined female team athletes prior to a competitive season can be found in Table 3.

Zeldis et al. (38) examined the physiologic characteristics of ten female collegiate field hockey players in their study of heart morphology as measured by echocardiography. Five age-matched non-athletic women served as controls. Maximal exercise performance was determined using the Bruce treadmill exercise protocol (5). Max $\dot{V}_{O_2}$ and heart volume were significantly greater for the athletes than for the controls. The authors concluded that "the increased heart volume found in the athletes may reflect an increase in stroke volume needed to maximize cardiac output which is directly proportional to oxygen uptake, thereby improving athletic performance."

Vacarro et al. (32) tested a women's collegiate basketball team prior to the competitive season. Max $\dot{V}_{O_2}$ was determined using a discontinuous progressive treadmill test. Each subject warmed up by walking on a treadmill at 3.5 mph for five minutes. A 1 percent elevation in treadmill slope was made following each minute of walking so that after five minutes all subjects were at a 4 percent slope. Following the warm-up a three minute rest was given before exercise was continued. Subjects were then required to run at 7.0 mph for consecutive one-minute bouts. Each bout was followed by a 2.5 percent slope elevation and one-to-two minutes of rest. When the subject expressed belief that she could continue for three more bouts, expired gas was collected for the last 30 seconds of each remaining

Table 3. Pre-Season Physiological Characteristics of Female Athletes Involved in Team Sports

Sport	N	Type of Work	Age yr	Weight kg	Height cm	% Fat	Maximal Values				
							Oxygen Uptake		Heart Rate bpm	$\dot{V}_E$ l/min	Lactate mM
							l/min	ml/kg/min			
Field hockey (38)	10	Treadmill	19.8	58.1	163.2	--	--	51.7	185.1	--	--
Basketball (32)	15	Treadmill	19.4	68.3	172.9	20.8	--	49.6	186.2	94.9	--
Volleyball (30)	15	Treadmill	21.6	73.4	183.7	--	3.04	41.7	181.3	111.1	11.2
Volleyball (20)	14	Treadmill	21.6	70.5	178.3	17.9	3.57	50.6	179.0	--	8.2

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minute and $\dot{V}_{O_2}$, ventilation ($\dot{V}_E$), and heart rate were determined. A mean max $\dot{V}_{O_2}$ of 49.6 ml/kg/min was reported. Exercise heart rates were found to be consistent with those observed in other studies involving women basketball players (27, 28). The authors concluded that this may indicate a trend in recent years toward an increase in the intensity of training and conditioning programs for women basketball players.

Spence et al. (30) examined the physiologic characteristics of 15 members of the 1975 U.S. Women's Volleyball training team. Six of the players were selected for the Pan-American games and nine were not. Comparisons were made between these two groups. The Pan-American group was significantly taller and heavier than the non-Pan-American group. The authors indicated that this difference allowed the Pan-American group to have a greater reach. Maximal oxygen uptake was determined by having the subjects warm up for three minutes and then run on a treadmill at a constant speed of 6 mph. The inclination of the treadmill was increased by 2.5 percent every two minutes until the subject was exhausted. The non-Pan-American group had a significantly greater max $\dot{V}_{O_2}$ (44.7 ml/kg/min) than the Pan-American group (41.7 ml/kg/min). The non-Pan-American group had slightly lower heart rates throughout the test than the Pan-American group. The authors noted that average post-exercise blood lactate level of 11.2 mM for both groups indicated that the work of the test was exhaustive (1). The authors indicated that "the magnitude of the difference between group means for post-exercise blood lactate levels

(Pan American 9.8 mM and non-Pan-American 12.1 mM) suggests that the non-Pan-American group was either more motivated for treadmill running or was at a higher level of training, or both." It was concluded that "while there may be significant individual differences among individuals, the means for this group of world class volleyball players was comparable to that reported in other studies (27, 28)."

Puhl et al. (20) examined the maximal oxygen uptake and exercise heart rates of the Women's University World Games Volleyball team using treadmill runs. It was concluded that the elite volleyball players had physiological characteristics similar to those reported for less elite female players (6, 13).

Post-Season Studies

A summary of the studies that have examined female team athletes after a season of competition can be found in Table 4.

Conger and Macnab (6) reported a mean max $\dot{V}_{O_2}$ of 40.7 ml/kg/min for the group of intercollegiate female athletes involved in their study. The Åstrand-Ryhming predicted maximal oxygen uptake test was administered as originally outlined (1). The work load for all subjects was 450 kpm, with the pedaling frequency established at 50 revolutions per minute. Heart rate recordings were taken on a Sanborn electrocardiograph. A pre-exercise heart rate was recorded 15 seconds before the beginning of pedaling and recordings were taken at the end of each minute of exercise. The subject pedaled continuously at 450 kpm until a steady state was attained (two consecutive heart rate recordings separated by one minute which differed no more than ±5 beats). The

Table 4. Post-Season Physiological Characteristics of Female Athletes Involved in Team Sports

							Maximal Values				
							Oxygen Uptake		Heart Rate	$\dot{V}_E$	Lactate
Sport	N	Type of Work	Age yr	Weight kg	Height cm	% Fat	l/min	ml/kg/min	bpm	l/min	mM
Basketball (6)	17	P[a]	19.8	63.9	167.0	26.9	2.70	42.3	--	--	--
Volleyball (6)	10	P[a]	19.9	59.8	166.0	25.3	2.60	43.5	--	--	--
Various (15)	26	Treadmill	19.7	62.2	165.9	19.4	2.53	41.0	195.1	91.1	--
Volleyball (13)	19	Treadmill	19.9	64.1	172.2	21.3	3.56	56.0	195.0	116.0	--
Softball (22)	9	Treadmill	21.2	--	--	--	--	55.3	184.4	--	--
Basketball (37)	13	Treadmill	21.4	64.0	167.5	28.9	2.89	45.4	193.5	107.4	10.7
Field hockey (37)	11	Treadmill	22.4	62.9	164.6	25.3	3.13	50.2	191.6	110.4	9.2
Softball (37)	5	Treadmill	20.6	74.4	175.0	26.9	3.34	44.8	185.4	118.3	11.3

[a]P = Predicted oxygen uptake.

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two heart rate values which met the criterion were then averaged to arrive at a steady state. No steady state value was accepted that occurred before the fifth minute of exercise. If the steady state heart rate was less than 120, the work load was increased to 600 kpm and the subject continued to pedal without rest. At least three additional minutes of exercise at this increased work load were required before a steady state was acceptable. The steady state heart rate value was then applied to the Åstrand-Ryhming nomogram and a maximal oxygen uptake value was estimated. The value was expressed in l/min and ml/kg/min. The basketball players were found to have a greater aerobic power and lower exercise heart rates than the volleyball players, but the differences were not statistically significant. The authors did not make any conclusions as to the relative fitness levels of these two groups of athletes.

Two points must be noted from the preceding discussion regarding the methods used to obtain max $\dot{V}_{O_2}$. The first is that the maximum oxygen intake values obtained with a bicycle ergometer have been found to be on the average 7 to 8 percent below values obtained on the treadmill (12, 19, 24, 25). Second, predicted max $\dot{V}_{O_2}$ values have been found to have systematic errors of up to 10 percent. In a review of tests of maximum oxygen intake, Shephard (25) concluded that the range of possible error found with predicted max $\dot{V}_{O_2}$ was too large to provide more than a very crude index of aerobic fitness.

Maksud et al. (15) reported a mean max $\dot{V}_{O_2}$ of 41.0 ml/kg/min for a group of female athletes when tested on a treadmill. A modification of the Balke and Ware (3) treadmill protocol was used. Heart rates

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rates were monitored throughout the test. The authors concluded that the maximal oxygen uptake for the female athletes in this study fell within the range of values reported by a number of investigators and summarized by McArdle and others (16). The authors concluded that "the relatively modest aerobic power observed in this study may reflect the variety of athletes included in this sample and the relatively modest intensity of training programs currently used by many female athletes. As information accumulates on the physiological responses of the female to strenuous exercise, the intensity of training may be modified. The highest values for aerobic power in American females are currently reported for track women (35). This probably reflects, among other things, the fact that the training employed by track athletes is more intense than that of basketball, field hockey, and volleyball players."

Kovaleski et al. (13) reported a max $\dot{V}_{O_2}$ of 56.0 ml/kg/min for his group of intercollegiate female volleyball players. Subjects ran on a treadmill to the point of volitional fatigue. It was concluded that this value agrees with those found in other studies of female volleyball players and female athletes in general, where the athlete was tested on the treadmill (27, 32). However, this value was higher than that reported by Conger and Macnab (6). Kovaleski et al. indicated that the value reported in their study may represent the maximal oxygen uptake inherent to female college volleyball players. They note that the lower value of Conger and Macnab may be due to the error involved in predicting max $\dot{V}_{O_2}$.

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Rubal et al. (22) compared various cardiorespiratory parameters of nine members of a women's collegiate softball team and ten sedentary females in their study of the hearts as measured by echocardiography. All athletes had participated in an endurance conditioning program consisting of running 20 to 30 miles per week for at least one year. The sedentary subjects were normally active college women, but did not participate in a regular exercise program. The aerobic work capacity of each subject was assessed by a graded maximal treadmill test using the protocol of Bruce (5). The athletes ran longer than the controls (17:03 min vs. 11:40 min), had lower resting heart rates than the controls (50.6 bpm vs. 71.2 bpm), and had a higher max $\dot{V}_{O_2}$ than the controls (55.3 ml/kg/min vs. 40.3 ml/kg/min). The authors concluded that aerobic conditioning was verified in the athletes by the observations of reduced resting heart rate, longer duration of treadmill exertion, and greater max $\dot{V}_{O_2}$ than the sedentary women.

In the study by Withers and Roberts (37), the maximum aerobic power was measured in 29 top-class female athletes representing three different sports. Maximum aerobic power was determined in accordance with the Froelicher et al. (10) protocol. The criterion for the attainment of max $\dot{V}_{O_2}$ was an elevation in $\dot{V}_{O_2}$ of less than 2 ml/kg/min as a result of an increase in treadmill elevation of 2.5 percent, while the speed was kept constant at 10.5 km/hr. The field hockey players registered the highest mean treadmill max $\dot{V}_{O_2}$. This was significantly greater than that of either the softballers or the basketball players. The authors concluded that: (1) the value for the field hockey players (50.2 ml/kg/min) was comparable to values reported in other studies on

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field hockey teams (2, 37); (2) when compared with the max $\dot{V}_{O_2}$ of the field hockey players, the statistically significant lower value reported for the softball players (44.8 ml/kg/min) was partly due to the nature of the game, which makes a smaller demand on the circulatory and respiratory systems; and (3) the average maximum aerobic power reported for the basketball players (45.4 ml/kg/min) may be adequate for top-class competition.

Pre-Season Training Study

A summary of the results obtained by Withers (36) on a women's lacrosse team after a pre-season conditioning program can be found in Table 5. The team underwent a three-month training program prior to the start of the season. All players trained twice a day for six days a week. This involved a total work time of approximately ten hours per week with half of the time devoted to running and weight training and the other half to developing lacrosse skills together with their incorporation into small side games. The principle of overload (1) was applied to all the fitness training. A circuit of weight training was performed about five times a week. The six-days-per week running program was initially continuous, but greater emphasis was gradually placed on interval training. The athletes were tested on the treadmill four times during the training period to determine the amount and rate of improvement. The Froelicher et al. (10) modification of the Taylor et al. (31) treadmill protocol was used. The initial max $\dot{V}_{O_2}$ was 44.0 ml/kg/min. The post-training max $\dot{V}_{O_2}$ was 52.9 ml/kg/min. Withers found that the greatest

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Table 5. Descriptive Data for a Women's Lacrosse Team Before, During, and After a Pre-Season Conditioning Program (28)

Test	Weight kg	max $\dot{V}_{O_2}$ l/min	max $\dot{V}_{O_2}$ ml/kg/min	% Fat
1	58.9	2.59	44.0	24.9
2	56.8	2.76	48.6	22.8
3	56.8	2.97	52.3	23.1
4	57.4	3.03*	52.9*	23.1*

*Significant at the 0.05 level.

improvements occurred during the first two months of the training program (Table 5). This observation, he noted, emphasizes the need for a lengthy pre-season training period so that the attainment of a good level of aerobic power can act as a foundation for the training of the more task-specific anaerobic processes. He concluded that the training program was of a sufficient duration and intensity to bring about positive changes in maximal oxygen uptake.

Pre-Season/Post-Season Studies

Studies which examine the effects of a season of team competition on the physiologic capacities of the female athlete can be found in Table 6.

Table 6. Pre-Season/Post-Season Physiological Characteristics of Female Athletes Involved in Team Sports

Sport	N	Type of Work	Age yr	Weight kg	Height cm	% Fat	Maximal Values: Oxygen Uptake l/min	Maximal Values: Oxygen Uptake ml/kg/min	Maximal Values: Heart Rate bpm	Maximal Values: $\dot{V}_E$ l/min	Maximal Values: Lactate mM
Basketball (28)											
Pre-season	7	Bicycle	20.6	61.3	166.4	--	2.10	34.4	186.9	88.5	--
Post-season	7	Bicycle	20.9	61.1	166.5	--	2.35	38.7	184.6	87.5	--
Basketball (27)											
Pre-season	14	Bicycle	19.1	61.3	169.1	20.9	2.76	44.8	187.8	120.1	--
Post-season	14	Bicycle	19.5	61.0	169.3	20.8	2.69	42.9	186.2	118.7	--

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Sinning and Adrian (28) examined the changes that occur during the competitive season in maximum aerobic power of seven members of a women's collegiate basketball team. The team was tested at the beginning and end of the season on a bicycle ergometer. The subjects warmed up by riding for ten minutes at a rate of 300 kpm/min. The subjects rested for five minutes and then completed three minutes of exercise at a rate of 300 kpm/min. Alternate periods of five minutes of rest and three minutes of exercise were then given until the subject was unable to complete an exercise period due to exhaustion. Team members participated in 25 organized practices and seven games over a 66-day period. Max $\dot{V}_{O_2}$ significantly increased from 34.4 ml/kg/min to 38.8 ml/kg/min post-season. The authors concluded that participation in basketball led to an improved cardiorespiratory function as measured by max $\dot{V}_{O_2}$, but that a comparison of these results with results from other studies (1, 6) indicated that the basketball players in this study had not approached their potential condition.

In another study in which the effects of competition on max $\dot{V}_{O_2}$ were examined, Sinning (27) reported a max $\dot{V}_{O_2}$ of 44.8 ml/kg/min for 14 collegiate women basketball players prior to the start of the season. The subjects exercised to exhaustion against increasing work rates on a bicycle ergometer according to the method described by Sinning and Adrian (28). The players were tested at the end of the season and a max $\dot{V}_{O_2}$ of 42.9 ml/kg/min was reported. Sinning concluded that although these women had higher levels of cardiorespiratory fitness, as measured by max $\dot{V}_{O_2}$, than previously reported in the literature

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(27), the significant decrease in max $\dot{V}_{O_2}$ could not be attributed to the effects of training during the season. Sinning attributed the differences to the fact that comparisons of pre- and post-season means revealed significant increases in weight which led to significant decreases in max $\dot{V}_{O_2}$ when expressed in ml/kg/min. Recent studies on male athletes have shown that a decrease in max $\dot{V}_{O_2}$ has been found to occur in several sports during a season of competition (9, 34). The authors noted that this may be due to a shift in the training regime during the competitive season from an aerobic emphasis to a more sport-specific training program.

Conclusion

In conclusion, the specific fitness levels that are typical of female athletes involved in particular team sports has yet to be determined. Current literature provides relatively little insight into the physiologic capacities of the female as a team sport member. Further research needs to be undertaken to determine the specific physiologic capacities needed to elicit the female athlete's optimum performance.

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CHAPTER III

METHODS AND MATERIALS

Measurements of physiological capacity in humans are discussed most commonly in terms of oxygen uptake. This is usually determined using progressive exercise protocols on either a bicycle ergometer or a treadmill. Other physiological data, such as heart rate responses, blood pressures, and blood lactate concentrations can be obtained if the protocol is appropriate. Comparisons can be made on data obtained from a given individual at various points in time in order to determine changes in the physiological parameters in question. This study was designed to determine specific physiological changes which occur in a women's collegiate field hockey team as a result of a season of competition.

Subjects

Eighteen members of the 1983 Michigan State women's field hockey team were tested prior to the competitive season (August); fourteen members were tested post-season (November). Four members were not able to be tested post-season due to injury and were dropped from the study. Prior to the test each subject underwent a physical examination by a medical doctor.

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Physical Characteristics

Each subject was weighed and measured during the test session. Relative body fat and lean body weight were determined by the hydrostatic weighing method. Body density was determined according to the formula proposed by Brozek (33); relative body fat was determined by Siri's formula (32).

Treadmill Test

The treadmill test involved a maximal discontinuous stress test. The test consisted of three minutes of exercise (runs) alternated with seated one-and-a-half-minute rest intervals. The initial run began at 6 mph, 0 percent grade. During the next run, the treadmill grade was increased to 5 percent with the speed remaining at 6 mph. For each successive run, the grade was increased by 1 percent and the speed was increased by 1 mph. Each subject was requested to run to the point of fatigue or until the attending physician terminated the run. A 15-minute seated recovery followed each test.

Expired gases were collected throughout the test using a modified Douglas bag method (7). Exercise bags were collected every minute during exercise, every 30 seconds during the rest intervals, and at 1, 2, 3, 4, 5, 7, 9, 12, and 15 minutes during the recovery. The percent of CO_2 in the expired air was determined on an Applied Electrochemistry medical gas analyzer (model CD-30) and the percent O_2 was determined using the Applied Electrochemistry Oxygen Analyzer (model S-3A). Oxygen uptake, ventilation, and respiratory quotient were computed for each expired gas bag according to the method of

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Consolazio et al. (7). These values were plotted against time to determine the subject's response to exercise.

The heart rate was monitored throughout the test using a modified Lead II EKG. The peak heart rate was recorded during the last 10 seconds of each minute during exercise, every 30 seconds during the seated rest interval, and at 1, 2, 3, 4, 5, 7, 9, 12, and 15 minutes of the recovery.

Blood pressures were taken by auscultation and recorded prior to exercise, during the first minute of each rest interval, and at 1, 5, 10, and 15 minutes of recovery.

Blood lactate samples were taken from the pre-warmed finger-tips of each subject prior to the onset of exercise, after each three-minutes of exercise, during the 15-minute recovery periods at 5, 10, and 15 minutes following the final exercise period. The samples were collected in a 20 μl pipette and analyzed using the Roche Lactate Analyzer (model 640).

Statistical Analysis

Descriptive statistics (i.e., mean and standard deviation) were determined for each of the parameters examined. A Student's t-test for the comparison of pre-season and post-season means (P 0.05) was run on all of the data. Statistics were run on the SPSS subprogram T-Test. The Sign Test (26) was used to determine the significance of the data nonparametrically.

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Training Method

Training during the field hockey season consisted of an organized practice, five times a week for one-and-a-half to two hours duration. Practice consisted of field hockey drills designed to improve sports skills. In addition to practice, an interval training program consisting of 100 meter sprint runs followed by short rest intervals, was carried out for one-half hour periods, three times a week.

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CHAPTER IV

RESULTS AND DISCUSSION

This chapter consists of the physiological results and discussions of the pre-season and post-season exercise test sessions of the Michigan State women's collegiate field hockey team. The physiological characteristics of heart rate, blood pressure, ventilation, oxygen consumption, and lactic acid will be presented and discussed separately. The physiological and physical characteristics of the team can be found in Table 7.

Heart Rate

The maximum heart rate decreased significantly ($P < 0.05$) as a result of a season of training. Heart rates were also found to be significantly lower throughout the post-season test (Figure 1), and during the recovery heart rates returned to normal more rapidly post-season.

The maximum heart rate of 191.0 bpm found in this study is within the range of values reported in other studies (13, 15, 20, 27, 28, 30, 36, 37, 38). This value is less than that found for several groups of endurance athletes (11, 23, 24). This may be due to the fact that endurance athletes generally train at near-maximum heart rates and may be able to tolerate a higher heart rate during an exhaustive test (1).

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Table 7. Physiological Characteristics of a Women's Collegiate Field Hockey Team

	Pre-Season		Post-Season	
	$\overline{X}_1$	s_1	$\overline{X}_2$	s_1
Age (years)	18.2	1.3	18.6	1.4
Weight (kg)	59.5	6.8	60.7	6.8
Height (cm)	162.1	6.9	162.3	7.1
Relative body fat (%)	25.1	5.4	26.5	6.1
$\dot{V}_E$ (l/min BTSP)	93.2	7.2	83.8	4.6
$\dot{V}_{O_2}$ max (ml/kg/min)	47.7	3.6	49.2	4.2
$\dot{V}_{O_2}$ max (l/min)	2.68	0.42	2.90	0.48
Maximum treadmill run time (min)	13:36	3:14	13:51	3:20
Maximum blood lactate (mM)	13.3	2.7	12.3	2.0
Maximum heart rate (beats/min)	196.0	10.2	191.0	9.8
Systolic blood pressure (mmHg)[a]	165.0	16.0	184.0	17.6
Diastolic blood pressure (mmHg)[a]	78.0	11.2	90.0	12.1

[a]Taken at $\dot{V}_{O_2}$ max.

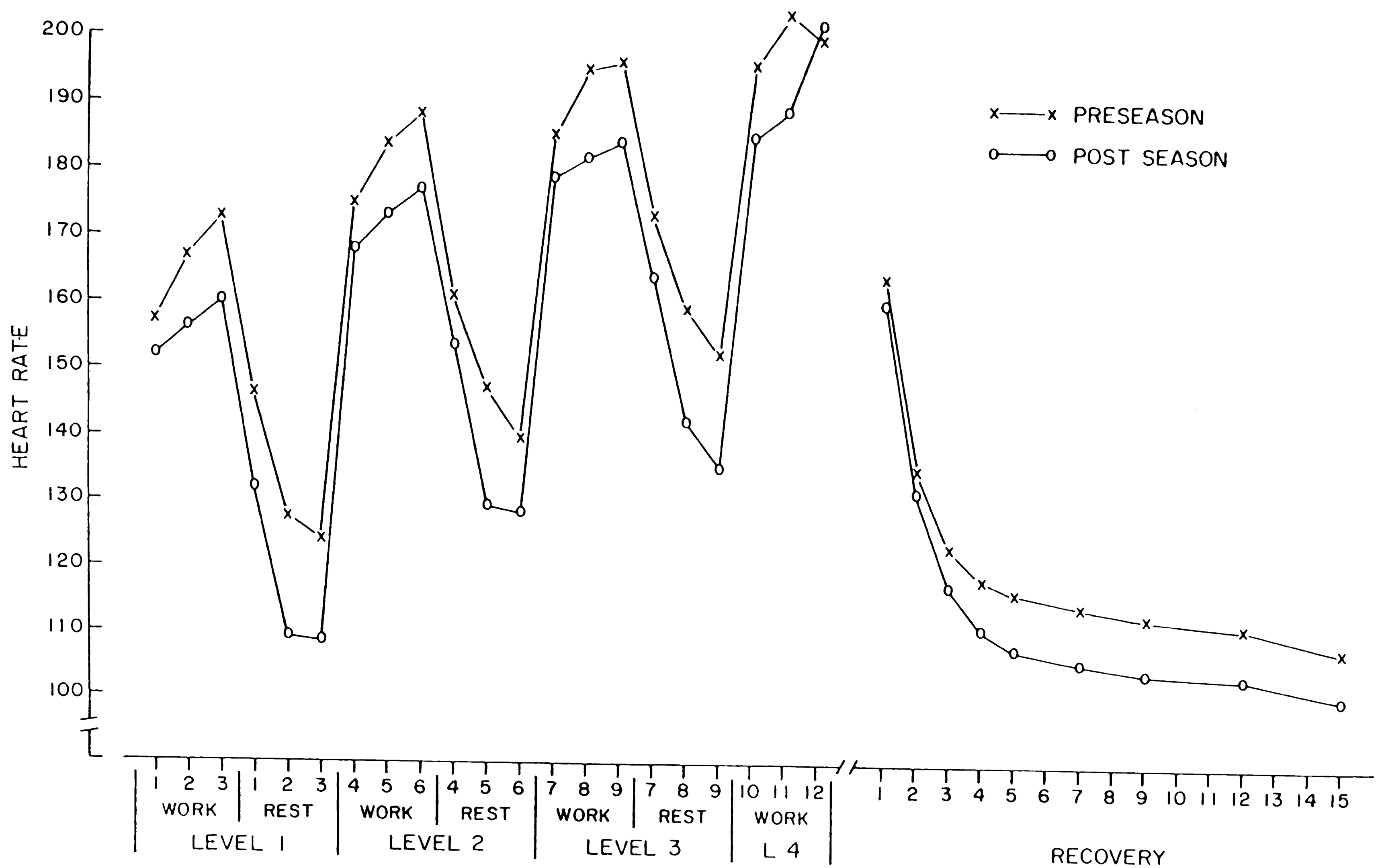

Figure 1. Heart Rate Response of a Women's Collegiate Field Hockey Team to a Maximal Intermittent Treadmill Test.

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A decrease in max heart rate has been found in other training studies involving team athletes (27, 28, 36). This may be indicative of a cardiovascular change in response to the increased activity level that occurs with training (1). The effect of physical training over a short period of time (two months in this study) is considered by Ekblom (8) to be "mainly a more efficient regulation of blood circulation; an increase in the dimensions of the oxygen-transport organs is only achieved through training of long duration." He attributed the increase in the efficiency of the regulatory mechanisms affecting blood circulation to an increase in stroke volume, which would lead to a reduction in heart rate.

Blood Pressure

Concurrent with the decrease in exercise heart rate was a significant increase ($P < 0.05$) in blood pressures obtained during exercise and through the tenth minute of recovery (Figure 2). This increase is not typically found as a response to aerobic training.

To the author's knowledge only Sinning and Adrian (28) have reported blood pressures for team athletes. They found a post-season systolic blood pressure of 162 mmHg and a diastolic blood pressure of 74 mmHg for a women's collegiate basketball team following a maximal bicycle test. Pre-season values were not reported.

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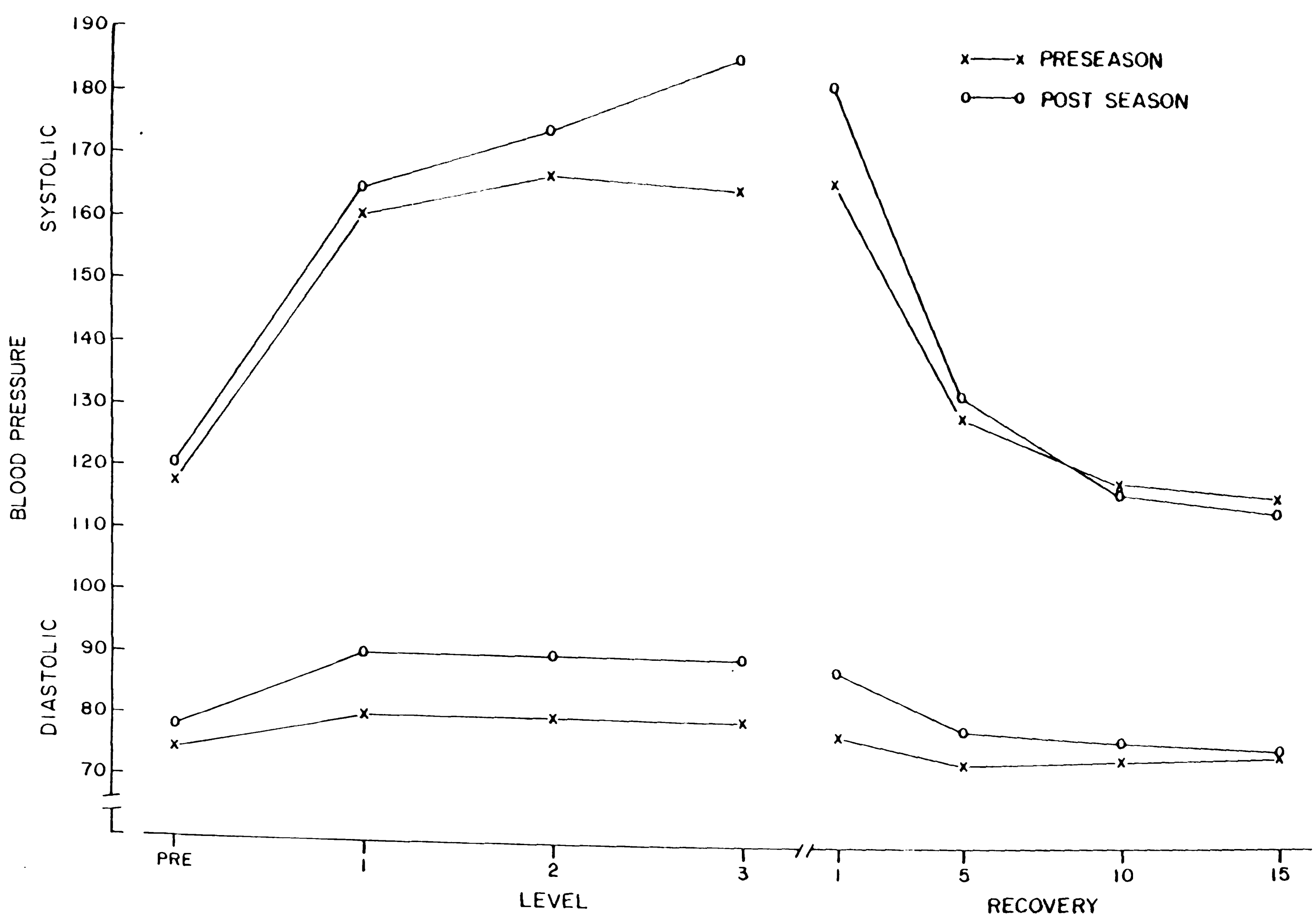

Figure 2. Blood Pressure Response of a Women's Collegiate Field Hockey Team to a Maximal Intermittent Treadmill Test.

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Ventilation

Maximum ventilation decreased significantly ($P < 0.05$) during the season (Figure 3); however, the ventilatory rate remained relatively constant in every level of the test but level 3 ($P < 0.05$). Rates were constant during recovery. Since the max $\dot{V}_{O_2}$ value did not change considerably, the field hockey players were removing more oxygen from the air they breathed.

The maximum ventilation values reported for the field hockey players are lower than those reported in several studies (11, 13, 24, 28, 30, 35, 36, 37). Similar values were reported for a group of athletes (15) from the sports of field hockey, volleyball, basketball, and swimming. Vacarro et al. (32) also reported a relatively low max ventilation of 94.9 l/min for a women's collegiate basketball team prior to a competitive season. Sinning (27) reported a max ventilation rate of 88.5 l/min for a women's basketball team during pre-season testing; a value of 87.5 l/min was reported post-season.

Oxygen Uptake

Max $\dot{V}_{O_2}$, as measured in l/min and ml/kg/min, did not undergo a significant change during the season. Oxygen uptake remained relatively constant between pre- and post-season testing at every exercise level and during recovery as indicated in Figure 4.

The post-season max $\dot{V}_{O_2}$ of 49.2 ml/kg/min determined for the field hockey players is considerably less than that reported for female endurance athletes. Saltin and Åstrand (24) reported a value of 61.8 ml/kg/min for a group of endurance athletes. Hermansen (11) reported

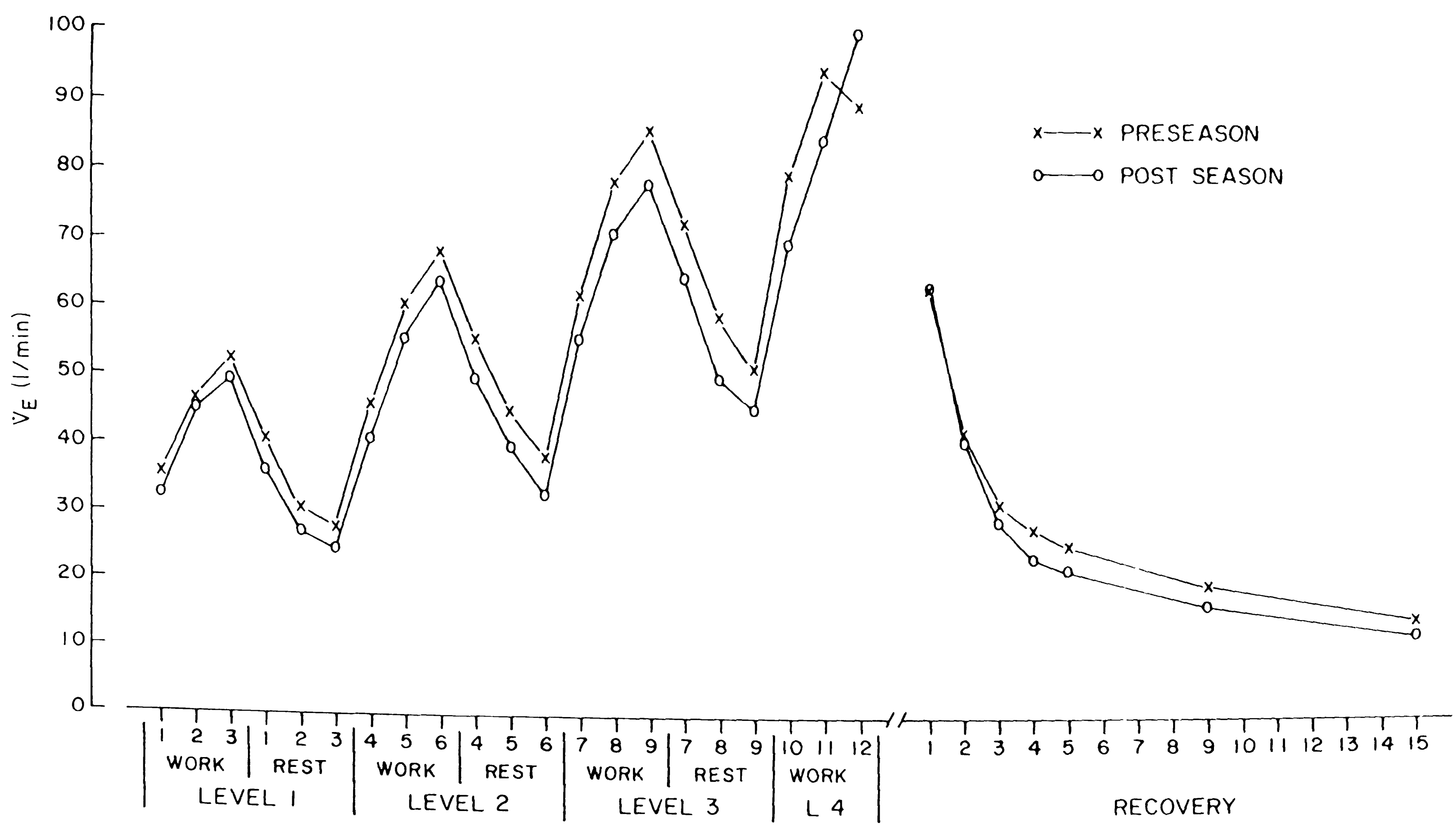

Figure 3. Ventilatory Response of a Women's Collegiate Field Hockey Team to a Maximal Intermittent Treadmill Test.

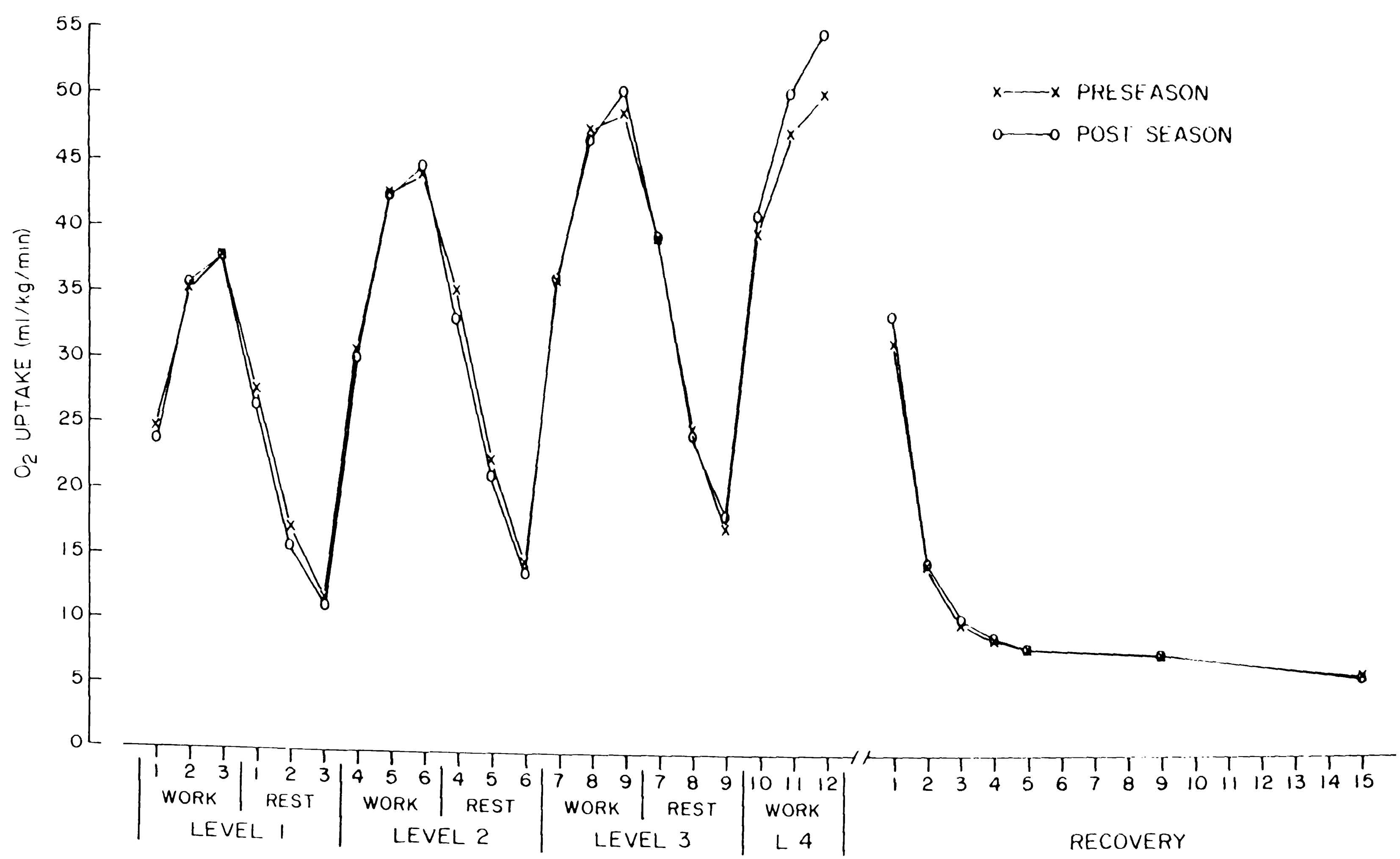

Figure 4. Oxygen Uptake of a Women's Collegiate Field Hockey Team During a Maximal Intermittent Treadmill Test.

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a max $\dot{V}_{O_2}$ of 56.9 ml/kg/min for female cross-country skiers and 57.5 ml/kg/min for women runners competing in the 400-1500 meter events. A value of 59.1 ml/kg/min was reported for women marathon runners (35). Rusko et al. (23) found a group of world-class women cross-country skiers to have a max $\dot{V}_{O_2}$ of 68.2 ml/kg/min.

The maximum oxygen uptake of the field hockey players involved in this study is comparable to that of 51.7 ml/kg/min reported by Zeldis et al. (38) and 50.2 ml/kg/min reported by Withers and Roberts (37) for field hockey players. A considerably lower value of 42.9 ml/kg/min was found by Maksud et al. (15) for a group of women field hockey players.

In a comparison with other women's team sports, the field hockey players in this study had a higher max $\dot{V}_{O_2}$ than those reported for basketball players (6, 27, 28), but a lower value than the 52.9 ml/kg/min reported by Withers (36) for lacrosse players. The field hockey players had a lower max $\dot{V}_{O_2}$ than the 55.3 ml/kg/min reported for softball players (22), but a higher value than the 45.4 ml/kg/min reported by Withers and Roberts (37) for softball players. The field hockey players registered a higher maximum oxygen uptake than that reported for volleyball players (6, 15, 30). Elite volleyball players (20) had a similar value of 50.6 ml/kg/min but the volleyball players in the study of Kovaleski et al. (13) had a greater value of 56.0 ml/kg/min.

The max $\dot{V}_{O_2}$ of the athletes involved in this study showed a slight but insignificant increase over the season; from an initial

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value of 47.7 ml/kg/min to a post-season value of 49.2 ml/kg/min. Other studies have also reported changes in the maximum oxygen uptake after a training period or after a competitive season. Women lacrosse players (36) significantly improved their max $\dot{V}_{O_2}$ after a three-month training period prior to a competitive season. The initial value was 44.0 ml/kg/min and the post-training value was 52.9 ml/kg/min. Withers attributed this significant increase to the strenuous nature of the training program. Women collegiate basketball players exhibited a slight decrease in max $\dot{V}_{O_2}$ after a competitive season (27). The pre-season value was 44.8 ml/kg/min and the post-season value was 42.9 ml/kg/min. Sinning and Adrian (28) reported an improvement in max $\dot{V}_{O_2}$ for a women's collegiate basketball team during the competitive season. The authors noted that "since there were no concomitant improvements in other cardiorespiratory parameters, the training program used by the team in their study was not strenuous enough to cause the participants to reach their capacity for physical conditioning."

Lactic Acid

Lactic acid concentration showed no significant changes between the two test sessions. Figure 5 indicates that the post-season lactate concentrations were lower at every exercise level and throughout recovery. When each set of measures were analyzed individually using the t-test, the differences were not great enough to be significant. However, when the exercise and recovery values were analyzed collectively using the Sign Test (26), they were found to be significantly

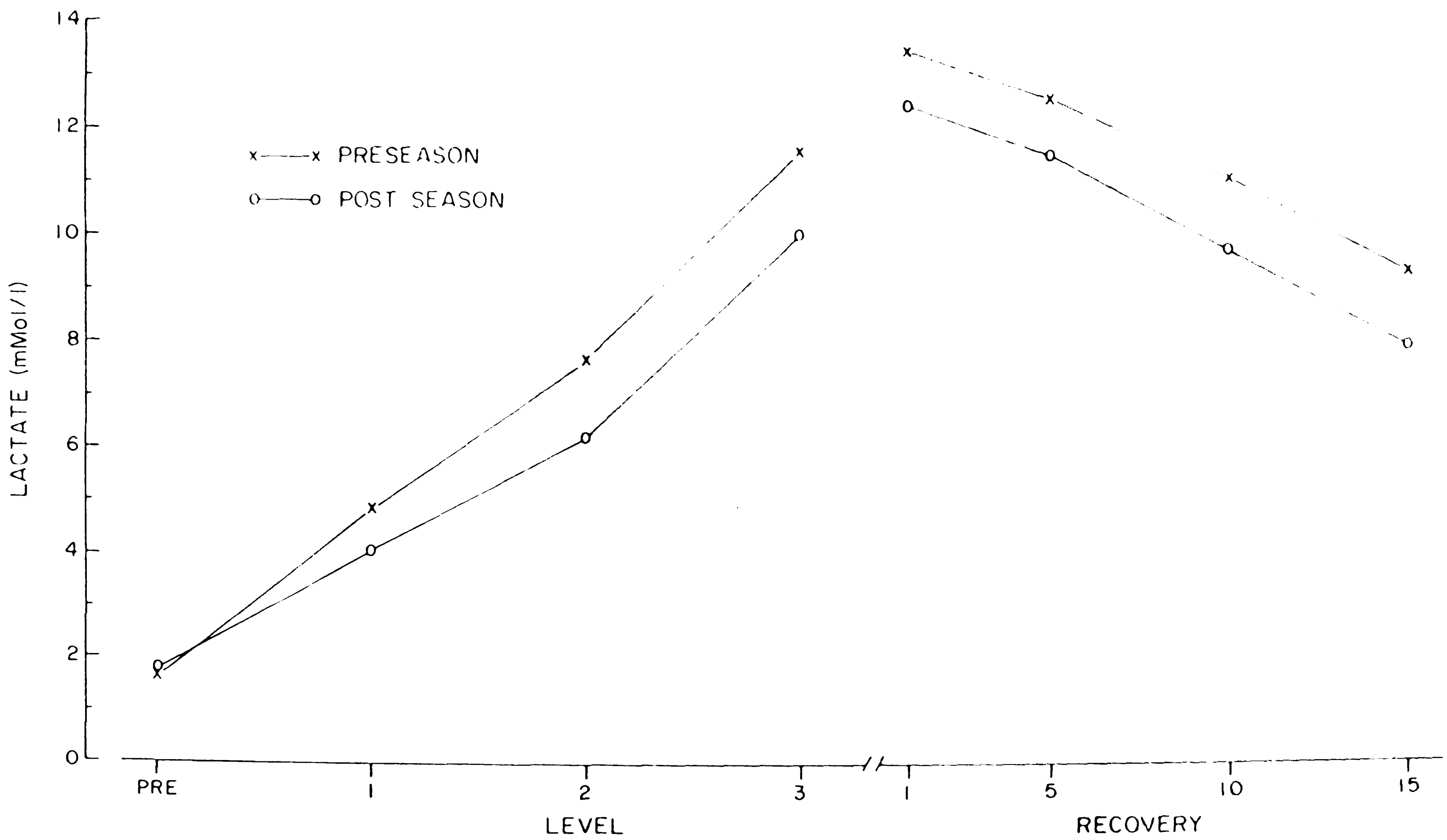

Figure 5. Lactate Response of a Women's Collegiate Field Hockey Team to a Maximal Intermittent Treadmill Test.

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($P < 0.01$) lower post-season. As expected, the peak lactates occurred in the first minute after exercise for both the pre- and post-season tests.

Changes in lactic acid concentrations have been used to examine changes that occur in endurance capacities (1, 11, 25). Lactate is an intermediate waste product of glycogen metabolism that is produced in muscles during exercise when the supply of oxygen is not sufficient to completely breakdown the glycogen. When lactate accumulates in muscles, the pH of the tissue is reduced from an alkaline pH to a more acidic pH (33). This results in a slowing of the muscle's contractile rate and a gradual cessation of muscular activity.

If the rate of lactic acid accumulation can be lowered during exercise, an improvement in endurance capacity will result (1). This will occur because, with muscle pH declining at a slower rate, an athlete will be able to perform for a longer period of time before becoming fatigued. The amount of lactic acid produced can be monitored by extracting small samples of blood, since lactate diffuses readily into the bloodstream from the working muscle fiber (33).

The quantity of lactic acid in the blood is not directly proportional to the quantity produced in the working muscle at a given time (33). This is due to the fact that some lactic acid is metabolized in the working muscle and never reaches the bloodstream. However, increases in the bloodstream parallel increases in the muscles (33). Therefore, an examination of lactate concentrations over a period of time should reflect changes that have occurred in muscle matabolism.

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The blood lactate values for the field hockey players in this study were higher both during pre- and post-season tests than those reported in other studies for either individual athletes or team athletes (11, 20, 30, 36, 37). The significant change in the blood lactate concentrations for the maximal treadmill test after the field hockey season suggest that there was improvement in their ability to metabolize glycogen and therefore, improvement in their performance capacity as measured by lactic acid concentration.

In this study there were significant changes in the cardiorespiratory parameters examined for the women's collegiate field hockey team after a season of competition. The data indicate that the athletes were performing at about the same oxygen uptake post-season as pre-season. However, the same work was performed post-season at lower ventilation values, lower heart rates, and lower lactates, suggesting that the women were performing more efficiently post-season. However, the post-season blood pressures were elevated. The response obtained was not the typical adaptation to aerobic training. It would appear that the data reflect a specific adaptation to field hockey training. How it may be categorized or classified is not clear at this time. It is not an aerobic response nor could it be classified as an anaerobic response. It would appear to be a response to repeated burts of high intensity activity of relatively short duration. There are clearly significant changes evident but interestingly they were not related to performance time nor to the oxygen uptake capacity.

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While it has been shown that an elevated max $\dot{V}_{O_2}$ is a prerequisite to success in endurance sports such as running (24, 35), this fact has not been clearly established with regard to the female field hockey player, since the game as played in the U.S.A. is primarily a skill oriented game. However, with the current increased emphasis on women's athletics, there will be a refinement of the skills involved in field hockey, thereby increasing the importance of specific physiological capacities in assessing the skill of the woman player.

The physiological parameters such as heart rate response to a given amount of exercise and the accumulation of blood lactic acid can provide important information regarding an athletes' physical abilities.

Further research is needed in the area of women team sports in order to determine and develop their optimum physiological capacities. When the specific adaptations are recognized, the training procedures can be appropriately modified.

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CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Fourteen members of a women's collegiate field hockey team were tested pre- and post-season for max $\dot{V}_{O_2}$, ventilation, heart rate, blood pressure, and blood lactate using a maximal intermittent treadmill test. Test results indicate a significant reduction in heart rates and a significant increase in blood pressures post-season. Ventilation rates and blood lactate concentrations were lower post-season but the difference was not significant. Oxygen uptake remained unchanged. Data from this study indicate that while the women performed at the same oxygen uptake post-season as pre-season, the combination of lower ventilation rates, lower lactates, and lower heart rates suggest that the women were performing more efficiently post-season. The increase in blood pressures is not a typical aerobic response and cannot be classified at this time. It would appear that the data reflect a specific adaptation to field hockey training.

Conclusions

The results of this study have led to the following conclusions:

1. The heart rates were significantly reduced by a season of field hockey training and competition.

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2. The athletes performed at the same oxygen uptake post-season as pre-season.
3. The combination of lower ventilations, lower lactates, and lower heart rates suggest that the women were performing more efficiently post-season.
4. Blood pressures were significantly elevated by a season of training and competition in field hockey.
5. A comparison of the data in this study with that of other studies indicates that there is room for improvement in each of the physiological parameters examined in this study.

Recommendations

1. The coach needs to employ a training program in addition to practice that will improve the players' aerobic capacity.
2. Further study needs to be undertaken to determine the extent of the female athletes' aerobic capacity in response to participation in a team sport.

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