THE EFFECTS OF PHYSICAL CONDITIONING PROGRAM ON SELECTED PHYSIOLOGICAL VARIABLES OF COLLEGE AGE WOMEN GYMNASTS

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CHAPTER I

INTRODUCTION

General purpose of the Study

The purpose of this study was to determine the effects of a physical conditioning program on selected physiological variables in college women gymnasts at Oklahoma State University.

Background and Significance of the Study

In the past twenty years womens' athletics has undergone a significant change. The change is clearly evident by comparing the current situation with the attitudes towards women in sports that existed in the nineteen forties. After World War II, very few sport options were available for the adult woman. Today, women are encouraged to be both competitive and physically active, giving birth to the recent phenomena of the American sportswoman.

In recent years the nature of work has changed and largely sedentary occupations have replaced the need for muscle use. In recognition of this, a growing awareness of the need for physical activity and exercise has emerged, resulting in an increased emphasis on sports for school age and adult women. In 1972 the Educational Amendments act was passed allowing for equal opportunities for both male and female students in organized school sports. The increased awareness of girls and women in the field of sport and recreation has been greatly enhanced by national television exposure given to successful women athletes (1).

Two decades ago women's participation in sports was decisively minimal; only 385 females participated in the 1948 olympic games. By 1952, more than 500 women competed in the Olympics in Helsinki. By 1972, changing times had revolutionized the previously male dominated world of sports and women's participation was no longer restricted. The fact is that girls and women can successfully compete in vigorous athletic activities and are equally capable of attaining high physical performance without either psychological or physiological harm (1). This fact has long been acknowledged by European experts who do not perceive physical activity as a potential threat to femininity. With the exception of the pioneer woman image, Klafs et al. (2) points out that American society has traditionally limited the role of the American woman. This restrictive perspective still finds support by many who believe that women's participation in competitive athletics is not only physically and psychologically detrimental, but also morally wrong. Data gathered from doctors, teachers, psychologists, and researchers refutes this opinion and there is no evidence to support these misconceptions. On the contrary, research studies indicate that females are quite able to successfully compete, especially in those sports where size and strength are not significant variables. There is nothing to prevent the normal healthy female from active participation in stenuous sports and such physical activity will not develop male characteristics but rather can serve to accentuate female qualities.

As it is generally true that women are not physically as strong as men, the resistance factor in activities requiring strength, may need to be reduced to conform to the individual's ability. While it is not unusual for male athletes to succumb to nausea and fatigure after strenuous endurance events, such as the half mile race, these types of events do not seem to overtax the cardiovascular system of women (2).

There is no doubt that women athletes are finally being recognized and have proved themselves to be as adept as men in the competitive sports arena. This change is reflected in the great number of athletic events in which women now participate. In addition to numerous state and regional tournaments the A.I.A.W. (Association for Intercollegiate Athletics for Women) has sponsored ten annual national championships in seven sports. The increased number of events for the female athlete in the Olympic games in recent years testifies to the growth and social acceptance of the women as athletes (3).

Historical Background of OSU Women Gymnastic Team

Fall, 1974, Larry Bilhartz was employed to be the coach for the women's gymnastic team at OSU. This team had five voluntary members which were recruited from the general student body. At this time the team did not compete in out-of-state competition, but the gymnasts wanted to hold a state championship.

During the Fall of 1975-1976, the membership of the team increased to 12 gymnasts. The team was still based on volunteer members recruited from the general student body. At this time there were two teams; a varsity team (A team) and a second team (B team). For the first time the OSU women's gymnastic team participated in out-of-state competition.

In the Fall of 1976-1977, the team consisted of 11 gymnasts. This was considered to be the first year for the team to have been recruited from outside the general student body. Only the varsity team participated in out-of-state competition.

During the season of 1977-1978, the team consisted of only five gymnasts, since several members dropped from the team due to heavy training at that time. That year, the competition was expanded to participate in the Big Eight Conference in addition to the state championship.

In the Fall of 1978-1979, the membership of the team remained the same and consisted of five girls. Accordingly, the grants in aid were expanded in order to have more gymnasts on the team. During this year, one more coach, as a student-assistant, was appointed for the team. This year marked a remarkable period in which the team participated in the National Collegiate Athletic Association (NCAA) competition, and the team was ranked sixteenth in the United States in national ranking.

For five years (1974-1979) the team utilized a normal conditioning program with strength training, side by side with formal gymnastic training. The gymnasium in the Colvin Center was used for the conditioning program.

During the 1979-1980 season, the team improved skills and increased in the number of participants. The number of team members increased to seven. The ranking of the team was fourteenth in the National Collegiate Athletic Association (NCAA) competition and second in the Big Eight Conference. During this year, the team utilized aerobic and strength training as the conditioning program.

In the Fall of 1980-1981, the membership of the team increased to nine girls. It was ranked first in the Big Eight Conference. This year the team did not compete nationally. The conditioning was expanded to include strength training, anaerobic and aerobic training, weight control regimen, and was well planned and supervised. The major objectives of this conditioning program were to develop cardiovascular fitness, flexibility, and strength for the girls. Therefore, the conditioning program needed more space and facilities. Consequently, the gymnasium in the Colvin Center and Gallaher Hall became the appropriate places for gymnastic training and the conditioning programs. In addition, body composition evaluation was added to the conditioning program.

During the Fall of 1981-1982, the membership of the team increased to 13 gymnasts. For the first time, the team participated in the two largest national competitions. The first competition was in the National Collegiate Athletic Association (NCAA); the team ranked ninth in this competition. The second competition was in the Association of Intercollegiate Athletics for Women (AIAW) and the team ranked eighth in this competition.

Today (1983), the team consists of 13 members coached and supervised by Head Coach, Larry Bilhartz, and two assistant coaches, Dave Henley and Debbie Yohman (*).

Recently, participation in aports and physical activities for girls and women has increased tremendously. However, the female response to vigorous physical conditioning and training is not nearly as well studied as the male response (4).

Drinkwater (5) noted that as more and more women take advantage of opportunities to participate in physically demanding activities, interest

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*Review with Larry Bilhartz, coach of the Women Gymnastic Team at Oklahoma State University, December 8, 1982.

in how they respond physiologically to these activities has increased.

McArdle et al. (6) states:

> Coaches and athletes are continually searching for ways to gain the competitive 'edge' and improve athletic performance. It is not surprising, therefore, that a variety of ergogenic substances and procedures are used routinely at almost all competitive levels (p. 305).

In preparing for the various competitive levels, emphasis is needed on the development of personal traits and factors which influence performance.

Recently, more attention has been given to the effects of physical conditioning programs as a means of performance improvement.

Klafs and Lyon (7) indicate that

> . . . a variety of physiological responses can be altered by conditioning that will contribute to improving the athlete's competitive performance. On the average the function of each body system can be improved approximately 25%. But the sum of these systemic responses may result in a 100% improvement in total performance capacity in terms of both magnitude and duration of work that the athlete can accomplish (p. 104).

Some of these functional improvements have been identified by Brouha (8):

1. Increased muscular strength.
2. Greater maximum oxygen consumption.
3. Higher maximum cardiac output (greater volume of blood pumped by the heart) and less of an increase in pulse rate and blood pressure during submaximal exercise.
4. More economical lung ventilation during exercises and a greater maximum lung ventilation.
5. Increased capacity to perform more work aerobically, thereby decreasing the tendency to incur an oxygen debt and lactic acid buildup, which causes fatigue.
6. Quicker, recovery in pulse rate and blood pressure after exercise.
7. Better heat dissipation during exercise (p. 33).

There are, at least, three basic capacities that the athletes may improve through physical conditioning and training programs. These capacities are: strength, cardiovascular endurance and flexibility.

Many physical conditioning programs have been proposed for improving the physiological capacity of various systems of the body, but to perform physical activities which increase physiological or functional capacity in one system does not greatly benefit the capacity of another system (9).

Klafs and Lyon (7) state:

> . . . because the body adapts 'responds' to the demands placed on it in a highly specific manner, all the components that are required in a given sport must be carefully identified. The conditioning activities, appropriate for improving each of these specific factors must be included in the conditioning program (p. 88).

In general, research has established that the physiological adaptations to physical conditioning and sport participation are quite specific to the nature of the sport and physical activity (10).

Recent studies have indicated that there is a high degree of specificity in regard to improving a particular physiological capacity. Evidence from these studies strongly suggests that a person should perform the conditioning and training exercise in a manner as close as possible to the way the individual is going to use the improved capacity. Developing a cardiovascular system for gymnastics, swimming, basketball and tennis, for example, can be achieved more readily when the athlete works with the specific muscles involved in the particular physical activity. The same is true for improving other systems (9).

Gymnastics as a competitive sport is popular all over the world. The growth of young women's participation in competitive gymnastics has been a product of the growing acceptance of female participation in sports and physical activities.

Because of the level of difficulty at which gymnasts are performing, a physical conditioning program that includes cardiovascular endurance, strength, felxibility and optimum body composition has become especially important.

A review of the literature shows an interest in how females respond physiologically to various sports and physical activities (5). Several studies have indicated that exercises promote significant alteration in body composition as determined by skinfold measurements (12). In addition, other studies have indicated that maximum aerobic capacity of women, as well as cardiorespiratory variables were improved by conditioning and endurance training programs (11).

This study was an attempt to compliment the scarcity of information on physiological components of college women gymnasts. Until more research in this area has been undertaken, data of physiological variables of women's gymnastics will continue to be inconclusive (7).

Statement of Problem

The purpose of this study was to identify the effects of a three-month conditioning program on selected physiological variables of female members of the Oklahoma State University Women's Gymnastic Team. The conditioning program emphasized cardiovascular functions, body composition and strength. The conditioning program consisted of running, warm up including stretching and flexibility exercise, formal gymnastic training and strength training with near maximal resistance exercise. A further purpose was to compare the results of physiological measures with published information for women gymnasts where available.

The primary research method used was the case study.

Hypotheses

1. There was no difference between pre- and post-test anaerobic threshold heart rate in the subjects.

2. There was no difference between pre- and post-test percentage of max $\dot{V}O_2$ at anaerobic threshold in the subjects.

3. There was no difference between pre- and post-test maximal oxygen consumption (ml/kg/min) in the subjects.

4. There was no difference between pre- and post-test supine resting blood pressure in the subjects.

5. There was no difference between pre- and post-test standing resting blood pressure in the subjects.

6. There was no difference between pre- and post-test supine resting heart rate in the subjects.

7. There was no difference between pre- and post-test standing resting heart rate in the subjects.

8. There was no difference between pre- and post-test percent body fat as measured by skinfold thickness (sum of 7) in the subjects.

9. There was no difference between pre- and post-test percent body fat as measured by underwater weighing in the subjects.

10. There was no difference between pre- and post-test circumference (predicted ideal weight) measures in the subjects.

11. There was no difference between pre- and post-test right grip strength in the subjects.

12. There was no difference between pre- and post-test left grip strength in the subjects.

13. There was no difference between pre- and post-test push strength in the subjects.

14. There was no difference between pre- and post-test pull strength in the subjects.

15. There was no difference between pre- and post-test right leg

strength in the subjects.

16. There was no difference between pre- and post-test left leg strength in the subjects.

Limitations

The following conditions were viewed as limitations of this study:

1. The sample size was small.

2. Factors, such as rest, diet, daily activity and elective running were not controlled.

3. The number of test dates and number of physiological components measured were limited to the availability of the laboratory facilities and equipment.

4. No attempt was made to control motivation.

Delimitation

This study was delimited in the following ways:

1. The subject population was restricted to highly trained, college-age females who were members of the Women's Gymnastic Team at Oklahoma State University.

2. The modes of conditioning and training were running, warm-up, formal gymnastic training, and strength training.

3. The training period was confined to a three-month period prior to the competitive season.

Assumptions

1. It was assumed that all subjects were in good health and excellent physical condition.

2. The test instruments and procedures were assumed valid.

3. It was assumed that the effects of formal gymnastic training was uniform upon all subjects.

4. It was assumed that the subjects were performing the conditioning program to the maximum of their ability.

Definition of Terms

Conditioning - "The methodical application of an exercise program carefully formulated to bring the athlete's physiological capacities to their peak in preparation for competition" (7, p. 101).

Cardiorespiratory Fitness - "The ability of the heart, lungs, and vascular systems to supply oxygen to the tissues of the body" (11, p. 7).

Maximum Oxygen Consumption ($\dot{V}O_2max$) - "The maximal amount of oxygen that an individual can consume, generally reported in ml/kg/min" (11, p. 7).

Exercise - "A non-resting state of the body; it can be classified according to speed of movement, resistance to movement, and duration of activity" (12, p. 4).

Muscular Strength - The force muscles exert in a single effort or contraction (145).

Flexibility - The ability of an individual to move the body joints through a maximum range of motion. Without undue strain (12).

Circuit Training - "A series of exercises where the participant performs prescribed activities based on any combination of time, sets and repetitions" (12, p. 3).

Aerobic - The process by which energy is expended in the presence of oxygen.

Weight Training - Progressive resistance using weight for resistance (7).

Blood Pressure - "The driving force that moves blood through the circulatory system. Systolic pressure is obtained when blood is ejected into the arteries; diastolic pressure is obtained when the blood drains from the arteries" (16, p. 633).

Anthropometry - "The measurement of the size and proportions of the human body" (16, 632).

Body Density (D) - The weight or mass of the body divided by body volume.

Obese (Obesity) - Having excessive accumulation and storage of fatty tissue (145).

Body Composition - "The components of the body divided into lean body mass, fat, and total body water" (12, p. 3).

Static Stretching - Holding of a body position that locks the joints around a muscle in a position of greatest possible muscle length and little concomitant muscle activity (17).

Warm-up - "Activation of physiological systems and elevation of body temperature by prior exercise" (17, p. 310).

Anaerobic Threshold - "The level of work of O_2 consumption just below that at which metabolic acidosis and the associated changes in gas exchange occur" (28, p. 236).

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to evaluate the effects of a conditioning program on selected physiological components of College Women gymnasts.

Though the effects of conditioning and training on physiological components for males are well documented, relatively little is known of the female response to a physical conditioning program (4).

Wirth et al. (18) state:

> . . . the past several years have seen a tremendous increase in the scope and intensity of women's athletics. However, the female response to vigorous training programs is not nearly as well studied as the male's response. Several studies have investigated the female response to physical work in areas which may be uniquely critical to the female (p. 223).

Studies specifically conducted to investigate conditioning effects on the physiological components of women gymnasts are scarce (5).

Literature related to the purpose of this study was reviewed. The review was limited to the following areas: physical conditioning for women, anaerobic threshold, maximal oxygen consumption, strength training, body composition, resting heart rate and blood pressure, and studies related to gymnastics.

Physical Conditioning for Women

Klafs and Lyon (7) have defined conditioning as, "the methodical application of an exercise program carefully formulated to bring the athlete's physiological capacities to their peak in preparation for competition" (p. 67).

In recent years, an increasing amount of research has been done concerning women in sports. These data have revealed that women are physiologically similar to men, and that physical conditioning programs that work for men will also work for women. "The existing differences are those of magnitude not basic physiological functions. The enzyme systems and cellular control mechanism are the same in both men and women" (20, p. 236).

There are, at least, three basic capacities that the athlete attempts to improve through a conditioning program. These capacities are: strength, cardiorespiratory endurance, and flexibility.

Principles of Conditioning

Certain basic principles of conditioning must be followed in order to improve cardiorespiratory endurance, strength, flexibility and other variables such as anthropometric characteristics. These principles are: overload, progression, regularity, and maintenance (7).

Overload. Strength, endurance, and flexibility changes occur when the human mechanism has been overloaded or challenged beyond its resting state (12). Any effective physical conditioning program must be based on the proper applications of physiological overload (9).

DeVries indicated that improvement has occurred when "the workload is greater than that which an individual is accustomed" (21, p. 64).

Katch and McArdle (9) stated that:

> . . . by exercising a system of the body at a level above that at which it normally operates, that system will adapt to function more efficiently. The method and extent of the overload will directly affect the conditioning of the particular system involved (p. 235).

After adaptation occurs, the intensity has to be increased if further improvement is to occur (22).

Studies specifically designed to investigate conditioning effects on the physiological components in female athletes are scarce (5). Data on the women gymnasts are sparse. However, Sinning and Adrian (23) examined seven members of a women's collegiate basketball team before and after a two-month period of practice and competition to determine if there were changes in cardiorespiratory response as a result of their participation. Although they found a significant increase in $\dot{V}O_2$ max from 34.4 to 38.7 ml O_2/kg. min., they concluded that the conditioning program for the basketball team was not strenuous enough to push the women to their optimum level of physical conditioning.

<u>Progression</u>. A progression approach has been integrated with the overload principle in which the work loads are increased gradually according to a systematic approach (12). Cureton (24) proposed that progression occur through a gradual warm-up to exercise of longer and more difficult duration.

<u>Regularity</u>. Klafs and Lyon (7) stated that:

> . . . to improve basic physiological capacity, the individual must work out regularly and frequently - high competitive levels demand daily workouts even if a satisfactory fitness level has been achieved (p. 68).

Maintenance. This principle refers to the fact that once a desired fitness or performance level has been achieved, maintenance is necessary or beneficial efforts or training will be lost (12). One will lose in four or five days what might have been gained in a day or two (7).

Some researchers estimate that once a conditioning program is discontinued, all the improvement gained during the conditioning process are lost in five to ten weeks. This is one reason why athletes in various sports begin a reconditioning program a month or two prior to the start of the competitive season (9).

Literature Relevant to the Anaerobic Threshold

"There are a great many organisms which can live and operate with or without oxygen. Even certain tissues of man are able to function either aerobically or anaerobically, the skeletal muscle tissue being a good example" (25, p. 32).

Hermansen (25) indicated that

> . . . in the intact human organism, the energy needed for muscular exercise is derived from oxidation of carbohydrates and fat (aerobic processes) and from splitting of glycogen and energy-rich phosphates in the muscle cells anaerobic processes. During prolonged exercise (10 minutes or more) aerobic processes play the most important role while, during short exhaustive work periods (up to 1 - 2 minutes), the energy needed is derived mostly from anaerobic processes (p. 32).

Recently, investigators have introduced a new parameter that may be closely related to the percentage of the capacity that one can maintain for a prolonged period of time (26). Wasserman and McIlroy (27) have termed this parameter the anaerobic threshold.

According to Wasserman et al. (28) "the term anaerobic threshold (AT) has been used to define the peak work rate or O_2 uptake at which aerobic metabolic processes can no longer meet the skeletal muscle requirements for ATP" (p. 236). Therefore, as work is incremented above the anaerobic threshold, progressive increases in anaerobic glycolysis must accompany aerobic metabolism to sustain adequate levels of ATP regeneration. The acceleration in glycolysis leads to an elevated muscle lactic acid concentration and a consequent metabolic acidosis (30).

Wilmore (26) defined anaerobic threshold "as that point in an exercise of increasing intensity at which the body starts increasing anaerobic metabolism above resting levels and at which blood lactate concentration starts to increase" (p. 192).

The concept of the anaerobic threshold (AT) has become important in the area of exercise physiology and has become validated in a number of studies in the past few years (21).

Several investigators agree with Wasserman and his colleagues that the anaerobic threshold concept provides additional insight into the basic circulatory and metabolic responses to exercise stress. Expressing the anaerobic threshold as a percent or fraction of maximal aerobic power allows meaningful comparisons between subjects and modules of activity (28).

DeVries (21) noted that:

> . . . use of the AT concept offers many potential advantages for evaluation of work capacity in healthy athletes (including gymnasts), as well as for clinical evaluation of cardiovascular-respiratory disease in general public (p. 222).

Astrand (31) indicated that:

> . . . When working at a rate of about 50% of the maximal oxygen uptake there is a slight increase in lactate concentration in exercising muscle and blood in untrained persons. With training this threshold can be moved toward 60 - 70% of the O_2max. A quicker adaptation of the

> oxygen transport system, better capillarization of the muscles and higher myoglobin content, can be factors behind this modification. At his relatively modest exercise intensity the energy demand will after some minutes be covered by the aerobic processes, and the lactate level will gradually return to a level typical for resting conditions. With higher rates of work the lactate level will be elevated and eventually it will continue to rise when the oxygen will definitely accumulate with further increase in the rate of work for then only the anaerobic processes can pay for the additional energy costs (p. 179).

According to Jensen and Fisher (20):

> . . . The anaerobic threshold is different for every person. Highly trained endurance athletes have higher anaerobic thresholds than do untrained or moderately trained athletes can work at 75% to 85% of the maximal $\dot{V}O_2$. Some highly trained endurance athletes can work at much higher levels than others (p. 42).

A faster and more comfortable means to determine the anaerobic threshold is by observing the minute ventilation and other gas exchange variables, such as carbon dioxide production during a progressive exercise test (32).

Wilmore (26) pointed out that:

> . . . With proper instrumentation, this threshold can be assessed very accurately by observing the ventilation, carbon dioxide production, and ventilatory equivalent for oxygen responses to exercise. All three processes increase linearly with increases in the level of work up to the point of the anaerobic threshold, at which time their rate of change increases. This increase in rate of change results in greater nonlinear increases in ventilation, carbon dioxide production, and ventilatory equivalent for oxygen, while the increases in the level of work remain linear. The anaerobic threshold can be expressed in terms of percentage of VO_2max at which it occurs. An anaerobic threshold of 60 percent of VO_2max would indicate, theoretically, a greater performance potential for the same VO_2max than an anaerobic threshold of 45 percent of VO_2max. The higher percentage indicated that the individual can work at relatively higher levels of metabolism before having to rely on the inefficient, limiting process of anaerobic metabolism (pp. 47-48).

A study by Farrell et al. (33) showed that the anaerobic threshold, or the onset of plasma lactate accumulation, may well be the reason runners cannot run at a higher fraction of their $\dot{V}O_2$max. The investigation found that the best pace a marathon runner can maintain for the 26.2 mile race is very close to that pace corresponding to his or her anaerobic threshold. The trained runner appears to be able to maintain a pace at just below that point where significant amounts of lactate start to accumulate in the blood.

Wasserman and his colleagues (28) found values for the anaerobic threshold in 83 normal subjects between the ages of 17 and 91 years of age ranged between 45 and 180 W depending on age and physical fitness, with one exception. This was a 33-year-old male who had a 25-W incremental work test with an anaerobic threshold between 25 and 50 W (plotted at 25 W). The lower limit of normal appeared the same for all age groups and both sexes.

Green et al. (34) investigated the interrelationship between the ventiliatory anaerobic threshold (VAT), the blood lactate anaerobic threshold (LAT), and the alteration in muscle metabolism. Ten subjects (five men and five women students enrolled in the Kinesiology Department at the University of Waterloo) performed progressive exercise to exhaustion on two occasions for determination of the VAT and the LAT. For both AT criteria the initial breakpoints, the relationship between ventilation (VE) and O_2 uptake ($VO_{2\ VAT}$) and lactate (LA) and power output (PO_{LAT}) were determined by multisegmental linear regression. During three subsequent tests the subjects performed progressive exercise to various percentages of the $VO_{2\ VAT}$.

The $\dot{V}O_2$ max and the VO_2, La, and PO determined at VAT during the progressive tests to exhaustion were tabulated. As expected the VO_2 max (liter/minute) and the VO_2 and PO_{VAT} were all higher in the male subjects. No difference, however, was evident between the sexes in the percent of $\dot{V}O_2$ max at which the VAT occurred. The blood La concentration determined from the PO at which the $VO_{2\ VAT}$ occurred was 2.26 M for the men and 1.62 M for the women.

The results of this study indicated two significant findings, namely that 1) the gas exchange AT as determined by the relationship between VE and $VO_{2\ VAT}$ and the AT as determined by blood LA accumulation (LAT) were not coincidental. 2) Increase in muscle glycolysis occurred before the detection of the AT as determined by either gas exchange or blood La criteria.

Literature Relevant to the Maximal Oxygen Consumption

Maximal oxygen consumption ($\dot{V}O_2$ max) is regarded as a reasonable indicator of cardiorespiratory endurance capacity or "physical fitness." Indeed, several investigators have taken the view that maximal oxygen uptake is the best physiological measurement for determining one's cardiorespiratory endurance capacity (22, 35, 36, 37).

According to Getchell et al. (38), cardiorespiratory endurance is widely accepted as a component of fitness and for many people it is considered the most important.

Although many studies (39, 40, 41) have investigated the maximum oxygen consumption (max $\dot{V}O_2$) of females, little information had been made available regarding women's cardiovascular responses to severe exercise (42). Most informative results have been reported by Astrand (39) and these have become guidelines for comparative studies.

Novak et al. (43) indicated that:

> . . . If the best female competitors are considered by their participation in respective sports events, an interesting information is revealed. While track and field events are dominated by adult women, figure skating, gymnastics and particularly swimming seem to have more world record holders or winners in the teenage group (p. 275).

Cardiorespiratory endurance is regarded as the ability to sustain intense, vigorous activity for a prolonged period of time, resisting muscular fatigure and recovering quickly (7). Astrand and Rodhal (22) referred to endurance as "the ability to work for prolonged periods of time utilizing the largest possible percentage of maximal oxygen."

Maximal oxygen consumption values are related directly to body weight and, therefore, are commonly expressed in ml/kg body weight/minute (44).

The maximal oxygen consumption ($\dot{V}O_2$ max) is defined as the maximal rate at which oxygen can be consumed (43). For any individual it is a good criterion of how well various physiological functions can adapt to the increased metabolic need of work or exercise (21).

According to Astrand and Rodhal (22) the maximal aerobic power ($\dot{V}O_2$ max) is defined as the highest oxygen uptake the individual can attain during physical work while breathing air at sea level. To evaluate whether or not the subject's maximal oxygen uptake has been attained, objective criteria should be used, such as measured oxygen uptake lower than expected from the work load, and/or blood lactic acid concentration higher than about 8MM.

Maximal oxygen consumption depends upon age, sex and body size and/or body composition. Most individuals will reach their maximal aerobic power as a result of growth around fifteen to seventeen years of age. For the majority of the population, a gradual decline begins around age thirty. On the bicycle ergometer, an average maximal oxygen uptake as measured for college men is between 3.0 and 3.5 L/min. For college women it is between 2.0 and 2.5 L/min. or 35 to 43 ml/kg/min. (16).

In order for improvement to occur, DeVries (21) suggested a threshold value for work intensity. The heart rate must be raised from the resting rate to 60 percent of the maximal value.

The primary emphasis of aerobics was on the development and assessment of cardiorespiratory endurance via continuous and rhythmical exercise that incorporate large muscle groups (21).

Cooper (45) postulated that if the exercise is vigorous enough to produce a sustained heart rate of 150 beats per minute or more, the training effect benefits begin about five minutes after the exercise starts and continues as long as the exercise is performed.

McArdle and Magel (6) indicated that in general, tests to measure the aerobic capacity involve a progressive increase in work usually performed on a treadmill, bicycle ergometer, or step test to the point at which further increments of work are accompanied by a plateau, decrease, or slight increase in the oxygen consumption.

A variety of submaximal tests have been devised to evaluate the functional ability of the oxygen transport system (46). Many of these tests make use of the essentially linear relationship between heart rate and oxygen consumption (47, 48).

Several studies in which maximum oxygen uptake was measured by a maximum work load test, have shown significant improvements from pre-to-post tests (44, 49, 50).

Brown (51) found an eighteen percent improvement in max $\dot{V}O_2$ when he evaluated women track athletes before and after a six week, four to six days per week, physical training program.

Swedish and Norwegian studies were first to report values for maximal oxygen uptake for women athletes (11).

In 1960, Astrand's work with 44 Swedish women of different ages set up suggested norms on maximal oxygen consumption for females (52).

Saltin and Astrand (53) have observed that women perform better on a maximal oxygen consumption test if they are permitted to warm-up with submaximal loads before their maximal exercise. These investigators also believe that a testing method which utilizes a submaximal load (heart rate of at least 140 beats per minute) and then a supermaximal load which can be maintained for two minutes, yields an oxygen consumption which should be close to maximum (54). Saltin and Astrand reported an aerobic capacity of 4.07 liters (63.6 ml/kg/min.) on one subject of top female athletes, mean age of 22.9 years. The highest ventilation for the female was 131.0 liters per minute. The maximum heart rate varied between 185 to 204 beats per minute, with a mean of 194.8 beats per minute.

Sinning and Adrian (23) found a $\dot{V}O_2$ max of 35.2 ml/kg/min. for a group of active young American women and 33.7 ml/kg/min. for a group of women basketball players. Maksud et al. (55) found $\dot{V}O_2$ max of 46.1 ml/kg/min. for women olympic speed skaters, and Larry Noble (56) reported a high of 61.77 ml/kg/min. for $\dot{V}O_2$max of female gymnasts.

Macnab (57) reported a value of 39.06 ml/kg/min. for a group of female Canadian physical education majors, and values for American physical education majors ranged from 33.62 ml/kg/min. which was reported by McArdle (58) to 41.32 ml/kg/min. which was reported by Higgs (59).

Drinkwater and Horvath (60) revealed an average $\dot{V}O_2$ max of 51.1 ml/kg/min. for a group of female track athletes, while Wilmore and Brown (61) reported a mean of 59.1 ml/kg/min. for a group of women distance runners. In a recent study, Maksud et al. (62) reported a $\dot{V}O_2$ max of 41.02 ml/kg/min. for a group of American women athletes.

Withers (63) examined the changes in body composition, maximum aerobic power ($\dot{V}O_2$ max) and maximum anaerobic power in seven Australian international women lacrosse players during three months pre-season conditioning program. Monthly tests were conducted and the data were analyzed by an ANOVA. The results showed that the mean $\dot{V}O_2$ max values were: 44.0, 48.6, 52.3, and 52.9 ml/kg/min.

Kovaleski et al. (64) studied physical and physiological characteristics in nineteen women intercollegiate volleyball players who participated in the 1978 volleyball season at Central Michigan University and compared the varsity group (n=10) with the junior varsity (n=9). Cardiovascular endurance capacity was assessed. The results showed that the maximal oxygen consumption (liter per min.) was noticeably different. The junior varisty had a higher oxygen uptake (3.80 liters per min.) than the varsity (3.34 liters per min.). When the subjects' weight was taken into account, the average maximal oxygen consumption was similar (56.7 ml/kg/min. for the junior varsity and 55.5 ml/kg/min. for the varsity).

Recently, in a study by Cohen et al. (65), physiological responses to ballet exercise and $\dot{V}O_2$ max during treadmill running were studied in elite professional ballet dancers (seven men, eight women, ages 20-30 years) from the American Ballet Theatre. Eight dancers performed maximal treadmill running tests yielding $\dot{V}O_2$ max values (ml/kg/min.) of 48.2 (range 43.8 - 51.9) for men and 43.7 (range 40.9 - 50.1) for women. Mean $\dot{V}O_2$ (ml/kg/min.) during barre exercise was 18.5 (38% $\dot{V}O_2$ max) for men and 16.5 (38% $\dot{V}O_2$ max) for women; during center floor exercise 26.3 (55% $\dot{V}O_2$ max) for men and 20.1 (46% $\dot{V}O_2$ max) for women, with a peak of 77% $\dot{V}O_2$ max for a male dancer.

The data in Edgley's study of female athletes at OSU (66) revealed that therewas no significant difference between groups in oxygen intake when expressed in mililiters per kilogram in liters per minute. A significant difference was recorded between athletes and non-majors, and also between majors and non-majors. The mean values of max $\dot{V}O_2$ for the athletes, major group and non-majors were found to be 45.98 (ml/kg/min.), 45.16 (ml/kg/min.), and 41.99 (ml/kg/min.), respectively.

Drinkwater (67) presented a comprehensive review of work done involving the aerobic capacity of female athletes. She reached three major conclusions:

> 1. Females can reach relatively high levels of cardiovascular fitness as expressed by maximal oxygen consumption through training but do not appear to be able to achieve the level of highly trained males.
>
> 2. A trained woman can exceed an untrained male in maximal aerobic power.
>
> 3. Trained athletes, whether male or female, significantly exceed untrained subjects in the measure of cardiovascular fitness (p. 384).

Literature Relevant to Body Composition

Body composition has become a major field of interest for many professionals such as physical educators, exercise and sport scientists, as well as clinicians (68). "Physical exercise is believed to modify body composition by reducing body fat stores and increasing the fat-free weight" (69, p. 21).

The assessment of body composition expressed the quality of major structure elements of the body-muscle-bone and fat. Height-weight tables are still utilized to evaluate the degree of "overweightness" based on age and "frame size," but these tables no longer provide enough data in regard to the relative composition or quality of an individual's body weight (70).

It is important to consider the individual's body composition and not depend only on the total body weight (71). Thus, body composition, the ratio of lean body mass to fat, undergoes significant changes during growth, and is based on the balance between energy intake and energy expenditure, or the extent of physical activity (72).

Pařízková (73) identified the following body composition pattern in training athletes: "an exceptionally low ratio of fat combined with a high ratio of lean body tissue" (p. 273).

The evaluation of the percentage of body fat has gained increasing emphasis as an important factor in physical fitness (74). Excessive fat and overweight has been associated with the onset of cardiovascular disease. The use of percentage fat determination is probably useful in reducing weight for most individuals.

According to Robinson (72):

> . . . Physical training has been shown to increase the proportion of lean body mass to fat during growth and development. The changes in body composition due to training take place without noticeable changes in body weight (p. 156).

Coaches and athletes are usually utilizing percent body fat measures as a means of assessing training and conditioning programs and estimating more optimal weights for sports performers (72).

Wilmore and Behnke (75) indicated that:

> . . . A number of investigators have addressed themselves to the task of developing a simplified and widely applicable method for accurately assessing percentage body fat and lean body weight in human subjects--some of these investigators have attempted to estimate obtainable anthropometric body measurements, including skin folds, diameters, and circumferences to allow a more compositional analysis for clinical, general evaluation, and research purposes (p. 267).

Anthropometric body measurements have been especially useful to estimate the fat and nonfat components of the human body, since the measurements are easily obtained and prediction equations using these measurements give a dependable estimate of body density as determined by well developed techniques (76).

Of the available methods for estimating the proportion of fat in the living body, the determination of body density by underwater weighing may be the most accurate method but requires heavy and expensive equipment (77).

Pollock et al. (77) indicated that:

> . . . the individual's body composition can be most accurately estimated by the underwater weighing techniques. This method also can be administered out of the laboratory in a swimming pool. The underwater weighing technique is based on the Archimedes principles of determining body density --- Although quite accurate, determining body fat by the underwater weighing is not very practical, therefore, anthropometric measurement (skinfold fat, girth and diameter measures) are used to estimate the various components of body composition, that is, body density, relative or absolute fat, and lean body weight (bone and muscle). Skinfold thickness, body diameter or breadths, and body circumferences or girths have been used in the past with reasonable accuracy to estimate body composition. This technique correlates well with the underwater weighing method (p. 245).

Skinfold measures have long been used to estimate total body fat content and variation (79). According to Brozek (80) skinfold measures skin plus the highly variable layer of subcutaneous adipose tissue. These measures are useful as an index of total body fat. Skinfold measures still remain widely used, extremely practical indicators of body composition.

Many estimations of body fat by one or more of these methods have been done on men. Much less information is available about females although some valuable research has been done in this area (72).

According to Durnin and Rahaman (81) several previous papers have suggested relationships between one of the accepted methods of determining body fat and a simpler technique which could be widely applied. As early as 1921, Matiegka (82) formulated an equation for calculating body fat from measurements of surface area and six skinfold thicknesses.

Brozek and Keys (83) were the first to use the relationship between skinfold thickness and body density for assessing fat content. Pascale et al. (84) in the U.S.A., produced an equation, and Pařízková (85) in Czechoslovakia, a nomogram for predicting percent body fat content from skinfold thickness.

Steinkamp and others (86) gave predictive equations based on measurements of body circumferences and skinfold thickness on 167 subjects in California.

The only comparable study on the British population was conducted by Fletcher (87) on twenty-four hospital patients, measurements being made of total body water and skinfold thickness.

Of specific interest to this investigation was research in body composition assessment which attempted to study changes in percentage of body fat, skinfold thickness, and body density. Studies related particularly to the body composition of women follow.

According to Wilmore (71): "Body composition of the female athlete varies considerably with the sport in which she is participating."

Behnke et al. (87) indicate that the variation in body fat appear to be the chief determinant of body specific gravity. It is evident that the body specific gravity increases as the fat content decreases.

A value of 1.10 may be estimated for the density of the fat-free human body (72). With these values as limits, Rathbun and Pace (89) derived the following equation for the conversion of body specific gravity to percentage fat:

$$\% \text{ Fat} = 100 \ (5.548/\text{S.G.} - 5044)$$

Sloan et al. (91) determined the body density of 50 healthy young women by underwater weighing, and five skinfold thicknesses and five girths were measured on each subject. Body density was also estimated from skinfold and girth (circumferences) measurements. In Sloan's investigation, all skinfold thicknesses were found to be significantly intercorrelated ($P < 0.01$) but the best single index of total skinfold thickness was the measurement taken over the iliac crest ($r = +.92$). On the other hand, all of the girth measurements were significantly intercorrelated ($P < 0.01$) and had a high correlation with a composite criterion girth. In addition, the best single predictor of density was skinfold thickness over the iliac crest ($r \pm .71$). The correlation with skinfold thickness of the back of the arm was of the same order ($r = -.68$). The multiple correlation between these two measurements and density was 0.74. The investigators reported that the addition of other skinfold or measurements failed to increase this correlation.

In 1963, Pařízková and Poupa (92) reported a mean value of 9.6% relative fat for highly trained gymnasts.

In an attempt to formulate simple equations for the prediction of the quantity of fat in the body, Durnin and Rahaman (81) measured the skinfold thickness and body density of 105 young adult men and women and 86 adolescent boys and girls. In this study, the relationships were calculated between the density and the skinfold measurement, singly and in every possible combination. The correlation coefficients for total skinfold thickness and body density in young adult men and women were -.835 and -0.778, respectively. The correlation coefficients were significant at ($P < 0.001$). In every instance the value for r was significant at the 0.001 level.

None of the anthropometric measurements gave as high correlations as skinfolds with density. Also, the attempts to increase the degree of correlation by combining several anthropometric measurements in the form of multiple regression analyses made little difference to the values for correlation. Thus, only skinfolds were used in the prediction of density.

Conger and Macnab (93) reported a comparison of strength, body composition, and work capacity on 40 female intercollegiate sports participants and 40 nonparticipants, the results showed that the participants were significantly taller, heavier, had more total body fat, but also a greater lean body mass than the nonparticipants.

Katch and Michael (94) determined the body density of 64 college females at the University of California, Santa Barbara, by the underwater weighing method. Six subcutaneous skinfold measurements, four girth measurements, and four bone diameters were taken on the subjects. The mean body density was 1.04 g g/m., which corresponded to 21.5% by weight of fat. The results also showed that the skinfold which revealed the highest correlation with density in a stepwise multiple regression analysis was the tricep skinfold (-0.59), while the best single girth measurement was the buttock (-0.52). The highest multiple correlation with density was from the iliac, tricep, and scapula skinfold, and the buttock, abdomen, and arm girths (0.72).

Pre- and post-season subcutaneous fat, girth, and weight measures were made by Lundegren (95) on twelve women varsity field hockey players and seventeen women varsity basketball players. Each experimental period consisted of eight weeks. For the field hockey players, the results showed that significant reductions occurred in fat measures at the arm, umbilical, and thigh sites, but that the only significant change in girth measurements was a reduction at the umbilical site. There was no significant change in body weight. Significant reduction in fat measures at the iliac and umbilical sites were found in the basketball players. The only significant change in girth was in the thigh. Basketball players as a group showed no significant change in body weight.

Katch et al. (96) conducted a study to determine the effects of two different physical training programs on the body composition and dietary regimen of ten female tennis players and five female swimmers. Measurements were made of body density by underwater weighing, subcutaneous skinfold fat, estimated percent of body fat, and calorie intake by seven-day dietary histories. These players were measured three times during sixteen weeks of physical training. The investigators found no significant changes in body density, body fat, or the diet within or between the swimmers and tennis players.

In a study by Wilmore and Behnke (75) the ability to accurately estimate body density and lean body weight from skinfolds, body diameters, and circumferences was investigated in a sample of 128 college-age females. The body density and lean body weight obtained from under-water weighing were used as the criteria for the regression analyses of the anthropometric data. It was found that body density could be predicted from five anthropometric measurements with a multiple R = 0.76. Lean body weight was predicted from five anthropometric measurements with a multiple R = 0.93. In addition, equations for predicting body density and lean body weight, which had been derived in previous investigations were independently analyzed on these same subjects. The results suggested that predictive accuracy is limited by the degree of similarity between the original and independent samples.

A series of anthropometric measurements were taken by Malina et al. (97) on 66 college-age female track and field athletes and on 30 non-athletes. The investigator reported that certain characteristics of body build and composition were specific to various track and field events and may therefore be vital to success in these events. The non-athletes were most like the distance runners in overall size. The controls, however, had more body fat and were slightly broader in build.

Johnson (98) designed a ten-week measured exercise program to reduce blood pressures and body fat, increase maximal oxygen consumption, and to study changes in energy intake and proportion of energy nutrients, using a sample of twenty college women. Body composition was determined by anthropometric measurements consisting of height, weight, bi-iliac width, and skinfolds at the triceps, biceps, scapula, and iliac crest taken prior to the exercise program and during the tenth week. Nutritive evaluation was made from a dietary history and three-day dietary records. The results demonstrated a significant decrease in estimated body density and a decrease in body fat. The decreased intakes of carbohydrate and total calories were significant, whereas that of protein was not. The investigator concluded that the measured exercise program produced a decrease in body fat and a reduction in energy intake for these college women with no significant change in body weight.

In a study by Katch and McArdle (76), five skinfold, 13 circumference, and eight bone diameter measurements were made on college-age men and women to determine the best combinations of measurements to predict body density as measured by underwater weighing. For the women, the scapula and iliac skinfolds, elbow diameter, and thigh girth provided the best combination of measures for predicting body density. The multiple R with these measurements was R = 0.84. The arm, abdomen, forearm, and thigh circumferences provided the best combination of girths for predicting body density (R = 0.80). In summary, it was reported that since the circumferences regression equations were as accurate in terms of perdicting body density as skinfolds, and almost as good compared to other combinations of measurements, the equations based on simple circumferences could be used instead of skinfolds to accurately predict the criterion body density.

Mayhew and Gross (99) evaluated the effects of high resistance weight training on the body composition of seventeen college women. Ten others served as nontraining controls. Subjects were evaluated by duplicate pre- and post-training measures of total body potassium, seven skinfold thicknesses, eight muscular girths, and four skeletal diameters.

The subjects underwent a comprehensive weight training program for forty-minute sessions, three days per week, for a nine-week period. The results revealed significant increases in lean body mass, flexed biceps and forearm girths, and shoulder width resulted from the weight training. Relative fat and chest depth were significantly decreased by the weight training program while skinfold thickness and body weight were unaffected. During the period of nine weeks of training, a sedentary control group made no significant changes in any anthropometric variable.

Brown and Wilmore (100) studied strength, body composition, and anthropometric measurements of seven women throwing event athletes (aged 16 to 23 years) after three and six months of training. The training program consisted of strength (with near maximal loads), running, team sports, and technique drills. Strength was determined by one-repetition maximum in the bench press and half-squat, and body composition was assessed by densitometry. After six months, the results showed that lean body weight increased only in the largest subject and in the two who did not strength train, while adipose tissue decreased in the three "average" and two "obese" subjects. Circumferences of the upper extremities increased in nearly all subjects, regardless of strength training, but thigh girth was essentially unchanged.

Wade (101) assessed college female swimmers (N = 15), mean age 18.6 years, for body composition and skinfolds at the beginning and end of nine weeks of competitive training. The investigator stated that during the course of the swimming season body density increased significantly, 1.052 to 1.054 g. cm-3, with no change in residual volume. There was no significant variation in total body weight or body weight in water. Based on the increase in relative body fat, 20.4 to 19.6% and absolute body fat 12.7 to 12.1 kg. occurred. Lean body weight did not exhibit a significant increase. Circumferences of the hip and the contracted biceps also showed no significant differences. In addition, significant decreases were noted in skinfold of the triceps, suprailiac, and subscapula. The means of these skinfold ranged from 11.9-14.5 mm. This decrease in skinfold measurements substantiates the loss of fat determined by hydrostatic weighing and suggests that the loss primarily involved subcutaneous body fat.

Withers (102) examined the changes in body composition, maximum aerobic power ($\dot{V}O_2$ max) and maximum anaerobic power in seven Australian international women lacrosse players during three months pre-season conditioning program. The results showed that the trend analysis for relative body fat [mean = 29.9 (initial), 22.8 (first month), 23.1 (second month), and 23.1% (third month)] indicated significant linear and quadratic components since the major adjustment had occurred by the end of the first month. Also the players experienced an overall average weight loss of 1.55 kg.

Kovaleski et al. (103) studied physical and physiological characteristics in nineteen women intercollegiate volleyball players who participated in the 1978 volleyball season at Central Michigan University and compared the varsity group (n=10) with the junior varsity group (n=9). The physical characteristics that were measured included age (year), height (cm), total body weight (kg), and body composition as assessed by the hydrostatic weighing technique. Residual lung volumes used to calculate body density were predicted by the method described by Wilmore (30) using percentage of measured vital capacity. Percentage of body fat was calculated according to the Siri formula (1956). The results showed that the varsity group was somewhat shorter (171.0 cm) than the junior varsity group (173.4 cm). Correspondingly, the varsity was lighter in total body weight (61.0 kg) than the junior varsity (67.5 kg) with a significant difference existing at the .05 level. The mean percentage of body fat for the varsity was 19.5% and for the junior varsity, 23.3%. The junior varsity players were heavier in total body weight, and they had more fat weight (15.8 kg) than the varsity (12.0 kg). Lean body weight of the varsity (49.1 kg) was not appreciably different from the junior varsity (51.3 kg). Based on the findings and conclusions of this study, the investigators stated that they should consider the striking differences in physical and physiological factors among sports teams, because this supports the hypothesis that physical and physiological fitness factors are unique for various athletes and athletic teams. Also, they suggested that team physicians, athletic trainers, exercise physiologists, and coaches could use this information to maximize the fitness qualities in athletes and assit in determining playing positions.

Puhl et al. (104) examined the physical and physiological characteristics of members of the U.S. Men's National (N=8) and Women's University National (N = 14) volleyball teams. The parameters measured included percent body fat, maximal oxygen intake ($\dot{V}O_2$ max) using treadmill runs, post-exercise blood lactic acid (anaerobic power), measure of vertical jumping ability, and peak isokinetic torque for knee flexion and extension, shoulder extension and plantar flexion at 30, 180, 240, and 300 degree/second.

Height (cm) Mean = 178.3 cm, Range - 171.8 - 186.0 cm

Weight (kg) Mean = 70.5 kg, Range = 61.4 - 80.3 kg.

Body density Mean = 1.0577, Range = 1.0413 - 1.0673

Lean body weight (kg) Mean = 57.8, Range 51.3 - 68.0

Body fat (%) Mean = 17.9, Range 14.0 - 24.5

According to the investigator there seemed to be little difference between these elite athletes and those of similar or less skill. This suggested that innate physical characteristics had less to do with the success level achieved in volleyball than did total time the individual had played the game. The data also suggested that sex differences of elite volleyball players are minimal when made relative to body weight or lean body mass.

Powers and Walker (105) measured and described the cardiorespiratory characteristics, body composition and grip strength of ten outstanding female junior tennis players. Each subject had been training for tennis competition for a minimum of four years, and all were considered by their coaches to have exceptional potential for success in tennis. Subjects were weighed underwater using the technique described by Katch, Michael, and Horvath (1967). Body fat was calculated by applying the equation of Siri (1961). The data revealed that the mean percent body fat (23.3 ± .66) for these athletes was slightly lower than data on female tennis players reported by Katch, Michael, and Jones (94) - 24.2%. When compared to other female athletes, these women had values for relative fat which were higher than those reported for basketball players (29.9%) (Sinning, 1973), gymnasts (15.5%) (Sinning, 1972), and distance runners (16.5%) (Wilmore, Brown, and Davis, 1977). Mean values of percent body fat for an average population of young women (ages 16 - 30 years) from the literature range from 21.9% to 26.2%, with wide variations across subjects in each study reported (Katch and Michael, 1968; Katch and McArdle, 1973). Thus, the investigators concluded that the female tennis players studied had relative body values that might be representative of an average sample of non-athletic young females.

Literature Relevant to Strength Training

Strength is frequently recognized by physical educators, coaches, and trainers as the most important factor in the performance of physical skills (106). A strength deficit keeps some skills somewhat static in their development while other skills which do not require strength progress accordingly. So, from strength increases, the athlete can accelerate his learning of specific skills (107).

According to Fox and Mathews (108), muscular strength may be defined as force or tension developed by a muscle or muscle group to perform repeated contractions (either isotonic, isokinetic, or eccentric) against a load or to sustain a contraction (isometric) for an extended period of time.

Wilmore (109) defined strength as the maximum ability to apply or resist force. The stronger the individual, the greater the force that he or she can generate.

The importance of strength to high level achievement in sports is rather clear to most athletes. If everything else is equal, higher levels of strength will enable the athlete to throw farther, push harder, jump higher and resist the efforts of an opponent to a greater degree (17).

Nelson (110) stated that:

> . . . gymnastics, perhaps more so than any other sport, encompasses an endless quantity of movements that place stress on the muscles, tendons and joint structures of the human body. While the main objective of the modern day gymnast is to perfect movement skills for the greatest aesthetic appeal, several physical fitness components are obviously highly developed in the process--Gymnastics has also been used during various periods of history by military leaders to develop such fitness components as strength and muscular endurance. In modern day gymnastics, certain events such as the beam and floor exercise require the use

> of a considerable degree of flexibility and strength in each performer's routine (p. 95).

Strengthening exercises are the cornerstone to top gymnastic performance and should be practiced diligently. Since most young people have developed their leg muscles fairly well with walking, jogging, running, biking, etc., the basic concern of strength training should be directed toward the upper body, including the arm, shoulder, chest, back and abdomen.

Pollock et al. (78) indicated that:

> . . . Strength and muscular endurance can be developed by any one, or a combination of three different modes or forms of training - isometric, isotonic, and isokinetic - using either eccentric (lengthening) or concentric (shortening) contractions (p. 56).

Weight resistance programs can be designed around each type of contraction.

Wilmore (109) stated that "with muscle training programs, there are generally increases in strength, power and muscular endurance." Isometric and isotonic training methods result in similar gains in strength, but isotonic training appears to produce substantially greater gains in muscular endurance. Isokinetic training may have the greater potential of the three types of muscle training for gaining strength, power and muscular endurance.

According to Meadows et al. (111) isotonic and isokinetic exercises are the most popular training programs presently being utilized for the development of muscular strength and endurance. With isotonic exercise the muscle shortens and/or lengthens while lifting a constant weight. Isokinetic exercise resembles the isotonic movement because the muscle moves through a range of motion, but the resistance varies to accommodate the force being provided by a particular muscle or group of muscles.

High resistance weight training is widely accepted as a method of muscle bulk-building in males. The question of the effect of relatively high resistance weight training on females remains unanswered (112).

Previous studies (113, 114) have failed to reveal significant alternations in female body composition with weight training.

According to Mayhew and Gross (99), the resistance loads and/or exercise, when specified, have not involved the large muscle groups, hence limiting the potential for changing body dimensions.

Significant changes in lean body mass have been found in female athletes following a physical training program and competition (79, 95, 99).

Katch et al. (96) did not find any significant changes in body composition of women tennis players or swimmers during training. However, relatively few studies of weight training have been carried out using female subjects. While some studies (113, 115, 116) have shown improvements in strength and a loss of adipose tissue in women with little evident muscular hypertrophy, none have utilized maximal resistance of the type used by male athletes (100).

According to Oyster (112),

> . . . today with the emphasis on women's athletics, more and more training programs are including pre-season or concomitants weight-training program. But many female athletes are hesitant to participate in programs of high-resistance weight-training for fear of the bulk-building effect that such programs have on a male. Because of lower androgen levels the female can expect a lesser degree of muscular hypertrophy than the male but the question remains; How much hypertrophy can be expected in female athletes after a high resistance program of weight training (p. 79)?

Brown and Wilmore (100) studied women athletes and found a 37% increase in upper body strength as a result of a maximal resistance exercise program. The investigators also found a significant 5.4 and 3.8% increase in shoulder and upper arm girths, respectively. Mayhew and Gross (99) found similar increases in flexed biceps and forearm girths and shoulder widths.

In other studies of girls and women, Wilmore (117), Capen (113), and Wells (116) found strength increases of up to 30% accompanied by only a slight increase in muscle size as a result of weight training programs.

A number of studies have been conducted during the past 30 or 35 years concerning the effects of weight training on various physical abilities (113). A summary of a selected number of these follows.

Using several individual strength measures as well as strength/strength and strength/weight, Morris (118) found significant differences between a group of outstanding women athletes and a group of non-athlete college women. The investigator included measures of hand, back, and leg strength. She also tested for differences within the athlete group and among the various sports represented. The only significant differences observed were in leg strength, total strength, and strength/weight.

A study by Capen et al. (113) was undertaken in an attempt to determine the effects of weight training on strength, power, muscular endurance and anthropometric measurements of fourteen college women from a group of physical education majors at the University of Tennessee. The training period was conducted three times per week for a period of ten weeks. Anthropometric measurements of the total group of fourteen subjects showed a slight difference in most measurements. The greatest and only significant difference between the initial and final test was a decrease of 1.0 millimeter in waist-skinfold measurement with a t of 2.20, which was statistically significant at the 4.64 percent level of confidence. The results of the tests for strength, athletic power, and muscular endurance of fourteen female subjects showed that there was a considerable increase in the scores of all of the final test items.

Conger and Macnab (93) measured strength of forty participants in women's intercollegiate sports and forty nonparticipants. The results indicated that the participants exhibited significantly greater strength in all the measures, even when weight was kept constant in determining the values.

Conger and Wessel (119) investigated the interrelationship of selected functional and body form measures, and examined the differences between groups varying in activity levels. The subjects for the study were 35 college women, placed in active groups termed "most active" and "least active" according to their response on an activity history-recall questionnaire. Functional measures included strength and flexibility. Strength was measured with a cable tensionmeter and followed the procedures outlined by H. H. Clark (120). The results showed that the greatest strength for all subjects were the measures of knee extension, ankle extension, and hip flexion. The results also indicated that the only significant difference between the mean strength of the two groups was revealed when a comparison was made of the trunk extension strength.

Richardson et al. (121) reported their results about college women enrolled in a program of conditioning exercises, using grip strength as a part of the physical fitness index. A seven-week isometric and isotonic conditioning program increased right and left grip strength seven and six percent, respectively.

Strength, body composition, and anthropometric measurements were made by Brown and Wilmore (100) on seven women throwing event athletes before and after three and six months of training. Strength was determined by one-repetition maximum in the bench press and half-squat. In five of the subjects, strength training with near-maximal loads was carried out three days per week using dumb-bells, barbells, and a leg press apparatus. After six months, the five subjects who weight trained increased in bench press strength by 15 to 44 percent and in the half-squat by 16 to 53 percent. The two subjects who did not weight train showed little or no strength gain. The investigators concluded that the women were capable of responding to strength training with considerable increases in strength and only minimal evidence of muscular hypertrophy.

Mayhew and Gross (99) evaluated the effects of high resistance weight training on the body composition of seventeen college women. The subjects underwent a comprehensive weight training program for forty minutes per session, three days per week, for nine weeks. Significant increases in total body potassium, lean body mass, flexed biceps and forearm girths, and shoulder width resulted from weight training.

Heyward and McCreary (122) investigated the relationship between static strength and relative endurance of the grip squeezing muscles for fifty women athletes (N = 50), age eighteen to thirty years. The relationship between maximal strength and endurance time was 4 = .00. (The relationship between an individual's ability to produce maximal force and to exert submaximal forces for extended periods of time during static muscular contraction.) The test-retest reliability coefficient for maximal grip strength was $r = .90$. The dependent t test indicated that the mean maximal strength for day one (39.41 kg) and day two (39.57 kg did not differ significantly. The value of the reliability coefficient for maximal strength was slightly lower than those reported for college men.

Oyster (112) studied fourteen women champion tennis players who were put on a high intensity weight training program at Ohio State University for seven weeks. Significant strength increases were found in the lower extremity measurements of ankle planter flexion and hip flexion. All other strength measures, except elbow strength, also showed increases although not significant. These strength increases were accompanied by concomitant decreases in all girth measurements. Three of the four skinfold measurements also decreased although not significantly. There was also a decrease in percent body fat and a slight decrease in weight.

According to Morrow et al. (123), various anthropometric, strength, and speed variables were obtained on 180 intercollegiate women volleyball players who participated in a regional round-robin tournament. The purpose of the study was to determine the factors underlying the motor performance of the women and then to see if there was any relationship between the factors and team success. The results indicated that the basic factors of speed/fat and strength were related to team success. Upper body strength and fat weight were identified as most important in differentiating between players of the most successful teams. These results suggested that training designed to increase upper body strength and decrease body fat should be considered by volleyball coaches. Strength and body fatness are variables that can be modified in women with training.

Power and Walker (105) measured and described the grip strength of outstanding female junior tennis players. Grip strength was measured in both hands using a Lafayette grip dynamometer. The results showed that the preferred hand-grip strength was significantly higher ($P < 0.05$) than the grip strength measured on the non-preferred hand, and was significantly greater ($P < 0.05$) than values recorded on female track athletes of the same age (unpublished data from investigator's laboratory).

The body build, explosive strength, grip strength, and cardio-respiratory fitness of a group of forty-three top class female field hockey players was assessed by Bale and McNaught-Davis (124). The findings were compared with similar investigators of female hockey players and sports women. A measure of static strength of the hands was obtained using a Harpenden handgrip dynamometer. The grip strength measurements showed stronger right than left hand grips. The mean grip strength measures of the group were similar to those of other top-class sports women.

Literature Relevant to the Resting Heart Rate and Blood Pressure

Resting Heart Rate

Heart rate is the number of times the heart beats per minute. The heart rate at rest varies widely from individual to individual and also within the same individual from one observation to another under similar circumstances (125).

The American Heart Association suggests that the normal range should be 50 to 100 beats per minute. It is difficult to say whether the variation in heart rate from individual to individual is actually this great or whether it indicates lack of rigid control of the factors that modify heart rate. It has been said that there is a tendency for the resting heart rate to be lower in subjects who are in good physical condition than in non-athletic subjects (126). At rest, heart rate is about 75 for non-athletes and 53 for athletes who train primarily aerobically. The decreased heart rate at rest for athletes is a consequence of physical training that is carried out continuously and over a long time span (127).

The average heart rate under resting conditions is about 78 beats per minute for men and 84 beats per minute for women (127).

Astrand and Rodahl (22) stated that although heart rate is about the same for males and females during rest, heart rate does not remain the same during work. Among young adults working at 50% of maximum oxygen consumption ($\dot{V}O_2$ max), males have lower heart rate values than do females. These values are about 130 for males and 140 for females. Maximum heart rate decreases for both sexes with age.

One of the ways in which an individual can evaluate the effects of his endurance fitness program is by comparing his resting heart rate before and after he started his endurance program. If his program increased his endurance fitness level, then his resting heart rate should be lower after training (128).

Heart rate has been the subject for numerous studies (4, 49, 50) dealing with the effects of training, and the results of these studies have shown a reduction in heart rate for the trained subjects over the untrained subjects.

Sloan (129) reported a lack of correlation between resting heart rate and the physical fitness index in relation to college female physical education studies.

The body composition and heart rate response to submaximal exercise were evaluated in twenty-one women ages 18 - 26 following a three day/week, nine week jogging program by Smith and Stansky (130). During this training period twelve women exercised at approximately 80 - 85% of maximum heart rate and nine girls at 70 - 75% of maximum heart rate. The results showed that resting heart rate decreased significantly in both experimental groups.

Cardiorespiratory characteristics, relative body fat, grip strength, selected body circumferences, and bone diameters were determined in 25 males and 25 females (whose exclusive mode of regular exercise was tennis) by Vodak et al. (131). Mean resting heart rates were 54 beats/minute for the males and 61 beats/minute for the females. Resting and maximal cardiorespiratory characteristics of the tennis players were tabulated. The results showed that the women displayed a higher resting heart rate when compared to the men. The investigators indicated that in their experience, the mean resting heart rate of the tennis players is approximately ten beats/minute slower than that seen in middle-aged persons claiming little or no regular strenuous exercise.

Resting Blood Pressure

Blood pressure is the lateral pressure or force exerted by the blood on a unit area of the blood vessel wall.

According to the American Heart Association, blood pressure is the amount of force that the blood exerts against the artery walls. It is usually expressed in millimeters of mercury and is the force that keeps the blood flowing through the arteries. It is generated by the heart as it contracts and is maintained by the elasticity of the artery walls. Everyone has blood pressure, for without it the blood would not circulate (132).

At rest the pressure rises to about 110 to 120 mm of mercury (Hg) per square centimeter of arterial wall surface in the arteries nearest the heart. Between beats the pressure drops to about 70 to 80 mm Hg. (17). Falls et al. (17) indicated that:

> . . . the baseline, or point at which the first heart sound (closing of A-V valves) is detected, is the minimal pressure during the rest phase (diastole) of the cardiac cycle. The pressure at the baseline is called the diastolic blood pressure. During the work phase (systolic) of the heart cycle, the pressure rises to a peak. This peak pressure is called the systolic blood pressure. After the peak is reached, pressure declines again to the diastolic level. A person's blood pressure is expressed as systolic pressure over diastolic pressure (p. 136).

For example, 120/80 indicates that the systolic blood pressure is 120 mm of mercury while the diastolic blood pressure is 80 mm (132).

According to Falls (17):

> . . . at rest, the average is about 120/75 in young adults. During exercise, the systolic pressure increases greatly, sometimes reaching a level above 200 mm Hg, while the diastolic pressure ordinarily remains relatively constant (p. 136).

Although 120/75 is about the average normal resting blood pressure for a young adult, there is a considerable range of normal for both systolic and diastolic pressure. In general, the upper limits of normal blood pressure for young adults are approximately 140 mm Hg for systolic and 90 mm Hg for diastolic pressure . . . Both diastolic and systolic pressure were reduced at rest as well as during exercise (17).

Blood pressure varies with age, sex, altitude, muscular development, and according to state of worry and fatigue. Usually it is lower in women than in men, low in childhood and high in advancing age (133).

DeVries (125) indicated that "the blood pressure in women prior to menopause tends to be slightly lower - and after menopause somewhat higher - than in men of the same age." In changing from supine to erect posture, the hydrostatic pressure increase required greater arterial pressure, and the response by the cardiovascular system usually overshoots the mark, so that systolic and diastolic pressure usually show an increase of 5 to 50 mm Hg.

According to Wilmore (117), literature on resting blood pressure has shown mixed results, with little or no change on resting blood pressure being reported as a result of training.

Training research studies (5, 50, 105, 131) have revealed lower diastolic and systolic pressures in trained than in untrained individuals.

Kilbom (50) reported decreases in resting blood pressure in middle-aged women. However, systolic, diastolic, and mean pressure were lower after training regardless of age (5).

In a study by Vodak et al. (133), the women (tennis players) displayed lower resting systolic and diastolic blood pressure when compared to the men. Mean resting blood pressures were 117/75 and 107/68 mm Hg for males and females, respectively.

Female tennis players were studied by Powers and Walker (105). The results revealed that the blood pressure is representative of average value found in non-obese females of the same age group. Mean resting blood pressures for fifteen outstanding junior female tennis players were 119.6/89 mm Hg.

Literature Relevant to Gymnastic Studies

Sprynarova and Parízková (134) measured the functional capacity during a load on a treadmill and body composition for ten gymnasts and ten swimmers. The mean age was 17.23 years. Their mean weight and height were 56.48 kg. and 162.27 cm., respectively.

In the group of swimmers, the investigators found, as compared with the group of gymnasts, significantly higher average indicators of the functional capacity in absolute values (maximum oxygen consumption 2.922 ± 0.243 L/min and 2.402 ± 0.212 L/min); and a significantly higher maximum oxygen consumption per kg of lean body mass (56.9 ± 5.2 ml/O_2/kg lean body mass and 51.2 ± 3.7 ml/O_2/kg lean body mass). When the indicators of functional capacity were calculated per kg of body weight, the differences between the two groups disappeared. In swimmers the researchers found, as compared with gymnasts, a significantly higher amount of lean body mass (51.60 kg and 46.92 kg) and also a significantly greater amount of body fat: 12.25 kg and 9.39 kg. On the other hand, the ratio of lean body mass was significantly smaller in swimmers (swimmers 80.79%, gymnasts 83.19%) and the ratio of fat in the total body-weight was significantly greater (swimmers 19.21%, gymnasts 15.71%) than in gymnasts. According to the investigators, comparison of the functional capacity of gymnasts and swimmers with regard to their particular sports activity can be summarized as follows:

> 1. The averages of the investigated indicators of functional capacity in absolute figures were significantly higher in swimmers, similarly as the maximum oxygen consumption calculated per kg. of lean body mass; when calculating the maximum oxygen consumption per kg. of body-weight, the differences between the two groups disappeared.

2. A more satisfactory functional condition of the swimmers, as compared with the gymnasts was suggested only by values of the oxygen utilization from ventilated air in the course of the maximum performance, which do not depend on body-weight.

3. Comparison of the aerobic capacity of both groups with data in the literature revealed that their aerobic capacity was, as compared with women not engaged in sports, higher. The qualifative evaluation of the aerobic capacity in gymnasts corresponded to average values, in swimming it can be rated satisfactory.

4. The aerobic capacity - one of the important prerequisites of a satisfactory swimming performance - has in our swimming-representative an inadequate standard as apparent from comparison with the examined group of gymnasts, as well as with regard to the qualitative evaluation of the aerobic capacity according to Astrand's criteria (p. 170).

Hirata (135) measured 102 female gymnasts at the Tokyo Olympics. The gymnasts had a mean age of 22.7 years, height of 157 cm. and weight of 52 kg. He described gymnasts as ". . . small and stout."

Pool et al. (136) studied some anthropological and physiological characteristics of 38 gymnasts who participated in the 1967 European Championships. The mean age was 20.5 years, height was 1.58 meters, and the weight was 52.6 kg. They had extraordinarily small skinfolds, which correlated negatively with their performance. Muscles were well developed and thoras width correlated significantly with the calf and upper arm (circumference); triceps and subscapular (skinfold) scores. The time necessary for the last part of the run for horse vault correlated significantly with the mark for this jump. The best gymnasts took a relatively long running distance. Jumping height, measured by a jump test, correlated also with mark for horse vault. Running time and jumping height also correlated significantly with the mark for floor exercise. Handgrip strength did not correlate with the performance. The anthropometric measurements of the subjects in this study were:

knee width 8.3 cm., calf circumference 34.2 cm., upper arm circumference 25.7 cm., triceps skinfold 8.7 mm., and subscapular skinfold of 7.3 mm.

Humphrey and Falls (137) designed a study to determine the effects that a full season of gymnastic practice and competition have on aerobic capacity, strength, flexibility, and anthropometric characteristics of college women. Subjects for the study consisted of the eight girls who completed the 1968-1969 gymnastics season. At the onset and at the completion of the gymnastics season, the following parameters were determined: VO_2/kg/min.; maximum minute ventilation volume during exercise; body weight; body fat in kilograms; percent body fat; total proportional strength; Well's Sit and Reach; and hyperextension flexibility of the spine. Statistical analysis revealed that only the difference between the preseason and postseason mean for the Well's Sit and Reach was significant. Aerobic capacity demonstrated a slight decline. Anthropometric measures remained fairly constant, and there was a positive gain in strength and hyperextension of the spine. The following conclusions were stated. Without special training emphasis, aerobic capacity, strength, and percent of body fat did not show significant positive gains during the women's gymnastic season. The flexibility of female gymnasts improved significantly during the season.

Sinning and Linberg (138) compared anthropometric measurements of college age women gymnasts to data reported in the literature on College Women and to the European gymnasts reported by Pool and others (136). Subjects were 14 members of the Springfield College 1970-1971 gymnastic team. The mean age was 20 years, weight 51.1 kg., and height 158.5 cm. The body fat content, as determined by underwater weighing, was 15.5 percent. Gymnasts were smaller in height and lower in weight than other college women. However, the height and weight were similar to that reported for European gymnasts. The college gymnasts had more muscular mass than regular college women, but their bone diameters were smaller in the trunk and lower limbs. The muscle circumferences were also smaller in the limbs and lower trunk. However, there were no significant differences found between the college gymnasts and the European gymnasts. Anthropometric measurements of the college gymnasts that were of importance to this study were bone diameter of the right and left elbow, 5.7 cm.; bicondylar diameter of the femur, right 8.4 cm.; and left 8.5 cm.; contracted biceps circumference 26.4 cm.; and calf circumference 33.4 cm.

Plowman (139), in her review of physiological and physical characteristics of women athletes, described gymnasts as ". . . small neat ecto-mesomorphs" (p. 350). The percentage of body fat was reported to be 17 percent for gymnasts.

Summary

In the past three decades there has been a tremendous increase in the scope and intensity of women athletes. However, the women's response to vigorous training programs was not nearly as well studied as the male's response (18). Research has shown several conditioning and training programs which have provided measurable effects on female athletes.

A review of the literature revealed that not much research has been done on top female gymnasts (5). Literature about the physical characteristics of women gymnasts is limited (138).

Several studies (134, 136, 138, 139) have indicated that female gymnasts were found to be shorter in height, lower in weight, higher in body density, and lower in fat content in comparison to data reported in the literature on other samples of college women athletes. Accordingly, some investigators (138) concluded that their findings suggested a physique that may be characteristic of women gymnasts.

A review of the literature showed a lack of information concerning the anaerobic threshold in highly skilled women athletes. None of the literature studies evaluated the anaerobic threshold of female gymnasts.

Although many studies (39, 40, 41) have investigated the maximum oxygen consumption (max $\dot{V}O_2$) of female athletes, little data has been made available regarding women's cardiovascular responses to conditioning and severe exercise (42). Most information has been reported by Astrand (39) and these have become the guidelines for comparative studies. There are some general agreements between researchers that men do have a higher max $\dot{V}O_2$ when measured in ml/kg/min. However, females by training have increased their cardiovascular capacity as much as 30%. There are also other factors which affect the oxygen intake level in women such as age, environment, and the amount of training in which they are involved (66).

The functional capacity during a load on a treadmill was assessed by Sprynarova and Parížková (134) in ten female gymnasts and ten female swimmers. In the group of swimmers, the researchers found, as compared with the group of gymnasts, significantly higher average indicators of the functional capacity in absolute values. When the indicators of functional capacity were calculated per kg. of body-weight, the differences between the two groups disappeared.

Of specific interest to this investigation was research in body composition measurement which attempted to study changes in percentage of body fat. According to Wilmore (70), body composition of the female athlete varied considerably with the sport in which she participated.

Periods of conditioning and training have been shown to modify the body composition of females (6, 9, 21). In women's gymnastics it is of considerable importance since there is an obvious advantage to having a low weight when performing skills that require supporting the body with the arms or moving it through intricate routines (138).

Parízková (92) reported a low mean value of relative fat for highly trained gymnasts.

Statistical comparison of Sinning's data (138) with data of Wilmore and Behnke (74) supported the earlier conclusion that the gymnasts tended to be smaller, leaner, and more muscular than other populations of young women.

A number of studies have been conducted during the past three decades concerning the effects of weight training programs on various physical abilities of female athletes (113). Several investigators (99, 100, 113, 116, 117) contributed the most significant evidence concerning strength development and body alterations in women subjects.

Brown and Wilmore (100) studied women athletes and found a 37% increase in upper body strength as a result of a maximal resistance exercise program.

Other studies (113, 116, 117) of girls and women indicated that strength increases of up to 30% accompanied by only a slight increase in muscle size as a result of weight training programs.

A seven-week isometric and isotonic conditioning program increased right and left grip strength seven and six percent, respectively, in

Richardson's study (121).

On female top gymnasts, Pool et al. (136) reported a high mean value for right and left hand grip strength.

No resting blood pressure and heart rates have been reported on female gymnasts.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to determine the effect of a conditioning program on selected physiological components of College Women gymnasts and to compare the status of the subjects with other similar groups as found in the literature. The primary research method for analysis of the data was the case study.

The procedures followed during the course of research were organized under the following headings: (1) selection of subjects; (2) organization of training program; (3) questionnaire and daily activity log; (4) statistical procedure, and (5) case study.

Selection of Subjects

The subjects for this study were the members of the women's gymnastic team at Oklahoma State University in 1982. The gymnastic team included 13 girls who had undergone prolonged training of eight to ten years of gymnastics. During the course of this study, the number of participants was reduced from 13 to ten; this was due to the illness of one participant, injuries suffered by another, and the withdrawal from the team by yet another. The team was homogeneous in regard to age, the youngest was 18 years, the oldest was 22.

Organization of Training Program

The physical conditioning program was devised by staff members of Oklahoma State University Human Performance Laboratory and was carried out under the supervision of the three gymnastic coaches. The investigator observed most of the training sessions. All subjects participated in the same mandatory conditioning program. It consisted of a series of warm-up exercises, formal gymnastic practice and strength training. In addition the subjects could elect to supplement the conditioning program by participating in running activities. This program was designed to encompass approximately four hours per day of participation five days per week for a total length of three months (September, October, and November, 1982). Formal gymnastic training was on Monday through Friday. Strength training and running, as well as formal gymnastic training were on Monday, Wednesday, and Friday (see Appendix A). This was all pre-competition training.

Administration of Tests

Measurements were taken twice during the study (pre-test and post-test) prior to the beginning of the competitive season (September through November, 1982). Due to injuries and illness four subjects were not able to complete the post-test for anaerobic threshold, maximum oxygen consumption, resting blood pressure, resting heart rate, and strength. Measurements included: (1) height and weight, (2) resting heart rate and blood pressure, (3) body composition assessments, (4) strength measurements, and (5) anaerobic threshold and maximum oxygen consumption.

The subjects reported to the Oklahoma State University Human Performance Laboratory in the afternoon. They were asked to refrain from eating for about three hours prior to testing, and instructed not to participate in any vigorous physical activity the day of their testing.

Height and Weight Measurements

Height and weight were measured on a Fairbanks-Morse scale. Height was measured in inches by a measuring scale fitted with a sliding head-piece that was brought down to touch the top of the head. All subjects were weighed in pounds without shoes and wearing only activity clothes. The measures were recorded on the data sheet to the nearest quarter inch and nearest pound, respectively. These measurements were converted to centimeters and kilograms, respectively.

Resting Supine and Standing Heart Rate and Blood Pressure

Resting heart rate and blood pressure were taken after approximately 3-5 minutes with the subject in a supine position. When taking the pulse, the subject used three fingers to palpate the pulse. The pulse was taken at one of two areas of the body; on the wrist just below the base of the thumb, or on either of the large carotid arteries. The examiner controlled the time and the subjects counted for 30 seconds. The rate for 30 seconds was multiplied by two and recorded as heart rate.

Arterial blood pressure was taken with the subject's left upper arm at approximately the heart level. A Baumanometer Cuff, Mercury Sphygmomanometer and Stethoscope were used in determining resting blood pressure.

Heart rate and blood pressure were taken in both supine and standing positions.

Body Composition Assessments

It was possible to estimate percentage and total amounts of body fat and lean body weight through anthropometric methods (including skinfold thickness and circumferences) and underwater weighing technique.

Skinfold Measurements

Skinfold measurements to determine the percentage of body fat on each individualwere taken. All measures were taken on the right side of the body in the vertical plane with subjects standing erect. The Lange Skinfold Caliper with jaw pressure of $10/gm/mm^2$ was used for these measurements. The following measurements were recorded: biceps, triceps, illiac, back, mid axilla, chest, abdominal, and thigh. The fold was held firmly between the index finger and thumb as the measurements were taken. The calipers were applied to the fold just below the fingers so the pressure on the fold at the point of measurement was exerted by the calipers and not the fingers. The eight measurements were recorded and then repeated in the same sequence (141).

The sum of seven measurements (tricep, iliac, back, mid axilla, chest, abdomen, and thigh), as described by Jackson et al. (142), were applied to the following formula to estimate body density:

$$\text{Body density} = 1.0970 - 0.00046971\ (\text{sum } 7) + 0.00000056\ (\text{sum } 7)^2 - 0.00012828\ (\text{age})$$

The body density was converted to percent of fat by the formula (140):

$$\%\ \text{Fat} = \left(\frac{4.95}{D} - 4.5\right) \times 100$$

Body Circumference Measurements

An analysis of body build by circumference was performed to determine a predicted ideal weight. This method uses the Behnke evaluation of eleven body circumferences. An anthropometric tape was used to measure the circumference of shoulders, chest, abdomen, buttocks, thigh, knee, calf, ankle, biceps, forearm, and wrist.

Subjects were standing while measurements were taken in order that measurements could be taken more easily of both right and left thighs, knees, calves, and ankles. Each measurement was recorded in centimeters, and the average for each measurement of the extremities was computed. These values were entered in tables and calculations based on the Behnke (143) eleven measure formula were made to determine the predicted ideal weight of each subject.

$$\text{Density} = \frac{C}{300}$$

$$\text{predicted weight (in kg)} = D^2 \times \text{height (in decimeters)}$$

Underwater Weighing Measurements

Underwater weight was taken as an alternative means to ascertain the percentage of body fat and to check the skinfold measurements (143). The subjects were weighed out of water wearing only swimming suits. Weight in the water was taken while the subject sat in a chair suspended from a wooden board which was fixed to a platform on the side of the indoor swimming pool. The subject exhaled all the air in her lungs and lowered her head under the water. She held the expiration while the weight was read on a chatillon scale. The constant weight of the seat and harness was subtracted from the subject's weight while sitting in the chair to obtain the net underwater weight. These weights were applied to Behnke formula of:

Net Underwater Weight + 2.2 (correlation for residual O_2 in lungs)

$$\text{Specific Gravity} = \frac{\text{Weight in Air}}{\text{Weight in Air-Net Weight in Water}}$$

$$\text{Percent of Body Fat} = \left(\frac{4.201}{\text{S.G.}} - 3.81\right) \text{X } 100$$

Strength Measurements

The use of cable tension testing for the determination of strength of muscles activating various joints of the body was originally developed by H. H. Clark (144). Grip strength, push and pull, and knee extension were used in this study. The Naragansett grip dynamometer was used to record strength scores of the right and left hands. The subject was instructed to squeeze as tightly as possible with the grip and keep the arm and elbow away from the body. Two trials for each hand were given, with several minutes rest allowed between trials.

The dynamometer with a push and pull attachment enabled the examiner to measure the strength of the pectoral muscles and the shoulder retractors.

A cable tensiometer was used for measuring muscular force during knee extension. With this instrument the researcher measured the pulling force (tension) which was applied to a cable during the static (isometric) contraction. The tension depressed a riser which in turn moved a maximum pointer along a calibrated 0 to 100 scale.

The subjects were given verbal encouragement during strength test administration. All strength measures were recorded in pounds, and the average of the two trials was recorded.

Determination of Anaerobic Threshold and Maximum Oxygen Consumption

A modified Balke treadmill protocol was used for collecting data to determine the anaerobic threshold and maximal oxygen uptake.

All subjects were given a brief orientation to the test procedure including treadmill walking and breathing through the Collins one way valve before starting the test. The headgear and nose clip were put on and a one way valve was placed in the subject's mouth. A treadmill speed of 3.4 miles per hour and 0% grade were used to start the test. The subject walked for three minutes at 0% elevation and was then raised to 5% elevation. The elevation of the treadmill was then increased 1% every minute until the subject signaled that she could no longer continue. The first expired air sample was collected in the tissot tank during the last 30 seconds of the first three minutes; and then during the last 30 seconds of each minute until the end of the test (145).

Each time an air sample was taken, ventilation volume was noted from the Kymography. A one liter sample bag was used to collect expired air samples from the Collins, 110 liter tissot tank. The expired air was analyzed for CO_2 with a Godart Pulmo-Analyzer and for O_2 with a Beckman and OM14 O_2 Analyzer. The Godart Pulmo-Analyzer was calibrated at the beginning of each test session with a certified calibration gas. The Beckman analyzer was calibrated at the beginning and at two minute intervals throughout the test with a certified calibration gas.

After the last minute on the treadmill test, the elevation was reduced to 0% grade and the subject continued to walk at a speed of 2.4

miles per hour for at least two minutes. The subject then sat on the stool for three minutes to complete the recovery. Recovery heart rate and blood pressure were recorded for third and fifth minutes.

Oxygen uptake was calculated and corrected to STPD by the Open Circuit Method described by Ricci (146).

Anaerobic threshold was determined by observing graphically the relationship between the workload and minute ventilation, carbon dioxide production, and ventilatory equivalent for O_2 response to exercise. This protocol was first suggested by Wasserman et al. (27) and Wilmore (26).

Questionnaire and Daily Activity Log

Questionnaire

A questionnaire was administered to obtain information regarding previous gymnastic and exercise habits prior to the pre-test, and to obtain information concerning menstrual cycle and medical problems if any (see Appendix B).

Daily Activity Log

A detailed record of each subject's daily activity including strength training and gymnastic participation was taken throughout the entire study (Appendix A). This data was incorporated into a case study for each subject.

Analysis of Data

The difference on pre-test and post-test for each subject was computed as a paired difference. The mean difference was then computed between the pre-test and post-test, and the sample paired differences were tested for significance by a match paired "t" statistic.

The mean values for the present group of subjects were compared with the mean values of other studies available in the literature.

The significance level of .05 was used for all statistical analyses.

The following formula was used for this study:

$$t = \frac{\bar{D}}{\sqrt{\frac{\sum^{n} (D_i - \bar{D})^2}{n\,(n-1)}}}$$

$$D_i = Yi - Xi$$

$$= \text{post} - \text{pre}$$

whereas

$$H_o : \mu_D = 0$$

or

$$\mu_y - \mu_x = 0$$

Case Study

Each subject was reviewed in depth in regard to starting status participation and progress during conditioning program and status at the end.

CHAPTER IV

RESULTS AND DISCUSSION

A total of ten gymnasts who represented the women's gymnastic team, "Cowgirls", for the Department of Athletics at Oklahoma State University during the 1982-1983 season, served as subjects for the present study.

The purpose of the study was to determine the effects of the conditioning program on selected physiological variables of college age women gymnasts.

Comparison between the physical and physiological characteristics of the present subjects with other groups of gymnasts, swimmers, basketball players, volleyball players, speed skaters, weight training participants, and lacross players were studied.

Questionnaire

A fitness evaluation questionnaire was administered to obtain information regarding previous gymnastic and exercise habits during the few months prior to the pretest. The questionnaire was designed to establish a general medical history of the subject by collecting data on activity history, present activities, overall medical condition, structural and physiological limitations, if any. The survey also included a set of questions seeking to determine whether the menses cycle was of any significant influence in relation to gymnastic activities.

Part one consisted of general data and established a profile of the survey participants. The subject's average age was 19 years, average weight 54 kg and average height 159 cm. The distribution of the individuals' data can be seen in Table I. Nine of the subjects reported having had a complete physical examination within the last five years. Questions pertaining to smoking and alcohol habits were included in this general data. Nine of the subjects cited that they had never smoked cigarettes. The other one smoked for two years. Of the ten subjects, two had never drank alcoholic beverages. The others affirmed limited intake. Individuals' drinking habits are presented in Table II. Classifications of subjects was as follows: five freshmen, three sophomores, and two seniors.

Part two of the questionnaire established the activity history of each subject. They had been competing in gymnastics between eight to ten years. All had completed at least five years on high school teams. Seven of the subjects had participated on the O.S.U. gymnastic team for at least a year. Clearly the subjects shared in common an active history in gymnastics and continued to be actively engaged in physical and sport activities as indicated by responses in part three; present activity. Aside from gymnastic workouts, all the subjects participated in an array of other activities such as jogging, dancing, swimming, and volleyball. None were involved in organized team sports. Half of the subjects spent at least seven hours per week engaged in physical activity. The remaining subjects averaged three and one-half hours per week. All averaged six to eight hours of sleep per day.

Part four, structural limitation, of the questionnaire asked the women to identify any past gymnastics related injuries, if any. At least two injuries were reported by every subject, ranging from muscle pulls

TABLE I

GENERAL DATA

Subject	Age (yrs)	Height (cm)	Weight (kg)
1	18	148	50
2	18	168	60.34
3	18	166	56.82
4	18	150	45
5	19	168	66
6	19	160	55.45
7	19	156	51.8
8	19	156	53.5
9	21	159	51
10	21	159	52.72
MEAN	19	159	54

TABLE II

ALCOHOL INTAKE

Subject	Less Than One Drink Per Day	Varies On Occasion	Very Infrequently	Not At All
1		X		
2				X
3			X	
4		X		
5			X	
6			X	
7		X		
8	X			
9				X
10	X			

and sprains to fractures. All injuries were specifically suffered as a result of gymnastic practice or in a meet event. All but one of the gymnasts reported that gymnastic performance was altered following injury. Although seven participants agreed that some trouble still persisted as a result of the injuries, only five had missed formal practice and conditioning time more than two days.

Part five, physiological limitations, of the survey was divided into two sections. Section one was aimed at detecting any serious medical condition such as heart problem, respiratory condition, stomach ulcers, epilepsy, frequent headaches, high blood pressure, or allergies. Three subjects cited continuing allergy conditions. One reported a past condition of stomach ulcers. All others cited no knowledge or evidence of an existing medical condition. In an effort to investigate just how debilitating were the effects of dysmenorrhea several questions asked for detailed information concerning menses and subsequent medical problems, if any. Of the ten subjects, nine experienced a monthly menstrual cycle and were able to respond to the questions concerning menses. Duration of menses and regularity, or lack of regularity for the subjects are indicated in Table III. Several claimed some degree of discomfort as specified in Table IV. All subjects answered "none" when asked to indicate such symptoms as general body weakness, excessive sweating, leg cramps, vomiting, or chilling. Table IV includes only the symptoms affirmed by survey participants. The final question asked "What is the effect of the menstrual period on your gymnastic performance?" The responses to the question are tabulated (Table V).

Dr. Margaret Bell (147), author of <u>A Future Study of Dysmenorrhea in College Women</u>, concluded that "when the effect of physical activity on the

TABLE III

EFFECTS OF DYSMENORRHEA

Subject	Onset of Menses		Duration			
	Regular	Irregular	Less Than 3 Days	4-5 Days	7-8 Days	Varies
1	X			X		
2		X	X			
3	NO MENSES					
4		X			X	
5		X	X			
6	X					X
7	X				X	
8	X			X		
9		X			X	
10	X			X		

TABLE IV

SYMPTOMS OF DYSMENORRHEA

Sub.	Abdominal Cramps	Backache	Headache	General Discomfort	Body Swelling	Nausea	Loss Of Appetite
1	X	X		X			
2					X		
3	NOT APPLICABLE						
4				X			
5							
6	X			X	X		
7	X	X			X		
8	X	X	X	X	X	X	X
9							
10					X		

TABLE V

EFFECTS OF MENSES ON GYMNASTIC PERFORMANCE

Subject	No Change	Poor Performance During	Better Performance	Poor Performance Prior To	Varies
1					X
2	X				
3	NOT APPLICABLE				
4					X
5	X				
6					X
7					X
8		X		X	X
9	X				
10		X			

menstrual function was reviewed, we confirmed the fact that the large majority noted no change of any type as a result of participating in sports. . ." The result of participants in this study infer the same; despite the discomfort of the women, only one was "sometime" unable to participate in gymnastic workouts during menses. For the other subjects no discontinuation of gymnastic practice or physical activities was indicated.

Physical Characteristics

A summary of the physical characteristics of the Oklahoma State University women gymnasts was presented in Table I. The mean age of the subjects was 19.0 years, lower than the reported values for other female gymnastic teams (93, 136, 138, 147, 148), but similar to Olympic Female Gymnasts. Physical characteristics of other gymnastic teams are summarized in Table VI. The mean height of the subjects was 159 cm. which was taller than European Top Female Gymnasts (136) and Springfield College Women's Gymnasts (138), shorter than the Intercollegiate Women's Gymnastic Team at the University of Alberta (93), Olympic Female Gymnasts at Munich 1972 (43) and highly skilled women gymnasts reported by Sinning (148). The subjects had a higher mean weight of 53.0 kgs than that reported for the above gymnastic teams excluding Sinning's subjects who had higher mean weight of 53.7 kgs. The mean body density of the subjects was 1.0727 gm/cc, which was lower than Czechoslovakian Olympic Female Gymnasts, but higher than other gymnastic teams and college women athletes (Tables VI and VII). The higher densities suggested relatively greater muscularity (148). Comparisons of mean values of physical characteristics between present subjects and other sports participants are summarized in Table VII. The

TABLE VI

COMPARISON OF PHYSICAL MEASURES OF (1982-83) OKLAHOMA STATE UNIVERSITY COWGIRL GYMNASTS WITH DATA REPORTED FOR OTHER FEMALE GYMNASTIC TEAMS*

Year	Subject	N	Age (yrs)	Height (cm)	Weight (kg)	Body Density (gm/cc)	Body Fat (%)	Reference
1963	Czechoslovakian Olympic Female Gymnasts	7	23	NDA	55.4[a] 55.2[b] 57.2[c]	1.072[a] 1.077[b] 1.069[c]	NDA 9.6[e] NDA	Parižlova and Poupa (147)
1967	Intercollegiate Womens' Gymnastic Team-Univ. of Alberta, Canada	4	19.43	163	57.9	NDA	23.8[d]	Conger and MacNab (93)
1969	European Top Female Gymnasts	38	20.5	158.4	52.6	NDA	NDA	Pool, Binkhorst, and Vos (136)
1972	Springfield College Women's Gymnastic Team of 1970-71	14	20	158.5	51.1	1.064	15.5[e]	Sinning and Lindberg (138)
1977	Olympic Female Gymnasts at Munich W.G. in 1972	5	19.0	163.5	52.5	NDA	12.9[d]	Novak et al. (43)

TABLE VI (Continued)

Year	Subject	N	Age (yrs)	Height (cm)	Weight (kg)	Body Density (gm/cc)	Body Fat (%)	Reference
1978	Highly Skilled Women Gymnasts	44	19.4	160.6	53.7	1.6645	15.34[f]	Sinning (148)
1982	Present Subjects	10	19.0	159	53.0	1.0727	11.33[g] 10.181[h]	Salih

*Values Represent Means

NDA - No Data Available

a - During routine training.
b - Preparation for Olympics.
c - After 16 weeks of rest.
d - Percent body fat was determined by use of Rathbun and Pace formula.
e - Percent fat computed according to the equation of Brozek, Grande, Anderson, and Keys (1963).
$\%\ \text{fat} = 100\ (4.570/D - 1.142)$.
f - Underwater weighing mean value (Sinning computed percentage of body fat for his subjects according to Brozek et al.).
g - Skinfole mean value (sum of 7).
h - Underwater weighing mean value computed by formula of Siri (1956).

TABLE VII

MEAN VALUES OF SELECTED PHYSICAL AND PHYSIOLOGICAL MEASUREMENTS FOR OTHER FEMALE SPORTS PARTICIPANTS

Subjects	N	Age (yrs)	Height (cm)	Weight (kg)	Body Fat (%)	Body Density (gm/cc)	Max HR (Beats/min)	VO_2 Max (ml/kg/min)
Olympic Female Swimmers (134)	10	19.54	166.22	63.85	19.2[a]	NDA	MDA	45.95
College Age Women Basketball Players (149)	14	19.$\frac{1}{12}$	169.1	62.0	20.82[a]	1.0506[a]	186.2	44.84
College Age Women Volleyball Players (104)	14	21.6	178.3	70.5	17.9[a]	1.0577[a]	179	50.6
U.S. Olympic Speed Skating Team (150)	13	21.5	164.5	60.8	NDA	NDA	191.4	46.1
Young Women (Participated in jogging program - Florida State University) (130)	9	19.6	160.8	54.5	22.3[c]	1.0469	NDA	NDA
Australian International Female Lacross Players 1977 (63)	7	23.0	164.0	57.35	23.1[c]	NDA	188.7	52.9
Present Subjects	10	19	159	53.0	10.70[c] 11.33[d]	1.0727	179[b]	51[b]

NDA - No Data Available; a - percent body fat calculated by formula of Brozek et al. (1963); b - Max HR and VO_2 Max only for 6 subjects; c - underwater mean values; d - skinfold mean value (sum of seven) and percent body fat was computed from density by the Siri equation.

data showed that the present subjects tended to be younger, shorter in stature, lighter in weight, and higher in body density than other college women athletes.

Cardiovascular Fitness

Descriptive data for each subject at the end of a three-month conditioning program is presented in the case study.

Measures of the selected variables related to the cardiovascular fitness were obtained during pre- and post-test. The data from these tests were analyzed by t-tests to determine if any significant differences existed in regard to the cardiovascular variables before and at the end of the conditioning program. The level of significance was established at .05% for the rejection of the null hypothesis. The results of these analyses are summarized in Table VIII.

Changes in Maximum Oxygen Consumption

Oxygen consumption, the ability of the working muscles to take in, transport, and utilize oxygen, has been widely accepted as the best measure of physical fitness. The subject's $\dot{V}O_2$ max was measured on the treadmill. Results of the maximal oxygen consumption were reported in Table VIII. An increase mean in $\dot{V}O_2$ max (expressed in ml/kg/min.) was found between the pre-test and post-test. This increase was not statistically significant. The subjects had a mean $\dot{V}O_2$ max of 43.39 ml/kg/min. in the pre-test which tends to be above the average level of cardio-respiratory fitness, and 51.01 ml/kg/min. in post-test, which was higher than the mean values reported by Novak et al. (43), Sprynarova and Pariźková (134), and Diehl (70). The present subjects had a higher mean $\dot{V}O_2$ max than those values reported for other female athletes except

TABLE VIII

MEAN CHANGES IN CARDIOVASCULAR FITNESS*

	N	Max VO_2 (ml/kg/min)	N	Anaerobic Threshold HR (bpm)	N	Anaerobic Threshold % of Max VO_2
Pre	6	43.39	6	141.67	6	66.41
Post	6	51.01	6	177.33	6	70.83
Diff		7.62		35.67		4.425
t		2.240		2.6024*		1.1602

*Significant at .05 level.

Australian Lacross players (Table VII).

Changes in Anaerobic Threshold

The nature of gymnastics requires a moderate level of anaerobic capacity in comparison with other female athletes such as speed skaters, cross-country skiers, Olympic distance runners, and rowers. Very vew studies have been done to investigate the anaerobic threshold level for women athletes (29, 33). Unfortunately, no data is available concerning anaerobic threshold for women gymnasts.

The individual respiratory gas exchange values of the present subjects are presented in Figures 1 through 10. The following mean values were determined at anaerobic threshold level during pre- and post-test: heart rate, 141.67 beats per minute and 66.41% of max $\dot{V}O_2$ on pre-test; for the post-test, heart rate, 177.33 beats per minute and 70.83% of max $\dot{V}O_2$. The results in Table VIII revealed that significant increase occurred in regard to anaerobic threshold heart rate, but no significant difference was found in percentage of max $\dot{V}O_2$ between pre-test and post-test. The mean anaerobic threshold of 70.83% max $\dot{V}O_2$ which was reported on the post-test was higher than mean values of 46.5%, 58.6%, and 68.8% of max $\dot{V}O_2$ reported by Davis et al. (156) for volunteer college males.

Changes in Resting Blood Pressure and Heart Rate

The results of the resting blood pressure and heart rate are presented in Table IX. No significant differences in supine blood pressure were found between pre-test and post-test, for both systolic and diastolic, while a significant decrease in standing blood pressure occurred between pre-test and post-test. On the pre-test, subjects'

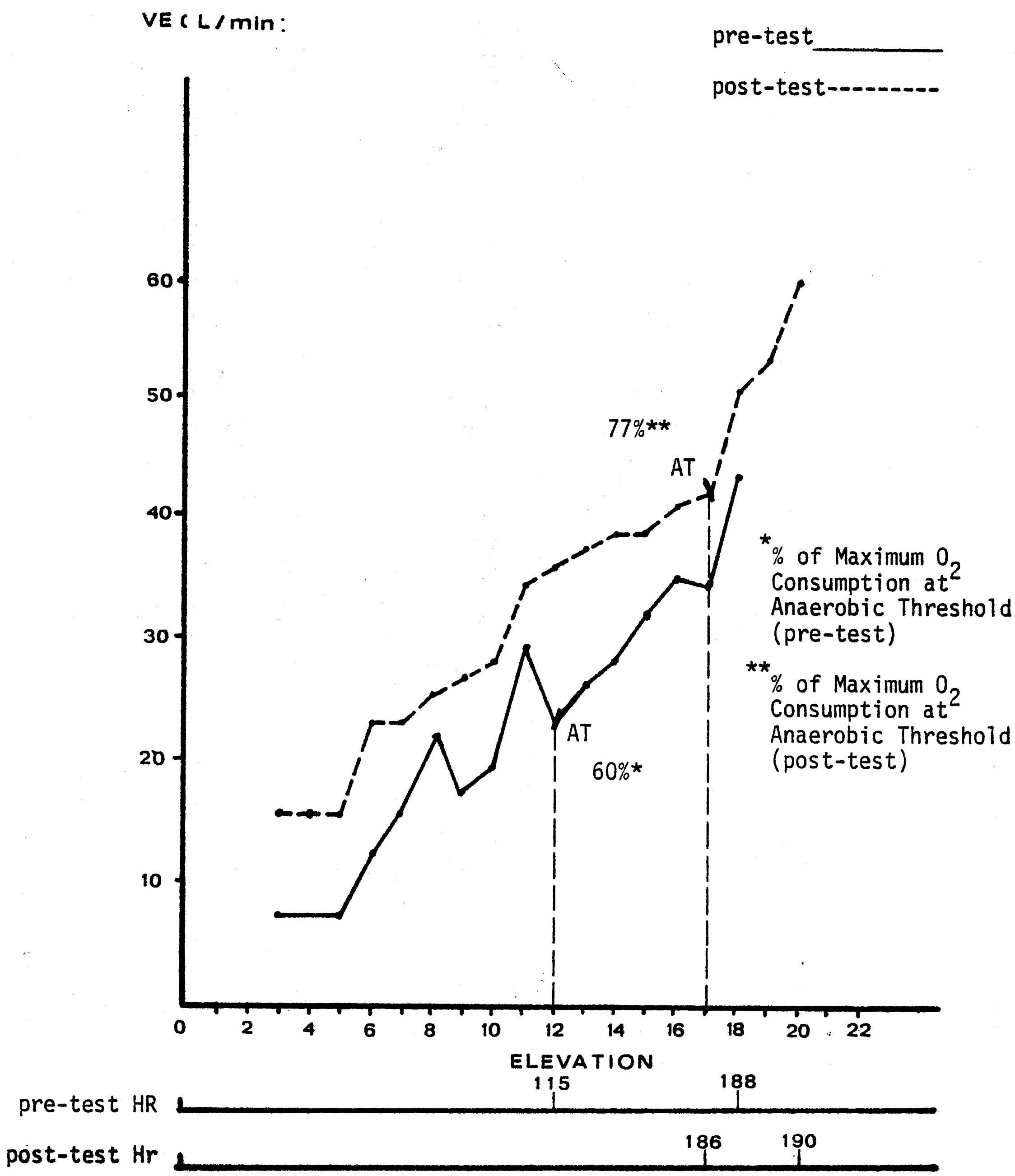

Figure 1. Minute Ventilation and Workload on Treadmill (3.4 mph speed: Subject 1

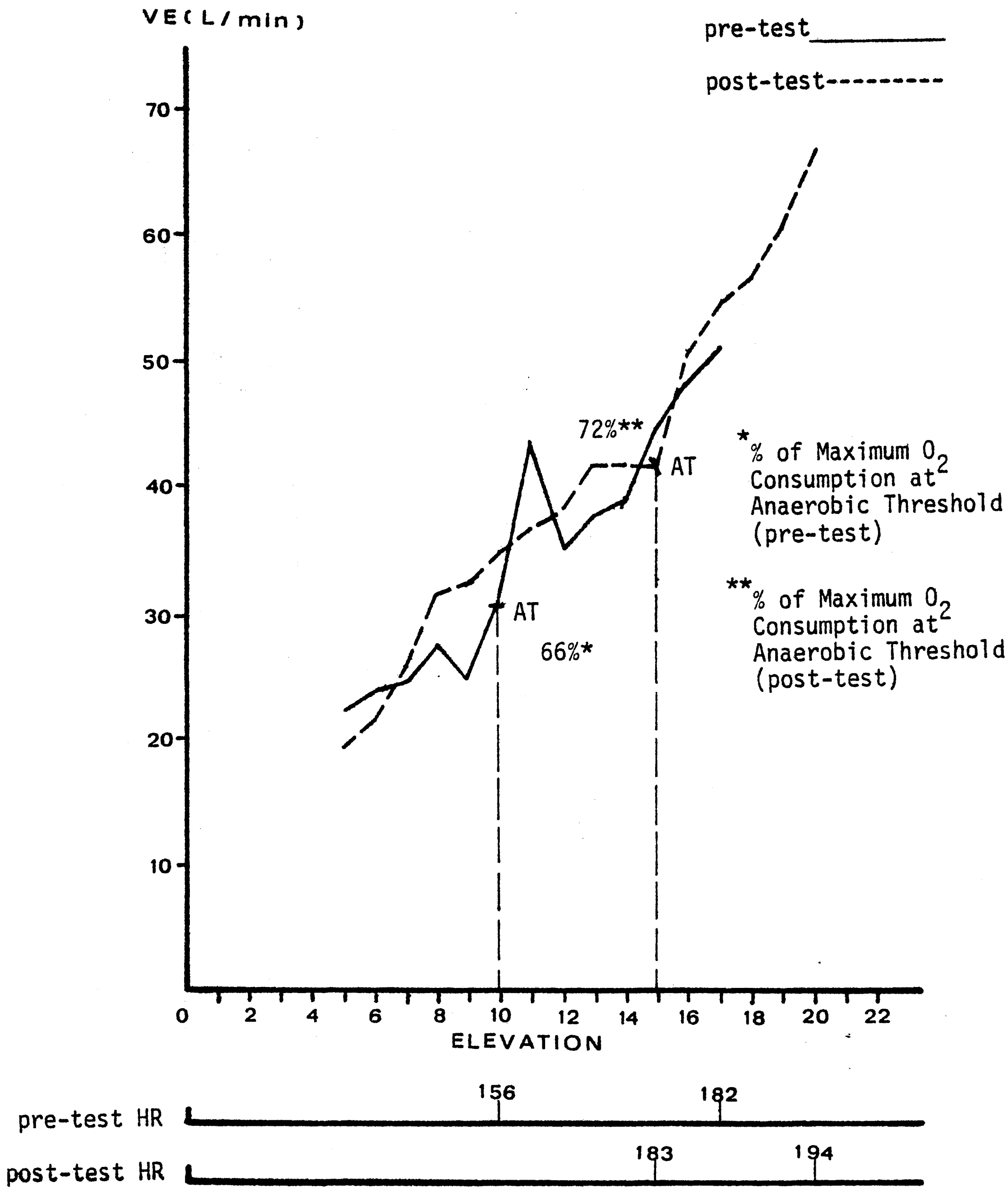

Figure 2. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 2

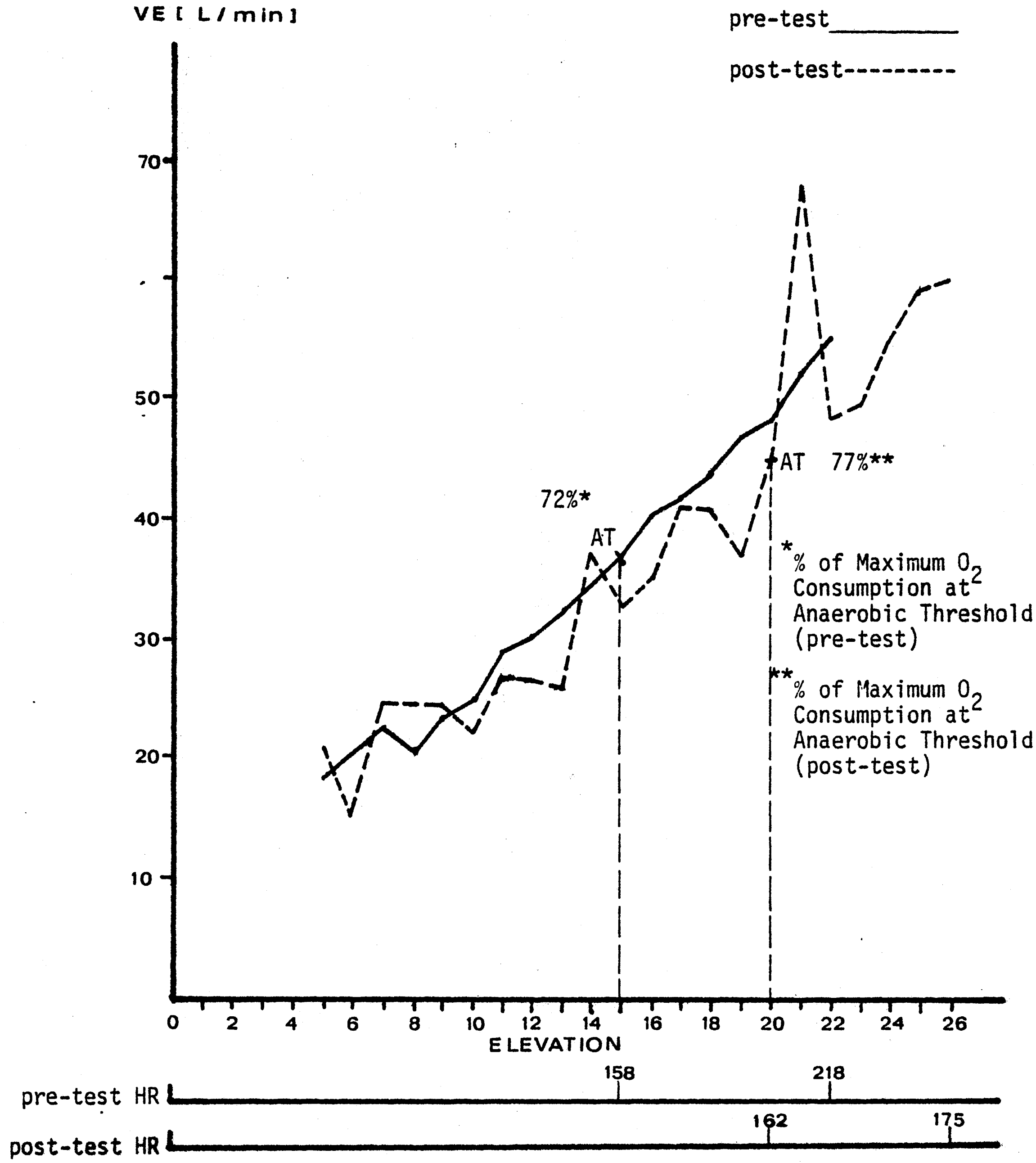

Figure 3. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 3

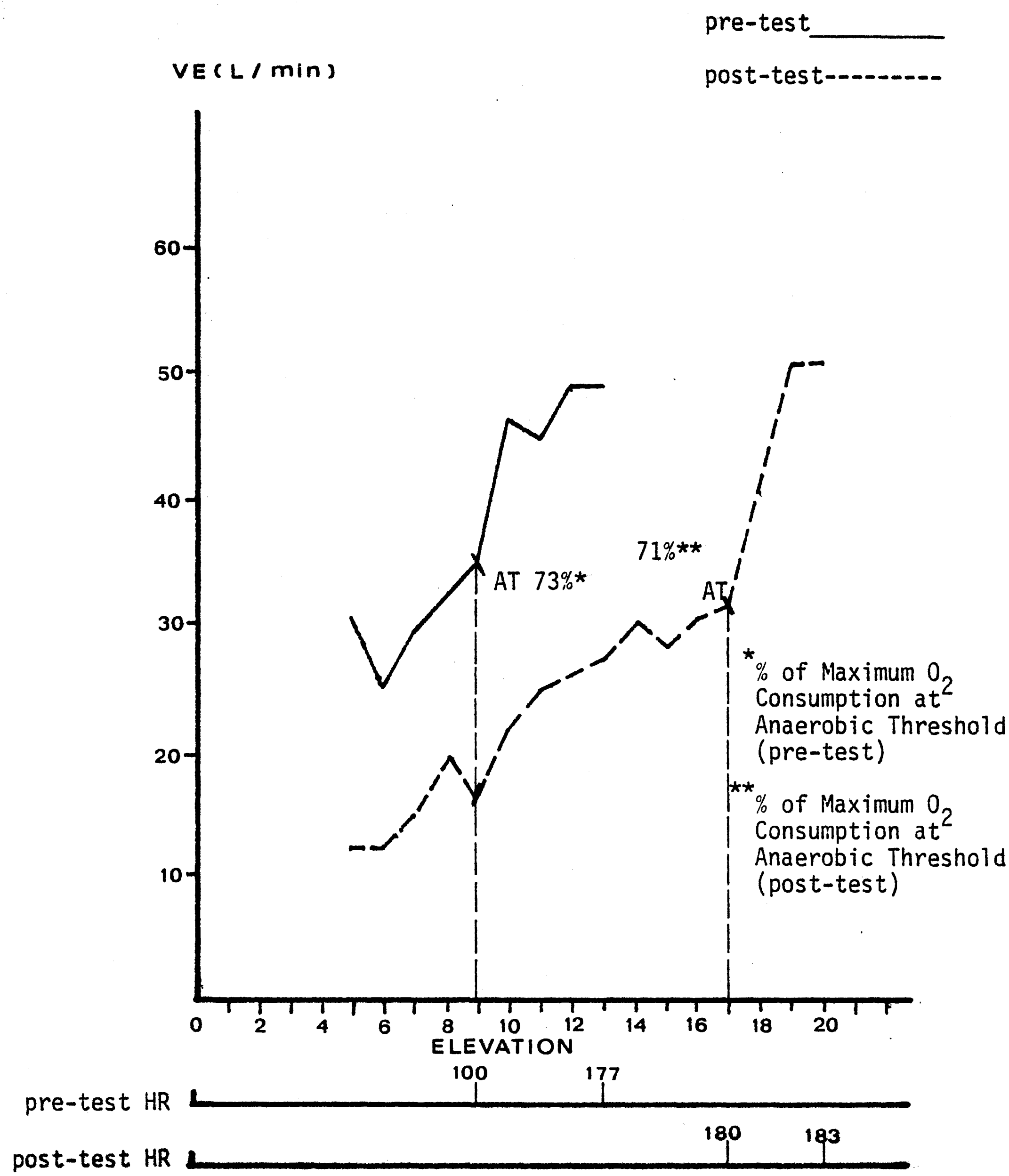

Figure 4. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 4

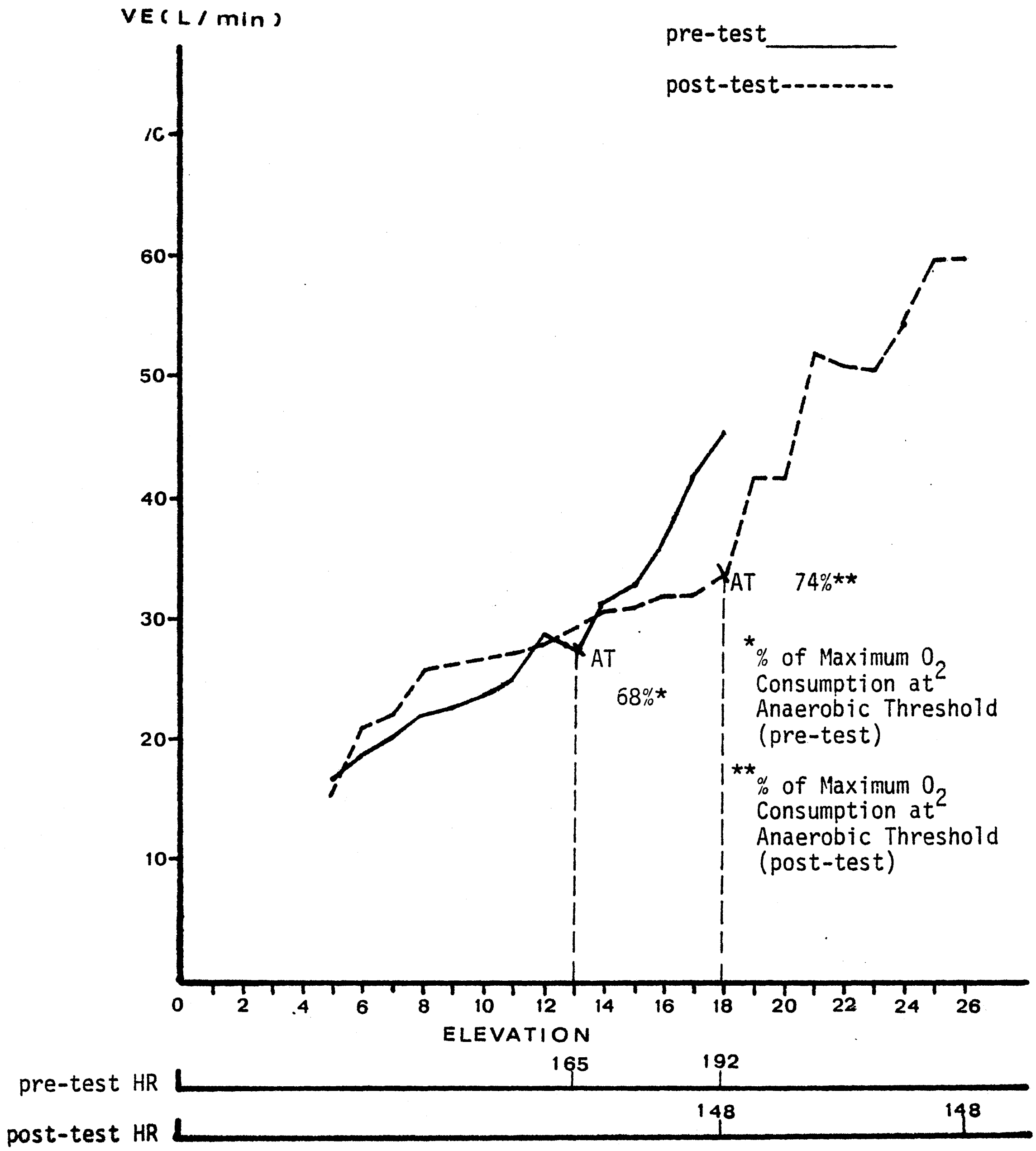

Figure 5. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 5

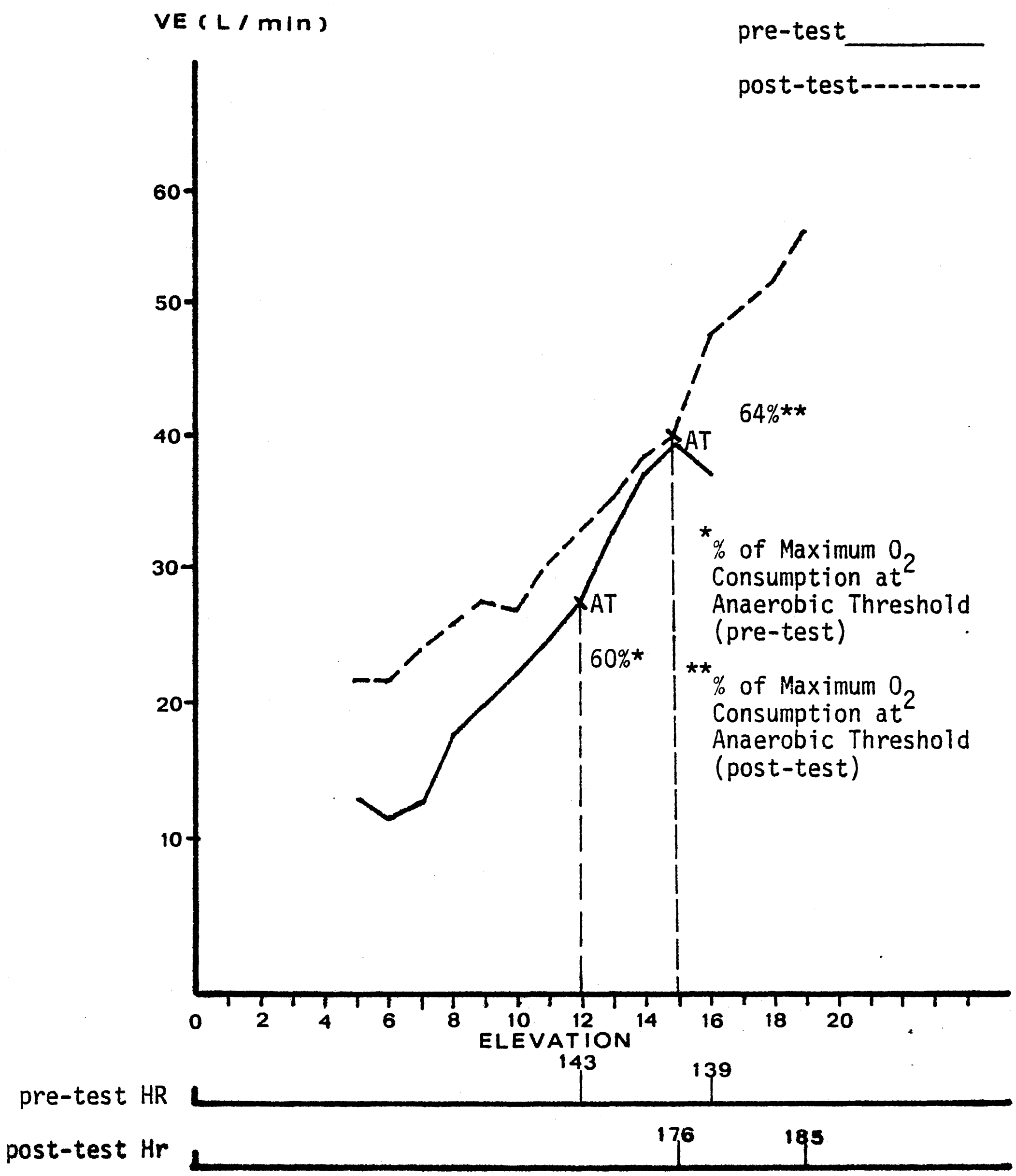

Figure 6. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 6

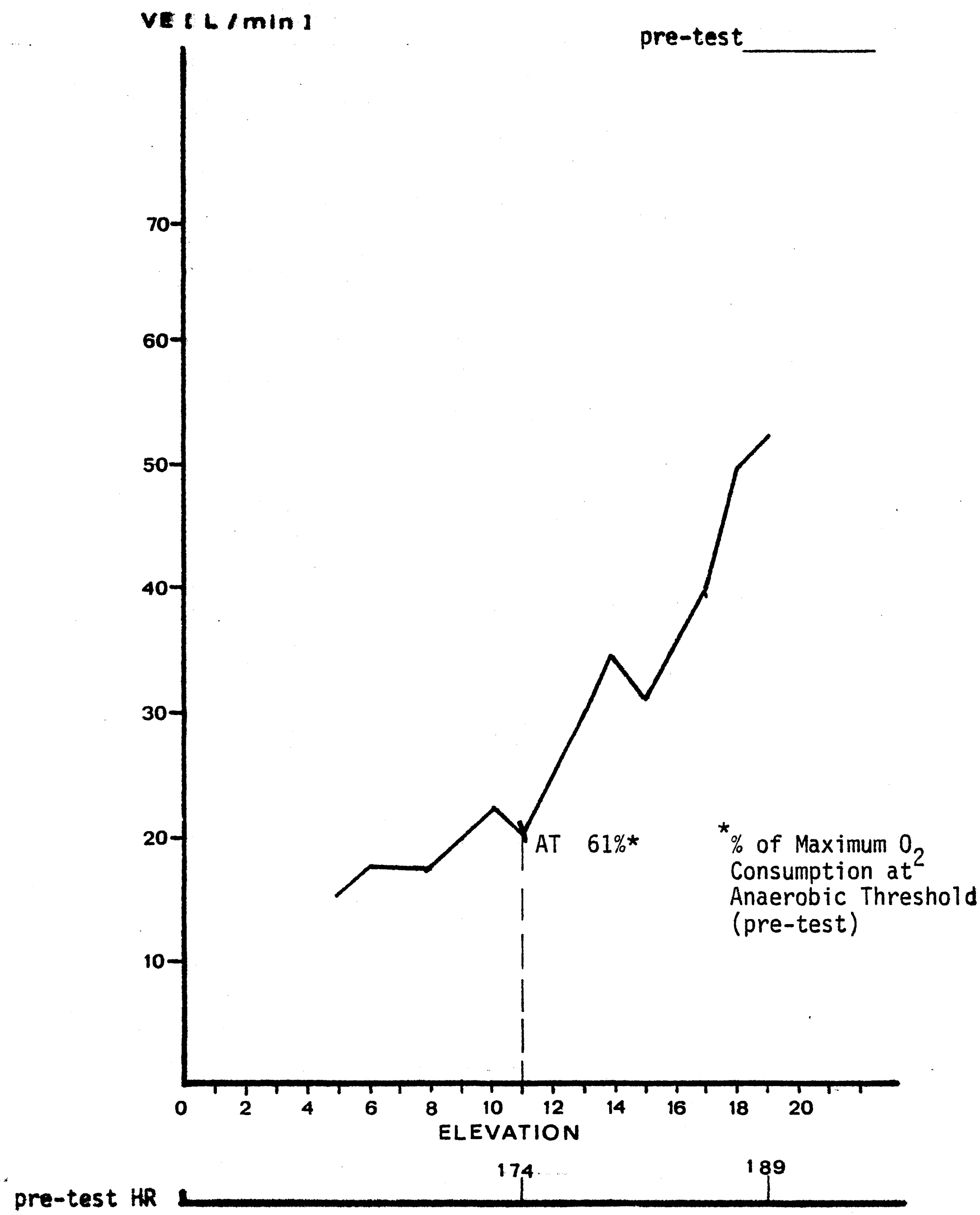

Figure 7. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 7

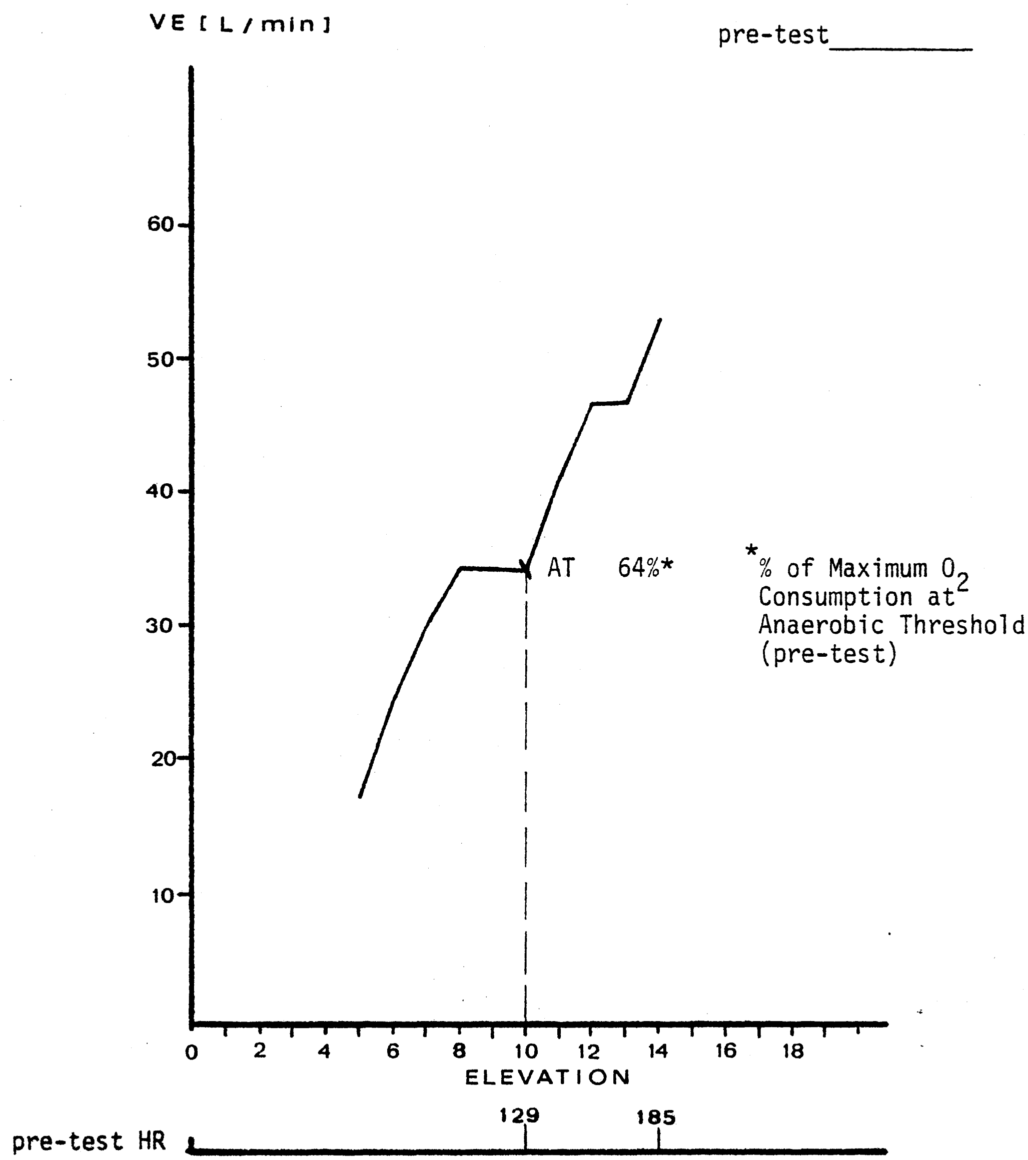

Figure 8. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 8

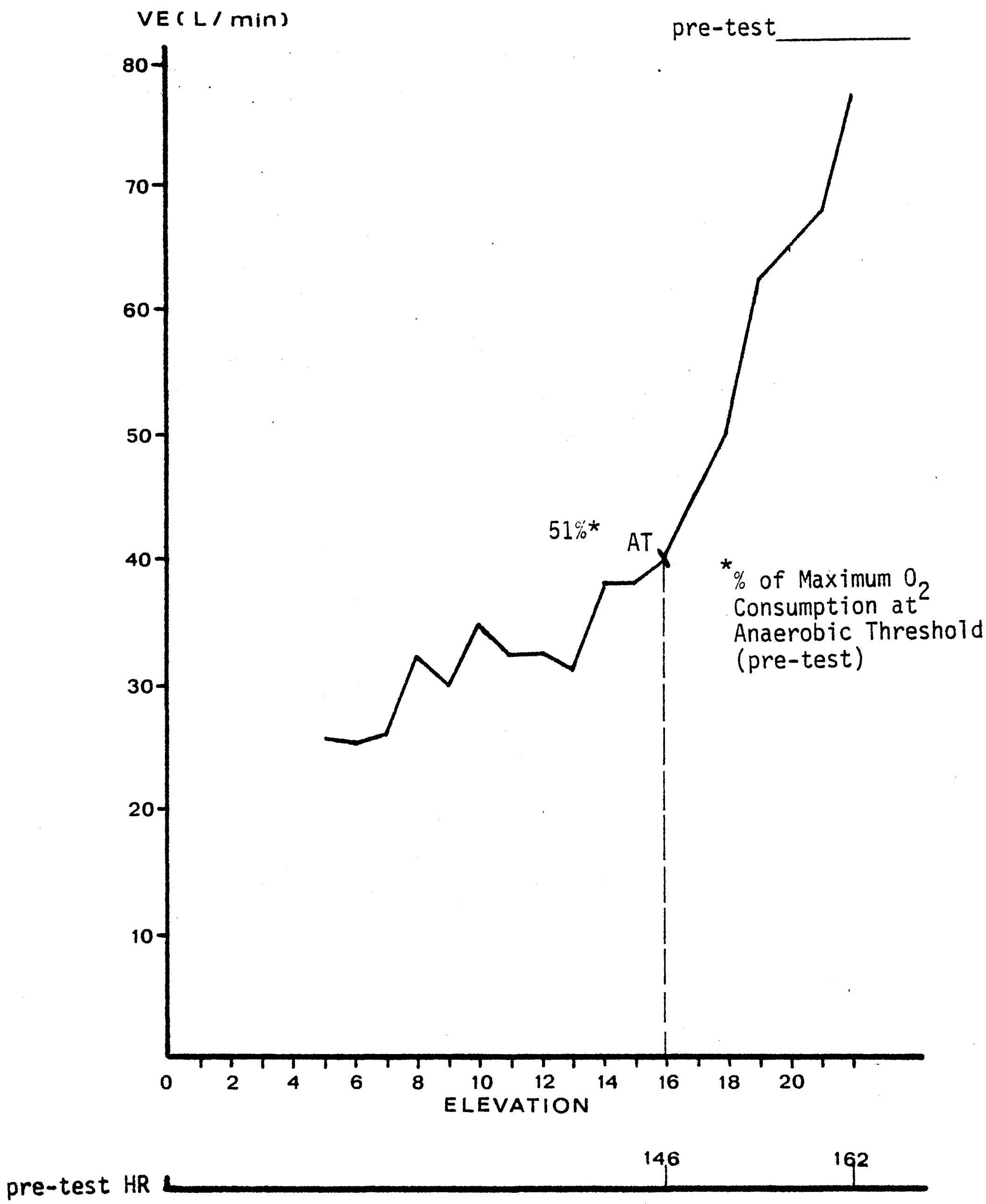

Figure 9. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 9

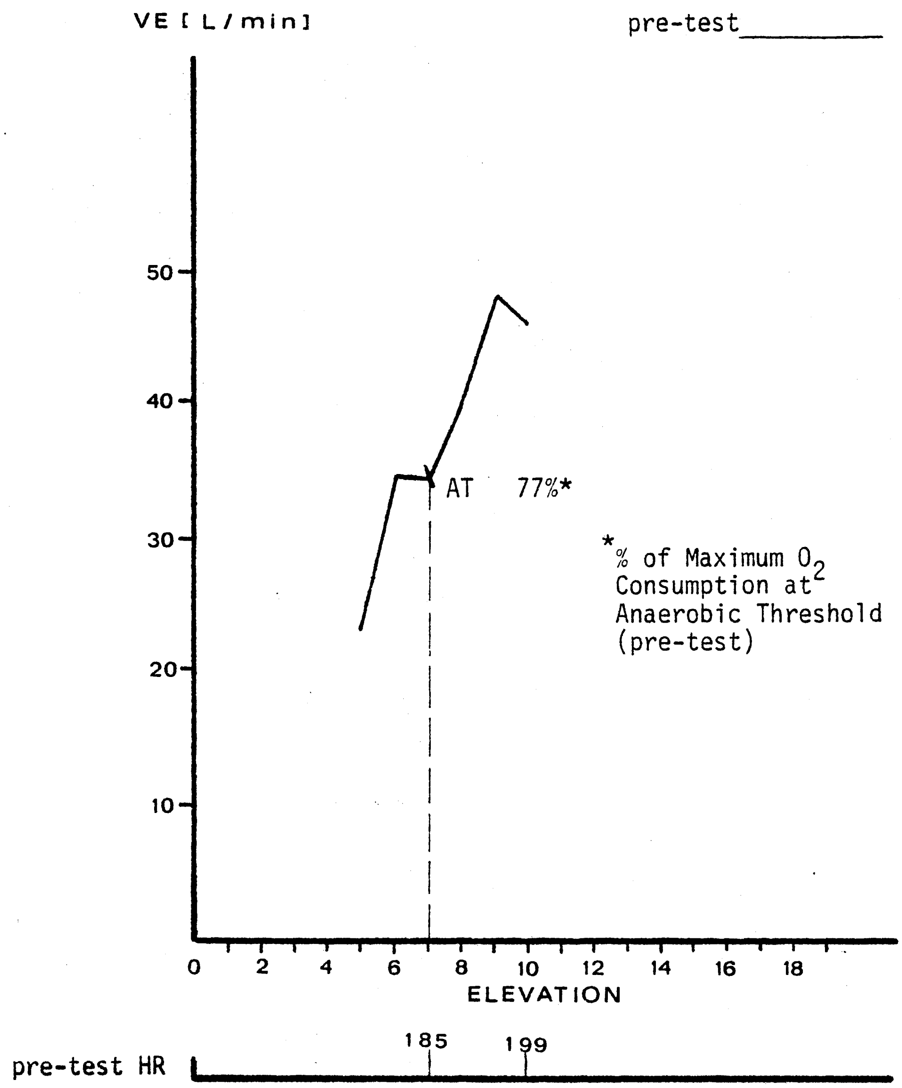

Figure 10. Minute Ventilation and Workload on Treadmill (3.4 mph speed): Subject 10

TABLE IX

MEAN CHANGES IN RESTING BLOOD PRESSURE AND HEART RATE

	Supine BP (mm Hg)			Standing BP (mm Hg)			Resting HR (Beats/min)		
	N	Systolic	Diastolic	N	Systolic	Diastolic	N	Supine	Standing
Pre	6	121.33	75.83	6	131.33	85.83	6	69.83	75
Post	6	118.833	81.67	6	125.167	84.667	6	65.167	70.833
Diff	6	- 2.5	5.833	6	- 6.167	- 1.167	6	- 4.667	- 4.167
t		- 0.892	2.0094		- 2.697*	- 0.347		- 2.38	- 1.595

*Significant at .05 level.

mean resting blood pressure was 121.33/75.83 mm Hg and 118.83/81.67 mm Hg for post-test. The mean (standing) value on the pre-test was 131.33/85.83 mm Hg; indicating that these values were representative of average values found in non-obese females of high school athletes (151). Literature on resting blood pressure has shown mixed results, with little or no change in resting blood pressure being reported by most investigators as a result of training. It is interesting to note the unusual increase in supine diastolic blood pressure in the present subjects. This might have occurred due to the heavy upper body weight training program.

Table IX also presents the resting heart rate changes between pre- and post-test means. The results showed that there were no significant changes between the pre-test and post-test means in the supine or standing positions. On the pre-test, the subjects' mean resting (supine) heart rate was 69.83 beats per minute and 75 beats per minute standing. On the other hand, in the post-test the subjects' mean resting (supine) heart rate was 65.16 beats per minute and 70.83 beats per minute standing. The above mean values were within normal ranges, but higher than means reported for women athletes. The American Heart Association, for example, suggested that the normal range should be 50 to 100 beats per minute. At rest, mean heart rate is about 75 for non-athletes and 53 for athletes who train primarily aerobically (128). Jordan (152) reported a mean resting heart rate of 60.1 beats per minute for adult women marathon runners which is lower than that of the present subjects. Powers and Walker (105) reported a mean resting heart rate of 68 beats per minute for outstanding female junior tennis players. In addition, Hagan et al. (153) reported a low mean resting heart rate of 55 beats per minute for middle-aged women distance runners, and 78 beats per minute for sedentary women.

Body Composition

Measures of the selected variables related to body composition (skinfold thickness, underwater weighing, and circumference) were obtained during pre- and post-test. The t test was used to determine the significance of differences between the means of each variable. The level of significance was established at .05% for the rejection of the null hypothesis for means. The results of these analyses are presented in Table X.

Changes in Skinfold Measures

The results of skinfold measures to determine the percent body fat on sum of seven are summarized in Table X. Included in this table are the pre- and post-test means for skinfold measures. A significant decrease was found between the two tests. The mean percent body fat was 12.81 for the pre-test and 11.33 in the post-test. These mean values were both lower than the mean of 23% reported by MacNab et al. (93) for college women gymnasts, and the 15.34% reported by Sinning (148) for highly skilled women gymnasts, and 15.5% reported by Sinning and Lindberg (138). On the other hand, the present subjects had higher mean skinfold value than mean value of 9.6% reported by Pařízková and Poupa (147). In addition, the present subjects had mean values lower than other sports participants reported in Table VII.

TABLE X

MEAN CHANGES IN BODY COMPOSITION*

	N	Skinfold (sum of 7) % Body Fat mm	N	Underwater % Body Fat	N	Circumference (Predicted weight) (lbs)
Pre	10	12.811	9	13.003	10	117
Post	10	11.33	9	10.181	10	115.283
Diff		- 1.481		- 2.822		- 1.717
t		- 2.455*		- 3.8998*		- 1.219

*Significant at .05 level.

Changes in Underwater Measures

Results of the data are presented in Table X. There was a significant decrease from pre-test to post-test. On the pre-test the present subjects had a mean value of 13.0% fat and 10.18% fat on the post-test. As a result of this change, the relative body fat decreased by 2.82%, demonstrating a significant decrease in body fat of the present subjects. Tables VI and VII present a summary of comparisons between the present subjects' mean percent body fat and the data reported for other gymnastic teams and sports participants.

An analysis of body build by circumference was performed to determine a predicted ideal weight. Table X presents the results of predicted ideal weight from circumference measures, which revealed that no significant difference existed between pre-test and post-test. The mean value of predicted ideal weight by circumference was 117 lbs on the pre-test and 115.282 lbs on post-test. Although there was a notable change in values of 1.72 lbs between pre- and post-test, no significant difference was established.

Strength Measurements

Strength was assessed through the use of cable tensiometer and grip dynamometer. Grip strength, push and pull, and knee extension were used in this study prior to and at the end of a three-month conditioning program. The data from these tests were analyzed by _t_ tests to determine if any significant differences existed in regard to strength variables before and at the end of the conditioning program.

Changes in Hand Grips

Results of the data are presented in Table XI, which reveals that there was a significant increase between pre-test and post-test in hand grip. The subjects had a mean value of 73.75 lbs, and 77.83 lbs for the right hand on the pre- and post-test, respectively. They had a mean value of 70.33 lbs and 74.42 lbs for the left hand on the pre- and post-test, respectively. Significant increases were found for both hands. The grip strength measurements showed stronger right than left hand grips. This was to be expected as most of the girls had dominant right hands. Gymnasts require good strength in both hands and arms. The present subjects had lower mean hand grips than European top female gymnasts of 99.0 lbs (45 kgs) and 83.6 lbs (38.0 kgs) for right hand and left. Heyward and McCreary (122) reported maximal grip strength value of 87.05 lbs (39.57 kgs) for women athletes. The same investigators also reported maximal grip strength of 86.11 lbs (3 g 14 kgs) for women gymnasts. Wessel and Nelson (155) reported grip strength value of 68.85 lbs and 75.32 lbs for college women. The latter values were lower than the values reported in post-test for the present subjects. Capen et al. (113) reported similar grip strength values of 66.42 lbs and 74.86 lbs for the left and right hands of selected groups of college women. Beunen et al. (154) reported similar grip strength values of 71.72 lbs (32.6 kgs) and 76.12 lbs (37.6 kgs) for the left and right hands for women gymnasts.

Changes in Push Measures

Results of the data are presented in Table XI, and reveals that there was a significant increase between the pre-test and post-test in

TABLE XI

MEAN CHANGES IN STRENGTH

	Hand Grip (lbs)				Push		Pull	Leg Strength (lbs)			
	N	Right	Left	N	(lbs)	N	(lbs)	N	Right	N	Left
Pre	6	73.75	70.33	6	64.33	6	57.5	6	79.98	6	79.73
Post	6	77.833	74.417	6	72.67	6	63.75	6	83.92	6	91.89
Diff		4.083	4.083		8.333		6.25		4		12.158
t		8.33*	8.33*		5.015*		4.155*		0.9094		5.245*

*Significant at .05 level.

push strength measurements. The present subjects had mean values of 64.33 lbs and 72.67 lbs on the pre- and post-test, respectively. No data are reported in the literature related to push strength measurements for women gymnasts or female athletes.

Changes in Pull Measures

Results of the data are presented in Table XI, which reveals that there was a significant difference between the pre-test and post-test in pull strength measurements. The subjects had mean values of 57.5 lbs and 63.75 lbs on the pre- and post-tests, respectively. No data have been reported about pull measurements related to women gymnasts or female athletes.

Changes in Leg Strength

Results of leg strength are presented in Table XI, which reveals that there was no significant difference between the pre-test and post-test related to right leg strength. The subjects had mean values of 79.92 lbs and 82.92 lbs on the pre- and post-tests, respectively. While there was an improvement in right leg strength at the end of the conditioning program, statistically there was no significant difference. A significant increase occurred in the mean value for left leg strength. The subjects had mean values of 79.73 lbs in the pre-test and 91.89 lbs on post-test. The leg strength measurements showed stronger left than right leg strength particularly for the post-test.

Case Study

During the course of this study, the investigator assessed the physical and physiological state of ten subjects who were the members of the women's gymnastic team, "Cowgirls", for the Department of Athletics at Oklahoma State University in 1982. Each subject was reviewed in depth in regard to starting status participation and progress during conditioning program and status at the end.

Subject 1

Physical Characteristics (Post-test)

Age: 18 years
Weight: 56.82 kg
Height: 166 cm
Body Density: 1.073
% Body Fat: 12.4

General Medical History

The subject has had good general health without any major illness in the past. She cited no history of cardiovascular or respiratory problems and has never smoked cigarettes. She reported that she has never had any menses. The date of her last complete physical exam was August 1982.

Activity History

The subject competed in gymnastics for eight years, starting at the age of ten. She was a member of the state championship team in high school. Classified as a freshman, she has participated on the college gymnastic team for a year. In addition to the conditioning program and formal gymnastic workouts, she engaged in leisure and physical education activities such as dancing, biking, and walking. Because of re-injuries caused during conditioning and gymnastic practices, the subjected missed the following days:

1. September - 10 days
2. October - 2 weeks
3. November - 2 days

Structural Limitations

Between 1972 and 1982 the subject has had the following injuries:

1. Spinal injury located in the neck - 1972-1973.
2. Ankle injury; muscle pull and sprains respectively throughout career.
3. Shin splints in 1981.
4. Shoulder injury in 1982.

Fitness Data

1. Cardiovascular changes

	Variables	pre	post	diff.
A.	$\dot{V}O_2$ Max (ml/kg/min)	40.23	45	4.77
B.	Anaerobic Threshold HR(beats/min)	115	186	71
C.	% of Max $\dot{V}O_2$	60	77	17

2. Changes in resting blood pressure and heart rate

	Variables	pre	post	diff.
A.	Supine BP (mm/Hg)			
	Systolic	130	120	-10
	Diastolic	72	88	16

B. Standing BP (mm/Hg)

Systolic	135	125	-10
Diastolic	78	88	10

C. Resting heart rate (Beats/min)

Supine	75	72	-3
Standing	77	74	-3

3. Changes in body componsition

Variables	pre	post	diff.
A. Skinfold (% Body Fat sum of 7)	11.8	11.3	-0.5
B. Underwater Weighing (% Body Fat)	14.95	12.4	-2.55
C. Circumference (predicted weight of eleven value)	121	120	-1

4. Changes in strength

Variables	pre	post	diff.
A. Hand grip (lbs)			
right hand	72.5	76	3.5
left hand	70	71	1
B. Push (lbs)	70	82	12
C. Pull (lbs)	49	56.5	7.5
D. Leg Strength (lbs)			
right	85.5	92.5	7
left	74.5	90	15.5

The results of this investigation showed a considerable increase in $\dot{V}O_2$max (ml/kg/min) for the subject (DK). The subject had a fair $\dot{V}O_2$ max of 40.23 ml/kg/min in the pre-test. At the conclusion of the conditioning program the subject showed an improvement in $\dot{V}O_2$max at 45.0 ml/kg/min, a difference of 4.77 ml/kg/min. The latter value was in the range considered below average for college age women athletes, but normal for the general college age female.

The present subject's anaerobic threshold heart rate was 115 beats per minute, and 186 beats per minute for the pre-test and post-test. The difference of 71 beats per minute indicated that there was marked degree of training improvement after three months of conditioning program. In addition, there was a considerable improvement in the percentage of max $\dot{V}O_2$ at AT.

The results indicated a noticeable decrease in resting systolic blood pressure in both supine and standing positions at the end of the conditioning program. On the other hand, diastolic blood pressure was increased, although 120/75 mm Hg was considered average resting blood pressure for a young adult.

Resting heart rate decreased in this subject in both supine and standing positions. The subject had supine and standing heart rate values of 75 and 72 beats per minute, and 77 and 75 beats per minute in standing on the pre- and post-test respectively. At rest average heart rate is about 75 beats per minute for non-athletes and 53 beats per minute for athletes who train primarily aerobically.

At the end of the conditioning program, there was a decrease in the percent body fat of this subject both skinfold and underwater measurements. From skinfolds she had a value of 11.8% fat in pre-test, and 11.3% fat in post-test. Underwater measurements indicated 14.95% fat and 12.4% fat during post-test. The results also showed a slight decrease in predicted ideal weight from eleven circumference measurements at the end of conditioning program.

The data demonstrated an increase in the grip strength scores as recorded at the end of the conditionong of 6.5 lb. In addition, the results showed a considerable increase in push and pull strength measurements. Right and left leg strength values also increased considerably.

Due to her re-injuries, this subject missed approximately 24 days of conditioning time and gymnastic practice which had no negative effect on her fitness level. In summary, this subject improved her $\dot{V}O_2$max, blood pressure, strength, and anaerobic threshold measures.

Subject 2

Physical Characteristics (Post-test)

Age: 18 years
Weight: 51 kg
Height: 159 cm
Body Density: 1.077
% Body Fat: 9.43

General Medical History

The subject has had good general health without any major illness in the past. She has never smoked cigarettes. She indicated that her menstrual cycle was irregular, but did not cause any loss of training time nor affect her participation in sport activities or gymnastic performance. The date of her last complete physical examination was September of 1982.

Activity History

The subject competed in gymnastics for more than ten years, beginning before she was 12 years of age. Participating in various regional and national competitions, the subject ranked 11th all-around in the 1982 AIAW national; 1st on uneven bars in SWAIAW regionals. She was named to the All Big Eight team, set two school records of 9.8 on bars at the NCAA regional and at senior nationals she ranked fourth place in beam competition. Her major was industrial engineering. She had been participating with the college gymnastic team for three years. In addition to the conditioning program and gymnastic workouts, she engaged in running and bicycling. Prior to the participating in the conditioning program, the subject spent approximately six hours a week engaged in various sport and physical activities. Re-injuries during conditioning and gymnastic workouts did not cause this subject to miss any full practice, but did necessitate lighter participation in the program.

Structural Limitations

Between 1978 and 1981, this subject suffered the following injuries:

1. Fracture located on stirrup (the stapes) - 1978.
2. Knee injury (cartilage - meniscus).
3. Ankle injury and sprains repeatedly.
4. Shin splints (slightly) - 1981.

Fitness Data

1. Cardiovascular changes

Variables	pre	post	diff.
A. Max $\dot{V}O_2$ (ml/kg/min)	44	45	1
B. Anaerobic Threshold HR (beats/min)	156	183	27
C. % of Max $\dot{V}O_2$	66	72	6

2. Changes in resting blood pressure and heart rate

Variables	pre	post	diff.
A. Supine BP (mm/Hg)			
Systolic	118	120	-2
Diastolic	72	84	12

B. Standing BP (mm/Hg)

Systolic	128	130	2
Diastolic	85	92	7

C. Resting heart rate (beats/min)

Supine	70	70	0
Standing	75	75	0

3. Changes in body composition.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of 7)	12.6	9.6	-3
B. Underwater Weighing (% body fat)	14.46	9.43	-5.03
C. Circumference (predicted weight of eleven value)	108	106	-2

4. Changes in strength.

Variables	pre	post	diff.
A. Hand grip (lbs)			
right hand	75	78	5
left hand	70	76.5	6.5
B. Push (lbs)	67	75	8
C. Pull (lbs)	57	57	0
D. Leg strength (lbs)			
right	76	90	14
left	74.5	92	17.5

The results of this study indicated a slight increase in $\dot{V}O_2$max (ml/kg/min) for the subject. In the pre-test the subject measured a $\dot{V}O_2$max of 44.0 ml/kg/min. A slight improvement was evident at the conclusion of the conditioning program; maximum oxygen consumption value increased to 45.0 ml/kg/min, a difference of only 1.0 ml/kg/min. These values conformed to the normal range of values for college-age women (157, 23), but below average for college age female athletes.

Anaerobic threshold heart rates of 156 beats per minute, and 186 beats per minute were reported for this subject in the pre- and post-tests respectively. The difference of 30 beats per minute indicated a high degree of improvement after three months of conditioning and training program. There was also a considerable improvement in the percentage of max $\dot{V}O_2$ at A.T.

A slight increase in resting systolic and diastolic blood pressures was seen at the end of the conditioning program. These increases were not significant; however, many variables can affect the blood pressure and it is difficult to obtain an average or typical measurement on any given day.

There was no change in resting heart rate in either supine or standing positions.

The results showed a considerable change in the percent body fat of this subject as evident in both skinfold and underwater measurements. The subject changed from 12.6% fat to 9.6% fat as measured by skinfold measurements. She also changed from 14.46% fat to 9.43% fat by underwater weighing. According to Johnson and Nelson's (106) scale and Cooper's (78) chart, this subject had a very low percentage of body fat in both skinfold and underwater measurements.

The data showed a slight decrease in predicted ideal weight from eleven circumference measurements conducted at the end of the conditioning program.

The results also illustrated an increase in grip strength at the end of conditioning program. She had gains of 5 lb in both the right and left hands. In addition, the data showed that the subject had a gain of 8 lbs in push strength, but there was no change in pull strength measurements. A considerable increase occurred in the right and left leg strength at the end of conditioning program. In summary, this subject lost body fat, increased strength and anaerobic threshold measures.

Subject 3

Physical Characteristics

Age: 18 years
Weight: 45 kg
Height: 150 cm
Body Density: 1.072
% Body Fat: 9.43

General Medical History

The subject has had good general health without any major illness in the past. She never smoked cigarettes. She reported her menstrual cycle to be irregular, varying from month to month. Though her menses was accompanied by general discomfort and slight pain, the subject indicated that this did not cause her to lose any training, conditioning, or gymnastic workout time or affect her participation in sport activities or gymnastic performance. The date of her last complete physical examination was in June 1982.

Activity History

The subject began gymnastic competition at the age of ten years and continued for seven years. She placed first in at least one event in every meet as a senior, averaged 9.15 for all four events. She placed first in district and sectional competition and third at state in all-around competition as a Sophomore in high school. She placed second on uneven bars at USGF Class 1 State meet in 1980 and also competed in USCF Club nationals in the same year. She was majoring in Business Administration. The subject participated in physical education class in high school and enrolled in physical education activity class in college. She engaged in social and recreational activities such as jogging and skiing. In the summer of 1982, prior to the conditioning program, she spent about two hours per week involved in physical activities. She reported injuries resulting from gymnastic practice and meets altered her performance in gymnastics slightly. The injuries and stomach pains caused her to lose a few hours of conditioning time and formal practice sessions:

1. The subject missed one full week in late October, 1982, due to a bad ankle.
2. Hyper-extended knee resulted in light participation in activities in the second week of October, 1982.

Structural Limitations

Between 1979-1982, the subject suffered the following injuries:

1. Muscle pull (hamstring): 1979
2. Hip injury (hip): 1980
3. Ankle injury (right): 1978-1980
4. Shin splints (right, left): 1981-1982

Fitness Data

1. Cardiovascular changes

Variables	pre	post	diff.
A. Max $\dot{V}O_2$ (ml/kg/min)	42.18	45.12	2.94

		pre	post	diff.
B.	Anaerobic Threshold HR (beats/min)	178	178	0
C.	% of Max $\dot{V}O_2$	72	77	5

2. Changes in resting blood pressure and heart rate.

Variables		pre	post	diff.
A.	Supine BP (mm/Hg)			
	systolic	130	118	-12
	diastolic	78	76	-2
B.	Standing BP (mm/Hg)			
	systolic	135	126	-9
	diastolic	85	80	-5
C.	Resting heart rate (beats/min)			
	supine	76	62	-14
	standing	84	68	-16

3. Changes in body composition.

Variables		pre	post	diff.
A.	Skinfold (% body fat - sum of seven)	14.8	11.8	-3
B.	Underwater weighing (% body fat)	13.46	9.43	-4.03
C.	Circumference (predicted ideal weight of eleven value)	107.40	96	-11.4

4. Changes in strength.

Variables		pre	post	diff.
A.	Hand grip (lbs)			
	right hand	72	75	3
	left hand	62	70	5
B.	Push (lbs)	45	48	3
C.	Pull (lbs)	54	63	9

D. Leg strength (lbs)

right	74.6	76.5	1.9
leg	67.5	75.6	8.1

Fitness data of this subject indicated a notable increase in $\dot{V}O_2$ max (ml/kg/min). The subject had a $\dot{V}O_2$ max of 42.18 ml/kg/min in the pre-test. At the end of the conditioning program, some improvement in her fitness was recorded; maximal oxygen consumption value increased to 45.0 ml/kg/min, a difference of only 2.94 ml/kg/min. The later value was similar to normal standards for college-age women (157, 23).

The anaerobic threshold heart rates of 178 beats per minute were reported for this subject in both the pre- and post-tests. It is possible that the high value the subject measured initially precluded any later change. A considerable improvement in the percentage of max $\dot{V}O_2$, a difference of 5% was found between the pre- and post-test.

The data also demonstrated a noticeable decrease in resting systolic and diastolic blood pressures in both supine and standing positions. In the pre-test this subject had a systolic score of 135 mm Hg and diastolic of 85 mm Hg. At the end of conditioning program these scores decreased to 126 mm Hg systolic and 80 mm Hg diastolic. In addition, there was a considerable decrease in resting heart rate value of 62 beats per minute in supine on post-test, and 68 beats per minute in standing on post-test. These values fell within the average of college women athletes.

The results showed a noticeable change in body composition for both skinfold and underwater measurements at the end of conditioning program. This subject had scores of 14.8% fat and 13.46% fat in skinfold and underwater measurements in pre-test. By the end of the conditioning program these values decreased to 11.8% and 9.43% fat. The subject had a low score in skinfold and very low score in underwater measurements in comparison with Johnson and Nelson's (106) scale and Cooper's (78) chart.

The data also demonstrated a decreased value in predicted ideal weight from eleven circumference measurements at the conclusion of the conditioning program.

The results also showed notable increases in the scores of both grip strength measurements. In the pre-test, the scores were 72 lbs and 75 lbs in post-test; 62 lbs and 70 lbs for the right and left hand respectively. This subject measured a higher value than in the norms of hand grip strength reported by Johnson and Nelson (106). In addition, the data showed that the subject had gains of 3 lbs and 5 lbs in push and pull strength, respectively. A slight increase occurred in the right leg strength and a considerable increase was noticed in the left leg. In summary, this subject improved on resting blood pressure, resting heart rate, and lost body fat in both skinfold and underwater weighing.

Subject 4

Physical Characteristics

Age: 19 years
Weight: 53.5 kg
Height: 156 cm
Body Density: 1.069
% Body Fat: 10.88

General Medical History

The subject indicated good general health without any major illness in the past. She has never smoked cigarettes. She reported a regular menses with moderate pain, discomfort and general body weakness. These symptoms of dysmenorrhea affected gymnastic performance. The subject reported "poor performance prior to and during cycle," varying from month to month. The date of her last physical examination was in August 1982.

Activity History

The subject competed in gymnastics for nine years, beginning at the age of 11 years. She was awarded USGF Class 1 in the national championships and a three time winner of the Leon Nance Award for most outstanding gymnast in the state. She has been a member of the All-Oklahoma team. A major in engineering, this is the subject's first year on a college gymnastics team. She engaged in social activities such as dancing and recreational games and individual sports such as tennis, skiing, sailing and racquetball. In addition, during the summer of 1982, she spent about six hours a week participating in above activities. Due to injuries resulting from gymnastic practice, her performance was altered severely. Back, ankle, and knee injuries were the most serious. During practice the subject wore a "T wear," a special ankle strap (supporter). The subject missed about 30 hours of conditioning time and formal gymnastic practice as a result of these injuries.

Structural Limitations

Between 1979-1982 this subject had the following injuries:

1. Knee injury - (right leg - cartilage) - in 1979.
2. Spinal injury - fractured lower vertebra - July 1981.
3. Hip injury - muscle pull in right hip - September 1982.
4. Ankle injury (right) - October 1982.

Fitness Data

1. Cardiovascular changes

Variables	pre	post	diff.
A. Max $\dot{V}O_2$ (ml/kg/min)	40.26	60.80	20.54
B. Anaerobic threshold HR (beat/min)	100	180	80
C. % of Max $\dot{V}O_2$	73	61	-12

2. Changes in resting blood pressure and heart rate.

Variables	pre	post	diff.
A. Supine BP (mm/Hg)			
systolic	110	110	0
diastolic	78	80	2
B. Standing BP (mm/Hg)			
systolic	130	120	-10
diastolic	85	80	-5
C. Resting heart rate (beats/min)			
supine	64	60	-4
standing	70	72	2

3. Changes in body composition.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of seven)	12.18	13	0.82
B. Underwater weighing (% body fat)	12.0	10.88	-1.12
C. Circumference (predicted ideal weight of eleven value)	110	114	4

4. Changes in strength.

Variables	pre	post	diff.
A. Hand grip (lbs)			
right hand	74	78	4
left hand	74	75	1
B. Push (lbs)	69	73	4
C. Pull (lbs)	69	76	7
D. Leg strength (lbs)			
right	87	89	2
leg	106	109	3

Fitness data of the present subject showed a significant change in $\dot{V}O_2$ max (ml/kg/min) and the end of the conditioning program. The subject had a fair score of 40.26 ml/kg/min in the pre-test, increasing to 60.80 ml/kg/min in post-test, indicating an improvement in measured fitness level. The value of 60.80 ml/kg/min was a higher score than all studies reported by Astrand (39), Drinkwater (5), and Sinning (23).

In the pre-test, this subject had a low anaerobic threshold heart rate of 100 beats per minute increasing to 180 beats per minute at the end of conditioning program, the large difference indicated an improvement due to training. There was a noticeable decrease of 12% of max $\dot{V}O_2$ at A.T. Possibly this decrease was due to injuries resulting from gymnastic practice which forced the subject to miss about 30 hours of her conditioning time and formal gymnastic practice.

No change was noticed in resting blood pressure between per- and post-tests, but a slight increase occurred in diastolic pressure. This subject had a value of 110/78 mm Hg in supine and 130/85 mm Hg while standing on the pre-test. Pressure of 110/80 and 120/80 mm Hg were reported at the end of conditioning program. There was also a decrease of four beats per minute in resting supine heart rate in post-test, but in the standing position there was a slight increase of two beats per minute at the end of conditioning program.

The data showed an increase in skinfold measures in the post-test for this subject. The subject had 12.18% fat in pre-test and 13% fat in post-test. Underwater measures showed a decrease in percent body fat, whereas the score was 12.0% fat in pre-test and 10.88% fat in post-test. The data also demonstrated a slight increase in predicted ideal weight from the eleven circumference measurements at the termination of the conditioning program.

This subject gained four pounds and one pound in the right and left grip strengths and four pounds and seven pounds in push and pull strengths, respectively. A slight increase occurred in the right and left legs strength for the present subject.

Due to her injuries and re-injuries, the present subject missed about 30 hours of conditioning program and formal gymnastic practice, and her performance was altered severely. Consequently, the results of this subject indicated that there were no significant increases or decreases in resting blood pressure, heart rate, percent of body fat, and strength. There was a considerable improvement in $\dot{V}O_2$max and anaerobic threshold heart rate at the end of the conditioning program.

Subject 5

Physical Characteristics (post-test)

Age: 21 years
Weight: 52.72 kg
Height: 159 cm
Body Density: 1.079
% Body Fat: 9.79

General Medical History

The subject has had good general health without any major illness in the past. She cited no history of cardiovascular or respiratory problems. She had smoked cigarettes for two years prior to pre-testing. She reported that her menstrual cycle was regular with no pain or problem other than body swelling. She did remark that her gymnastic performance was poor during menses. The subject had her last complete physical exam in 1980.

Activity History

The subject has competed in gymnastics for seven years, beginning at the age of 14 years and has been active on the college gymnastic team for four years. She has also participated in social activities and individual sports such as dancing and running. Prior to the conditioning program during the summer of 1982, subject engaged in variety of activities; swimming, running, and weight lifting, for about 21 hours per week. She placed third on the uneven bars competition at AIAW nationals, was two-time Big Eight bars champion and also won floor exercises in 1982. She was twice named to the All-Big Eight team, placed second in all-around competitions in NCAA regional and in 1978, subject was a Class 1 State High School Champion. She majored in physical education and has not missed any conditioning time or formal gymnastic workouts resulting from injuries or illness.

Structural Limitations

As a result of gymnastic practice and meets, the subject had shin injuries (on both legs) for a period of two years.

Fitness Data

1. Cardiovascular changes.

Variables	pre	post	diff.
A. Max $\dot{V}O_2$ (ml/kg/min)	53.53	54.5	0.97
B. Anaerobic threshold HR(beats/min)	158	162	4
C. % of Max $\dot{V}O_2$	67.27	74	6.73

2. Changes in resting blood pressure and heart rate.

Variables	pre	post	diff.
A. Supine BP (mm/Hg)			
systolic	120	125	5
diastolic	75	82	7
B. Standing BP (mm/Hg)			
systolic	130	130	0
diastolic	90	88	-2
C. Resting heart rate (beats/min)			
supine	66	62	-4
standing	68	66	-2

3. Changes in body composition.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of seven)	9.18	8.8	-0.38
B. Underwater weighing (% body fat)	9.6	9.79	0.19
C. Circumference (predicted weight of eleven value)	112.4	110	-2.4

4. Changes in strength.

Variables	pre	post	diff.
A. Hand grip (lbs)			
right hand	80	83	3
left hand	77	80	3
B. Push (lbs)	59.5	70	10.5
C. Pull (lbs)	59	63	4
D. Leg strength (lbs)			
right	78	63	-15
left	77.5	94.25	16.75

Fitness data of this subject showed a slight change in $\dot{V}O_2$ max (ml/kg/min) at the end of the conditioning program. The present subject initially had a very high score of 53.53 ml/kg/min in the pre-test and increased to 54.5 ml/kg/min in post-test.

This subject had also a high anaerobic threshold heart rate of 158 beats per minute in pre-test increasing to 162 beats per minute in post-test. Percentage of max $\dot{V}O_2$ at A.T. also increased from 67.27% in pre-test to 74% in post-test.

A marked increase in resting systolic and diastolic blood pressure was reported at the end of the conditioning program. These values conformed to the average values of 120/80 mm Hg. No change was reported for resting systolic and diastolic blood pressure at the termination of conditioning program in standing. Results showed a value of 130/90 mm Hg in pre-test and 130/88 mm Hg in post-test. Resting heart rate decreased slightly in post-test in both supine and standing positions, both within normal range.

This subject had a low value of percent body fat in both skinfold and underwater measurements, and little change was apparent at the termination of the conditioning program. Also, there was little change in predicted ideal weight from eleven circumference measurements.

In addition, the data indicated considerable increases in all grip strength measurements excluding the right leg which showed a slight decrease. This subject measured higher values than norms on hand grip strength. This subject also gained 10.5 lbs in push strength and four pounds in pull, right leg strength decreased 15 lbs and left leg increased 16.75 lbs at the termination of conditioning program.

Initially, this subject had high scores of $\dot{V}O_2$ max and percentage of max $\dot{V}O_2$ at anaerobic threshold, therefore only a slight improvement in cardiovascular fitness level was noticed at the end of the conditioning program. The results of present subject agree with other findings reported in previous studies dealing with the effects of physical training on highly skilled athletes (23, 5, 39). This subject reported that she was engaged in aerobic programs such as running throughout this study. There were no changes in strength or to body fat.

Subject 6

Physical Characteristics (Post-test)

Age: 18 years
Weight: 50 kg
Height: 148 cm
Body Density: 1.075
% Body Fat: 6.05

General Medical History

The subject has had good general health without any major illness in the past. She cited no history of cardiovascular or respiratory problems and had never smoked cigarettes. She reported a regular menses of 4-5 days duration accompanied by slight backache, abdominal cramps, and general discomfort. These symptoms had no serious effect on gymnastic performance though subject did report less balance during beam activity. She had her last complete physical exam on the 14th of September in 1982.

Activity History

This subject began competition in gymnastics at the age of ten and competed for five years. She has been on a college gymnastic team for one year and enrolled in a physical education class. The subject engaged in physical and social activities such as jogging, swimming, volleyball and dancing, and participated in these activities for about four hours per week during the summer of 1982. She has been four times All-State gymnast, gained the all-around championship in 1981 at state high school meet, placed second all-around in 1982 USGF and highschool state meet. She was twice named to All-Oklahoma team.

The subject never missed any days of practice or conditioning time during this study, but did omit some exercises due to foot injury. The ankle injury had slight effect on gymnastic performance but did limit her height and landing ability from gymnastic apparatus.

Structural Limitations

Ankle injury - left ankle - October 1982.

Fitness Data

1. Cardiovascular changes.

	Variables	pre	post	diff.
A.	Max $\dot{V}O_2$ (ml/kg/min)	40.11	55.63	15.52

	pre	post	diff.
B. Anaerobic threshold HR(beats/min)	143	176	33
C. % of Max $\dot{V}O_2$	60.18	64	3.82

2. Changes in resting blood pressure and heart rate.

Variables	pre	post	diff.
A. Supine BP (mm/Hg)			
systolic	120	120	0
diastolic	80	80	0
B. Standing BP (mm/Hg)			
systolic	130	120	-10
diastolic	92	80	-12
C. Resting heart rate (beats/min)			
supine	68	65	-3
standing	76	70	-6

3. Changes in body composition.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of seven)	12.19	10.5	-1.69
B. Underwater weighing (% body fat)	11.47	6.05	-5.42
C. Circumference (predicted weight of eleven value)	109	104.16	-4.84

4. Changes in strength.

Variables	pre	post	diff.
A. Hand grip (lbs)			
right	71	77	6
left	69	74	5
B. Push (lbs)	75.5	88	12.5
C. Pull (lbs)	57	67	10

D. Leg strength (lbs)

right	78.4	92.5	14.1
left	78.4	90.5	12.1

Fitness data of this subject showed a considerable change in $\dot{V}O_2$ max (ml/kg/min) at the end of the conditioning program. In the pre-test the value was 40.11 ml/kg/min increasing to 55.63 ml/kg/min, a difference of 15.52 ml/kg/min in the post-test, evidence that this subject's fitness level had improved. The later value of 55.63 was reported as a high value for women gymnast (5, 23).

The value of anaerobic threshold heart rate at 143 beats per minute was reported in pre-test, and 176 beats per minute was reported in post-test, a difference of 33 beats per minute. There was improvement in percentage of max $\dot{V}O_2$ at A.T. in post-test. A value of 60.18% of max $\dot{V}O_2$ was found in post-test. This value was similar to values reported by Davis (156) for college-age males.

In the supine position, the present subject had a normal resting blood pressure of 120/80 mm Hg in the post-test, with no change reported at the end of the conditioning program. In standing, the resting blood pressure slightly decreased in post-test. In resting heart rates, a noticeable decrease was found in post-test with normal value reported in supine and high value in standing position.

The data showed a notable decrease in present body fat of this subject for both skinfold and underwater measures at the end of conditioning program. Initially, this subject recorded a low value of 12.19% fat and 11.47% fat in pre-test for both skinfold and underwater measurements, while in post-test she showed a very low value of 10.5% fat and 6.05 for skinfold and underwater measures, respectively. There was also a slight decrease in predicted ideal weight from eleven circumference measurements at the conclusion of conditioning program.

The data revealed considerable increases in the scores of hand grip strength measurements. For right hand grip, the value was 71 lbs in pre-test and 77 lbs in post-test, while the value for left hand was 69 lbs in pre-test and 74 lbs in post-test, indicating a higher value than the norms of hand grip strength reported by Johnson and Nelson (106). This subject also gained 12.5 lbs in push strength and 10 lbs in pull; right and left legs strength increased 14.1 lbs and 12.1 lbs, respectively.

Subject 7

Physical Characteristics (Post-test)

Age: 19 years
Weight: 55.45 kg
Height: 160 cm
Body Density: 1.069
% Body Fat: 13.46

General Medical History

The subject has had good general health without any major illness in the past. She cited no history of cardiovascular or respiratory problems and has never smoked cigarettes. She reported that her menses was regular, but varied from month to month, accompanied by moderate pain, abdominal cramps, body swelling and general discomfort. These symptoms of dysmenorrhea however did not result in loss of training time. She indicated that she had slight eye allergies but this condition did not cause any problems. The date of her last complete physical examination was in September of 1982.

Activity History

The subject started competitive gymnastics before the age of 12, competing for eight years, both in high school and college level. She had been a member of the college gymnastic team for two years. She was active in several sports; running, racquetball, swimming, and weight lifting during the summer of 1982 prior to involvement in the conditioning program. As a member of the 1981 State Championship team, the subject placed third in all-around and bars competitions, second place on beam, fifth place on vaulting, and eighth in floor exercise. She was a consistent all-around competitor on last year's Cowgirl squad. As a result of gymnastic practice and meets she suffered several injuries that did affect her gymnastic performance. Because of these injuries she missed one hour of conditioning time and gymnastic workouts. In addition she missed two full days of gymnastic practice and conditioning time. The subject was unable to take the post-test for $\dot{V}O_2$ max, anaerobic threshold, resting blood pressure, heart rate and strength tests because of injury to her thigh caused by landing on the beam.

Structural Limitations

Between 1974 and 1982 the subject had the following injuries:

1. Fractures - left wrist - 1974.
2. Muscle pull - hamstring - September 1982.
3. Left ankle.
4. Shin splints (both).
5. Stress fracture (right) - April 1982.

Fitness Data

1. Cardiovascular measures.

Variables	pre
A. Max $\dot{V}O_2$ (ml/kg/min)	40.46
B. Anaerobic threshold HR (beats/min)	187
C. % of Max $\dot{V}O_2$	62

2. Resting blood pressure and heart rate measures.

Variables	pre
A. Supine BP (mm/Hg)	
systolic	128
diastolic	80
B. Standing BP (mm/Hg)	
systolic	132
diastolic	85
C. Resting heart rate (beats/min)	
supine	76
standing	78

3. Body composition measures.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of seven)	13.05	13	-0.05
B. Underwater weighing (% body fat)	14.20	13.46	-0.74
C. Circumference (predicted weight of eleven value)	113.7	116.17	2.47

4. Strength measures.

Variables	pre
A. Hand grip (lbs)	
right hand	66
left hand	64
B. Push (lbs)	75
C. Pull (lbs)	59
D. Leg strength (lbs)	
right	97.5
left	92.5

Fitness data of this subject was reported only for the pre-test, excluding body composition measures which were reported on both pre- and post-test. The subject was unable to take the post-test for $\dot{V}O_2$max, anaerobic threshold, resting blood pressure, resting heart rate, and strength because of injury to her thigh.

The data in pre-test showed that this subject had an average $\dot{V}O_2$max of 40.46 ml/kg/min which is within the range of 35-43 ml/kg/min reported by Astrand (39) and Drinkwater (5).

The anaerobic threshold heart rate of 187 beats per minute was reported in the pre-test. This subject scored high when compared with other scores of the subjects of this study. The percentage of $\dot{V}O_2$max at A.T. for this subject was 62% which was similar with these values of 58.6% and 63.8% of max $\dot{V}O_2$ for volunteer college-age males by Davis (156).

The data also showed that the supine resting blood pressure was close to normal value of 120/75 mm Hg reported by Falls (17) for young adults. While standing resting blood pressure was reported for this subject of 132/85 mm Hg. In addition, supine and standing resting heart rates were high value of 76 beats per minute and 78 beats per minute, respectively.

The results showed a slight change in body composition for both skinfold and underwater measurement at the end of conditioning program. In the pre-test the values were 13.05% fat and 14.20% fat, and 13% fat and 13.46% fat were in post-test in both skinfold and underwater measures, indicated that these scores were low and the subject's body composition was stable.

The data also demonstrated high scores on all strength measurements in pre-test. This subject had higher values than those reported by the Johnson and Nelson's (106) studies.

Fitness data showed that this subject was initially in a normal stable condition.

Subject 8

Physical Characteristics (Pre-test)

Age: 19 years
Weight: 66 kg
Height: 168 cm
Body Density: 1.068
% Body Fat: 14

General Medical History

The subject has had good general health without any major past illness. She has never smoked cigarettes. She took medication for allergies to dust, grass, and weeds and reported that she had slight respiratory problems (allergic asthma). She reported an irregular menses of less than three days duration unaccompanied by any symptoms of dysmenorrhea. The date of her last complete physical exam was September of 1982.

Activity History

The subject has competed in gymnastics for six years, starting before the age of 13. She has been active for one year on the college gymnastic team and enrolled in a physical education class. She had been active in such individual sports as jogging, tennis, and racquetball and spent about six hours per week in physical activity during the summer of 1982. Her strong areas were balance beam and floor exercise. In 1981 she placed first in state on vault competition, fourth in floor exercise and all-around. Also, she placed first in all-around in Conference and District Competition for two successive years. Injuries and re-injuries due to gymnastic practice and meets altered her performance moderately. Her knee dislocation was the most serious injury and affected her gymnastic performance until the conclusion of the conditioning program. However, she did not miss any conditioning time or gymnastic workouts. Due to her injuries the subject did not take the post-test for $\dot{V}O_2$ max, anaerobic threshold measurement, resting blood pressure, or resting heart rate.

Structural Limitations

Between 1979-1982 the subject had the following injuries:

1. Dislocated knee cap, in 1979.
2. Fracture, located on little finger.
3. Knee injury, located on right knee, in 1980.
4. Muscle pull and shin splints.
5. Ankle injury, chipped ankle bones, 1978.

Fitness Data

1. Cardiovascular measures.

Variables	pre
A. Max $\dot{V}O_2$ (ml/kg/min)	33.9
B. Anaerobic threshold HR (beats/min)	129
C. % of Max $\dot{V}O_2$	64

2. Resting blood pressure and heart rate measures.

Variables	pre
A. Supine BP (mm/Hg)	
systolic	120
diastolic	80
B. Standing BP (mm/Hg)	
systolic	126
diastolic	80
C. Resting heart rate (beats/min)	
supine	68
standing	72

3. Body composition measures.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of seven)	13.1	13.5	0.4
B. Underwater weighing (% body fat)	15.39	14	1.39
C. Circumference (predicted ideal weight of eleven value)	142.6	145.5	2.9

4. Strength measures.

Variables	pre
A. Hand grip (lbs)	
right hand	93
left hand	88
B. Push (lbs)	84
C. Pull (lbs)	71
D. Leg strength (lbs)	
right	87.5
left	97.5

Fitness data of this subject was reported only for the pre-test, excluding body composition measures which were reported on both pre- and post-test. The subject was unable to take the post-test for $\dot{V}O_2$max, anaerobic threshold, resting blood pressure, resting heart rate, and strength because of her injuries.

The data in pre-test showed that this subject had a poor value $\dot{V}O_2$max of 33.9 ml/kg/min which conforms to the range of 28-38 ml/kg/min as reported by Hodgkins and Skubic (166) for college-age girls.

An anaerobic threshold heart rate of 129 beats per minute was reported in pre-test, indicating a low score when compared with other scores of the subjects in this study. The percentage of max $\dot{V}O_2$ at A.T. was reported for this subject of 64%. This was similar to the values reported by Davis' (156) study.

The resting blood pressures were similar to those reported by Falls (17) for young adults. The present subjects' values of 120/80 mm Hg were reported in the pre-test.

Supine and standing resting heart rates were also within average range as reported by Johnson and Nelson (106). This subject was recorded at 68 beats per minute in supine and 72 beats per minute in standing position.

The fitness data also showed a slight increase in percent body fat as evident in skinfold measurement, and a slight decrease of percent of fat in underwater measurements at the end of conditioning program. This subject had low score of 13.5% fat and 14.0% fat for skinfold and underwater, respectively, in post-test. A slight decrease in predicted ideal weight from eleven circumference measurements at the end of conditioning program was noted.

The results demonstrated high values for all strength measurements in pre-test. This subject had higher values than those reported by Johnson and Nelson (106) for college-age girls.

Fitness data indicated that this subject was initially in a normal stable condition.

Subject 9

Physical Characteristics (Pre-test)

Age: 18 years
Weight: 60.34 kg
Height: 168 cm
Body Density: 1.079
% Body Fat: 6.19

General Medical History

The subject has experienced good general health with no history of major illness in the past. She never smoked cigarettes. She reported an irregular menses of less than three-day duration and cited only occasional body swelling and no pain or discomfort. The date of her last complete physical examination was early August of 1982.

Activity History

The subject started gymnastic competition at the age of eight, continuing on for about ten years. She has been a member of the college gymnastic team for a year. She reported that running, hiking, and bicycling were the sports in which she most frequently participated, and social activities such as volleyball and group running. Her competitive activity history includes Class No. 1 competition for TWIGS gymnastic club in Dayton, Ohio. At O.S.U she was first on the vault, and third place in all-around in the 1982 state meet. She also won first on vault and second in all-around at nationals. She also qualified for USGF nationals four times. She reported having spent three hours per week in physical activities, running and volleyball in the summer of 1982. The injuries and re-injuries as a result of gymnastic practice and meets affected her performance only slightly, and she missed minimal time during conditioning and workouts. Because of her illness, she did not participate in post-test for max $\dot{V}O_2$, anaerobic threshold, resting blood pressure, and heart rate tests.

Structural Limitations

Between 1979-1982 the subject had the following injuries:

1. Dislocation (twice), of middle left finger, and small right finger, in 1977 and 1978.
2. Spinal injury, a stress fracture of the fifth lumbar, in 1978.
3. Fracture of middle left finger in 1977.
4. Shin splints (chronic).

Fitness Data

1. Cardiovascular measures.

Variables	pre
A. Max $\dot{V}O_2$ (Ml/kg/min)	56.36
B. Anaerobic threshold HR (beats/min)	146
C. % of max $\dot{V}O_2$	51

2. Resting blood pressure and heart rate measures.

Variables	pre
A. Supine BP (mm/Hg)	
systolic	110
diastolic	76
B. Standing BP (mm/Hg)	
systolic	118
diastolic	80
C. Resting heart rate (beats/min)	
supine	59
standing	64

3. Body composition measures.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of seven)	10.9	8.8	-2.1
B. Underwater weighing (% body fat)	11.50	6.19	-5.31
C. Circumference (predicted weight of eleven value)	131.7	130	-1.17

4. Strength measures.

Variables	pre
A. Hand grip (lbs)	
right hand	104
left hand	93
B. Push (lbs)	87
C. Pull (lbs)	81
D. Leg strength (lbs)	
right	102
left	100

Fitness data of this subject was reported only for the pre-test, excluding body composition measures which were reported on both pre- and post-test. However, the subject was unable to take the post-test for $\dot{V}O_2$max, anaerobic threshold, resting blood pressure, resting heart rate, and strength because of illness.

The pre-test data showed the present subject with a high value of 56.36 $\dot{V}O_2$max.

Anaerobic threshold heart rate in the pre-test indicated that the subject scored low when compared with other scores for the subjects of this study. The percentage of max $\dot{V}O_2$ at A.T. was reported for this subject, the score was 51% of max $\dot{V}O_2$ at A.T. which was similar to the values reported by Davis (156).

In supine and standing resting blood pressures, the scores were 110/76 mm Hg, and 118/80, respectively. These values were above average rated as good in accordance with study by Falls (17). The resting heart rate was 59 beats per minute and 64 beats per minute for supine and standing, respectively. These values were above the average reported by Cooper (78).

The data showed decreases in percent body fat of this subject in both skinfold and underwater measurements at the end of conditioning program. The subject had a percent fat of 10.9 in pre-test which decreased to 8.8% fat in post-test by the skinfold measures. This subject had 11.5% fat in pre-test which decreased considerably to the very low value of 6.19% fat. Also, little change in predicted ideal weight from eleven circumference measurements was noted.

In addition, the data showed a very high score in all strength measures.

Fitness data of this subject indicated that the subject was initially in a good stable condition.

Subject 10

<u>Physical Characteristics</u> (Pre-test)

Age: 19 years
Weight: 51.8 kg
Height: 156 cm
Body Density: 1.068
% Body Fat: 15.32

<u>General Medical History</u>

The subject had good general health without any past major illness. She cited no history of cardiovascular or respiratory problems and has never smoked cigarettes. Her menstrual cycle was regular lasting seven to eight days accompanied by moderate pain. Symptoms of dysmenorrhea such as abdominal cramps, backache, and body swelling were sometimes severe enough to cause her to lose one or more days of training. She did not report any complete physical exam within the past two years.

Activity History

The subject began gymnastic competition prior to the age of seven and continued for eight years throughout highschool. She has been a member of the college team for a year. In college she enrolled in a physical education class and was involved in both social and individual physical activities such as swimming and tennis. During the summer of 1982 she engaged in these activities for approximately seven hours per week.

As a result of injuries due to gymnastic practice and meets she missed many hours of conditioning time and formal gymnastic practice. Her gymnastic performance was significantly altered as a result of the injuries and consequently she was unable to take the post-test for $\dot{V}O_2$max, anaerobic threshold, resting blood pressure, resting heart rate, and strength tests. Nor was the subject able to take the underwater weighing test for the pre-test.

Structural Limitations

The subject had the following injuries:

1. Muscle pull, hamstring.
2. Ankle injury.

Fitness Data

1. Cardiovascular measures.

	Variables	pre
A.	Max $\dot{V}O_2$ (ml/kg/min)	33.12

B. Anaerobic threshold HR (beats/min) 185

C. % of max $\dot{V}O_2$ 80

2. Resting blood pressure and heart rate measures.

Variables	pre
A. Supine BP (mm/Hg)	
systolic	110
diastolic	70
B. Standing BP (mm/Hg)	
systolic	120
diastolic	88
C. Resting heart rate (beats/min)	
supine	68
standing	72

3. Body composition measures.

Variables	pre	post	diff.
A. Skinfold (% body fat - sum of seven)	18.31	13	-5.31
B. Underwater weighing (% body fat)	--	15.32	--
C. Circumference (predicted ideal weight of eleven value)	114.2	111	-3.2

4. Strength measures.

Variables	pre
A. Hand grip (lbs)	
right hand	76
left hand	68
B. Push (lbs)	57
C. Pull (lbs)	58

D. Leg strength (lbs)

right	50
left	--

Fitness data of this subject was reported only for the pre-test, excluding body composition measures which were reported on both pre- and post-test except underwater weighing which was not reported on pre-test. However, the subject was unable to take the post-test for $\dot{V}O_2max$, anaerobic threshold, resting blood pressure, resting heart rate, and strength because of her illness and injuries.

The data in the pre-test showed that though the present subject measured a low value $\dot{V}O_2max$ of 33.12 ml/kg/min. This figure is within the range of 28-38 ml/kg/min reported by Hodgkins and Skubic (106) for college-aged girls.

The anaerobic threshold heart rate of 185 beats per minute was reported in the pre-test indicating that the subject scored high compared with other scores for the subjects of this study. A value of 80% of max $\dot{V}O_2$ at A.T. was reported for this subject which was a very high value when compared to the values reported by Davis (156).

In supine and standing, the resting blood pressure was similar to those reported by Falls (17) for young adults. This subject had a value of 110/70 mm Hg which was above average in supine, and 120/88 mm Hg in normal average for standing. Supine and standing resting heart rates of 68 and 72 beats per minute were found in the pre-test.

The data showed that there was a considerable decrease in the percent body fat of this subject as evident in skinfold measures at the end of conditioning program. In the pre-test, the value of 18.31 percent of body fat was reported, decreasing to 13% body fat. Though no value was determined in the pre-test for underwater measurements, a value of 15.32% fat was measured in the post-test. Both values conform to the above average values reported by Cooper (78) and Johnson and Nelson (106). In addition, a marked decrease in predicted ideal weight from eleven circumference measurements was reported.

The data revealed a high value in strength measures of 76 lbs and 68 lbs for the right and left hands grip. Values of 57 lbs, 58 lbs and 50 were reported for push, pull and right leg, respectively.

Fitness data showed that this subject was initially in a normal stable condition, excluding $\dot{V}O_2$max which was reported with low value of 33.12 ml/kg/min.

Summary of Results

The main purpose of this study was to determine the effects of a conditioning program on selected physiological variables of the college-age women gymnasts.

A total of ten gymnasts, who represented the women's gymnastic team, "Cowgirls", for the Department of Athletics at Oklahoma State University during 1982-1983 season, were tested prior to the conditioning program and after the three-month program terminated in which the following measurements were taken: age, height, weight, maximal oxygen consumption, anaerobic threshold, resting heart rate and blood pressure, body composition and strength. Only six subjects of ten were able to take the pre- and post-test. The other four were unable to participate in the post-test because of illness or injuries. Comparison of the physical and physiological characteristics of the present subjects with other groups of gymnasts, swimmers, basketball players, volleyball players, speed skaters, jogging participants, and lacross players were made. Descriptive data for each subject at the end of conditioning program was presented in a case study. The data from pre- and post-test were analyzed by t-tests to determine if any significant differences existed in regard to the physical and physiological variables. The .05 level of confidence was chosen in reporting all results. Significant differences were found in the trial effect indicating an increase or decrease from pre- to post-test values.

The subjects were younger, shorter in stature, lighter in weight than other college women but similar to other women gymnasts. The present subjects were similar to but slightly lower in $\dot{V}O_2$max than other female athletes reported in the literature. Also, they had less body fat than other female athletes and female gymnasts, except the Czechoslovakian.

Significant differences due to conditioning program effects were found in $\dot{V}O_2$max (expressed in ml/kg/min) and the anaerobic threshold heart rate (beats per minute) throughout the study, but no significant difference was found in the percent max $\dot{V}O_2$ at anaerobic threshold. The data obtained from supine resting blood pressure and heart rate revealed that there were no significant differences between pre-test and post-test. Resting blood pressure in the standing position decreased significantly in the post-test. No significant difference was found in standing resting heart rate.

Total skinfold measures, sum of seven, and percent of body fat in both skinfold and underwater measures decreased significantly between pre-test and post-test. No significant difference was found in predicted ideal weight from eleven circumference measures. Significant increases were also observed in all strength measures except for right leg strength.

CHAPTER V

CONCLUSION AND RECOMMENDATION

Gymnastics as a competitive sport is popular all over the world. The growth of young women's participation in competitive gymnastics has been a product of the growing acceptance of female participation in various sports and physical activities. Because of the level of difficulty at which gymnasts are performing, a physical conditioning program that enhances cardiovascular endurance, strength, flexibility, and body composition becomes very important (7). While the major objective of the modern-day gymnast is to activate movement skills for the greatest improvement, several physical components are obviously highly developed in the process. With contemporary trends in gymnastics, certain events such as uneven bars, beam, and floor exercise require the use of a considerable degree of strength, flexibility, speed, muscular power, and cardiovascular function in each performer's routine.

With the above in mind, the present investigation was undertaken to identify the effects of a three-month conditioning program on selected physiological variables in the female gymnastic team of Oklahoma State University. The conditioning program emphasized cardiovascular function, body composition, and strength. Due to some unfortunate circumstances, only ten gymnasts were able to participate in this study. As a result of re-injuries and illnesses, four subjects were unable to take the post-test in strength and cardiovascular variables. The results of this investigation were compared with mean values of other national and international gymnastic teams and sport activities. In addition, descriptive data for each subject was presented in case study form. The data from this study were analyzed by t-test to determine the significance of differences between pre-test and post-tests.

In all statistical analyses .05 was selected as the confidence level.

Conclusions

With the scope and limitations of this study the following conclusions have been done:

1. There was a significant difference between pre- and post-test anaerobic threshold heart rate. Therefore, the first null hypothesis was rejected.
2. There was no significant difference between pre- and post-test percentage of max $\dot{V}O_2$ at anaerobic threshold. Therefore, the second null hypothesis was accepted.
3. There was no significant difference between pre- and post-test maximal oxygen consumption (ml/kg/min). Therefore, the third null hypothesis was accepted.
4. There was no significant difference between the pre- and post-test supine resting blood pressure. Therefore, the fourth null hypothesis was accepted.
5. There was a significant difference between pre- and post-test standing resting blood pressure. Therefore, the fifth null hypothesis was rejected.
6. There was no significant difference between the pre- and

post-test supine resting heart rate. Therefore, the sixth null hypothesis was accepted.

7. There was no significant difference between pre- and post-test standing heart rate. Therefore, the seventh null hypothesis was accepted.
8. There was a significant difference between pre- and post-test percent body fat as measured by skinfold thickness (sum of seven). Therefore, the eighth null hypothesis was rejected.
9. There was a significant difference between pre- and post-test percent body fat as measured by underwater weighing. Therefore, the ninth null hypothesis was rejected.
10. There was no significant difference between pre- and post-test means of circumference (predicted ideal weight). Therefore, the tenth null hypothesis was accepted.
11. There was a significant difference between pre- and post-test right grip strength. Therefore, the eleventh null hypothesis was rejected.
12. There was a significant difference between pre- and post-test left grip strength. Therefore, the twelfth null hypothesis was rejected.
13. There was a significant difference between pre- and post-test push strength. Therefore, the thirteenth null hypothesis was rejected.
14. There was a significant difference between pre- and post-test pull strength. Therefore, the fourteenth null hypothesis was rejected.
15. There was no significant difference between pre- and post-test

right leg strength. Therefore, the fifteenth null hypothesis was accepted.

16. There was a significant difference between pre- and post-test left leg strength. Therefore, the sixteenth null hypothesis was rejected.

Recommendations

As a result of having conducted this study and from having acquired a reasonable familiarity with the literature concerning the physical and physiological adaptation of the female gymnasts to the training and conditioning program; and in order to obtain valid results, the following recommendations are made with regard to further study:

1. The conditioning and testing program should be extended over a longer period of time including the competitive season.
2. The number of tests, then should be increased to include a mid-training test to more accurately assess the effects of conditioning program on cardiovascular function, strength, and physique alteration.
3. The extended use of the conditioning program requied a great amount of motivation in order to achieve specific objectives of cardiovascular endurance, strength development, and physique alterations. It could be that the best method to inspire and attract the gymnasts to accomplish these objectives is to combine various type of activities such as running, swimming, circuit weight training, and cycling.
4. More studies should be conducted to determine the effects of conditioning or training program on other related variables

such as flexibility, strength of various muscle groups including knee extension, knee flexion (curl), elbow extension, elbow flexion, and hip extension.

5. Studies should be conducted to compare the physical and physiological characteristics of college female gymnasts with other college women athletes such as swimmers, cross-country skiers, and weight training participants.
6. More college female gymnasts should be enlisted as subjects in studies similar to the present one.
7. There is a need for longitudinal studies to be undertaken to follow young female gymnasts from high school through the college level who have intensive involvement in competitive gymnastics. This would allow identification of the effects of the conditioning and training program on major physical and physiological components over a longer period of time so that changes might well be observed.

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APPENDIXES

APPENDIX A

CONDITIONING PROGRAM (INCLUDING FORMAL GYMNASTIC TRAINING) USED BY WOMEN GYMNASTIC TEAM IN THE DEPARTMENT OF ATHLETICS AT OKLAHOMA STATE UNIVERSITY

CONDITIONING PROGRAM (INCLUDING FORMAL GYMNASTIC TRAINING) USED BY WOMEN GYMNASTIC TEAM IN THE DEPARTMENT OF ATHLETICS AT OKLAHOMA STATE UNIVERSITY

SUGGESTED DAILY ACTIVITIES
(5 days a week, 4 hrs/day)

Stage	Type of Activities	Time	Days/Week
1. Warm up.	a. Walking, jogging, and running	5 min.	5 days a week (M - F)
	b. Flexibility exercise	5 min.	5 days a week (M - F)
	c. Stretching exercise (subject works out alone or with her partner) Such as: Hamstring, hip flexors, low back estensors, and ankle extensors	15 min.	5 days a week (M - F)
	d. Tumbling Skills Combinations	20 min.	3 days a week (M-Tu-Th)
2. Formal Gymnastic Practice	a. Gymnastic skills on side horse vaulting	40 min.	5 days a week (M - F)
	b. Gymnastic skills on balance beam	40 min.	5 days a week (M - F)
	c. Gymnastic skills on uneven parallel bars	40 min.	5 days a week (M - F)
	d. Gymnastic skills: floor exercise, routines, and dance movements	40 min.	5 days a week (M - F)
3. Conditioning Exercise (Strength and Endurance Training) A. Strength Training *Free weights (barbells) and Universal Gym were used for this type of training) *Overload principle was utilized progressively throughout the duration *Repetitions (up to 10) and weights (5 pounds each week) were increased regularly	a. Activities related to the upper body parts such as: 1. Hand walking on parallel bar 2. Jump to support on uneven parallel bars 3. Pull ups, until knees touch the bar 4. Handstand to straddle forward roll to handstand through pressing (with partner or coach)	15 min.	2 days a week (Tu - Th)
	b. Strength training exercises for various muscle groups (lower body parts)	30 min.	3 days a week (M-W-F)

Stage	Type of Activities	Time	Days/Week
3. A. (Continued)			
*lower legs and ankles	1. Scissor jumps with weight carried on shoulder 2. Sitting and standing heel rise 3. Straight leg jump with weight carried on shoulder		
*back and posterior aspects of legs	4. Long steps with weight carried on shoulder 5. Leg curl 6. One half and two-third squat with weight		
*abdominal aspects	7. Hip lifts 8. Curl ups 9. Twist with barbells on shoulder		
*wrist	10. Wrist curl and wrist roll		
B. Endurance Exercise			
1. aerobic type (optional and not controlled)	Running - recommended (subjects jogging, swimming, and bicycling if time available)	20-30 min duration	3 days per week with T-HR. as per exercise prescription (60-85%)
2. Anaerobic type (required and not controlled) (distance increased and time decreased gradually)	Running up hills for speed and power * In doors during bad weather (running fast on stairs) * Subjects ran in group around the course or up hill as fast as they could for 3-5 times, rested for a minute, and then ran backward for 3-5 times with 2/3 of their speed.		

Stage	Type of Activities	Time	Days/Week
4. Cooling Down	Stretching and Flexibility Exercise a. Hamstring b. Hip flexors c. Low back extensors	10 min.	5 days

APPENDIX B

QUESTIONNAIRES

QUESTIONNAIRES

FITNESS EVALUATION

In order to have health information of value to our study, we would appreciate your responses on the following: (this information will be held in the strictest confidence).

I. General Data

Name ______________________________ ____________
(First) (Middle) (Last) Date of Birth

Local Address ______________________________

Age ____________________ Phone ____________________

Weight __________ (lbs) Height _____ (ft) __________ (in)

Do you smoke? Yes __________ No ______________

Years Smoked ______________ Non-Smoker ______________

Former Smoker ______________

Do you drink alcohol? ______________ Less than one drink __________ 1-2/day _____________ 3+/day _________

Varies (depends on the day, week or occasion ______________

Only in the off-season ______________________________

Date of last complete physical exam: ____________________

Doctor __________________, City ____________________
(Name)

How are you classified in school? Fres. _______ Soph _____

Jr. ________________ Sr. __________________

What is your major course of study? ____________________

II. Activity History - Please circle your response.

1. At what age did you begin competition in gymnastics?

   Under 6 6 7 8 9 10 11 12 13 14 15

   16 17 18

2. How many years have you been competing in gymnastics?

   1 2 3 4 5 6 7 8 9 10 or more

3. Did you compete in gymnastics on a high school or club team? Yes ____________ No ____________ No team ________

4. How many years have you been on a college gymnastic team? 1 2 3

   4

5. Would you have continued practicing your gymnastic skills if you had not had an opportunity to compete at the College level? Yes __________ No _________ Don't Know _________

6. Did you participate in a physical education class in high school? Yes _________ No _________ Not Available ______

III. Present Activity

1. Are you enrolled in a leisure and/or physical education activity class this year? Yes _____________ No __________

2. What type of physical activity do you engage in most frequently? (excluding gymnastic workouts).

   a. Social activities (such as dancing and recreational games) _____________________.

   b. Individual sports (such as swimming, and tennis) _____

   c. Organized team sports (such as basketball, and volleyball) _______________________.

   d. Any other, (List): ___________________________________

   e. None ____

3. What type of physical activity did you engage in most frequently last summer? (excluding gymnastic workouts).

   a. Individual sports, list: ____________________

   b. Organized team sport, list: ____________________

   c. Social activities, list: ____________________

   d. Others, list: ____________________

   e. None ____________________

4. Approximately, how much time per week did you spend in physical activity last summer? (excluding gymnastic workouts).

   a. 7 or more hours ____________________

   b. 5-6 hours ____________________

   c. 3-4 hours ____________________

   d. 2-3 hours ____________________

   e. 1-2 hours ____________________

   f. None ____________________

5. How much sleep do you average per day?

   a. Less than 6 hours ____________________

   b. 6-8 hours ____________________

   c. More than 8 hours ____________________

IV. Structural Limitations

1. Check any of the following injuries that you have had.

Injury		When	Location of Injury
Dislocation	________	________	________
Spinal injury	________	________	________
Fracture	________	________	________
Knee injury	________	________	________

Muscle pull ________ ____________ __________________

Hip injury ________ ____________ __________________

Ankle injury _______ ____________ __________________

Shine splints ______ ____________ __________________

Others , List: ______ ____________ __________________

2. If answer to the above question was yes, was your gymnastic performance altered following injury? Yes _______ No ______

   Which injuries affected performance? ____________________

   ____

3. If you have had one of the above injuries since you have been in college, does this represent a re-injury from high school?

   Yes _______________ No ___________________

   If yes, which ones? ________________________________

   ____

4. Do you still have trouble as the result of your injury?

   Yes _______________ No ____________________

   If yes, which ones? _______________________________

   ____

5. Was the injury a result of gymnastic practice or gymnastic meet?

   Yes ________________ No _____________________

   Which injury? ______________________________________

   ____

6. How much conditioning time and formal gymnastic practice have you missed this year as a result of any of above injuries?

   ____

   ____

Less than one day ________________

One day ________ 2-5 days ________

More than 5 days ________ Others,

list: ________________

____

V. Physiological Limitations

A. Have you ever had or do you have:

1. Allergies - Yes ________ No ________ If yes,

list: ________________

____

2. High blood pressure - Yes ________ No ________

3. Any heart disease since birth - Yes ________ No ________

4. Abnormal heart rhythm - Yes ________ No ________

5. Respiratory problems - Yes ________ No ________

If yes, list: ________________

____

6. Lack of appetite - Yes ________ No ________

7. Ulcers or other stomach related problems - Yes ________

________ No ________

8. Epilepsy - Yes ________ No ________

9. Trouble with dehydration (excess loss of salt and water)

Yes ________ No ________

10. Frequent headaches - Yes ________ No ________

B. Menstrual History:

1. Have you ever had or do you have menses? Yes ________

No ________

2. What is the duration of the menstrual cycle?

Less than 3 days ________________

7-8 days ______

More than 8 days ______

Varies from month to month ______

3. Do you consider your menstrual period? regular ______

Irregular ______

4. Are your menstrual periods severe enough to make you lose one or more days of training? Yes ______

No ______

5. If number three was yes, what type of problem do you have?

a. Abdominal "cramps" ______

b. Backache ______

c. Headache ______

d. General discomfort ______

e. General body weakness ______

f. Body swelling ______

g. Nausea ______

h. Excessive sweating ______

i. Leg cramps ______

k. Vomiting ______

l. Chilling ______

m. Loss of appetite ______

6. What degree of pain do you have during the menstrual period?

a. No pain ______

b. Slight pain ______

c. Moderate pain ______

d. Severe pain ______

7. Do you cease to flow when tired, worried or constipated?

   Yes ____________________ No ________________________

8. What is the effect of the menstrual period on your gymnastic performance?

   a. No change ______________________________________

   b. Poor performance during menses ___________________

   c. Better performance _______________________________

   d. Poor performance prior to menses _________________

   e. Varies ____

APPENDIX C

LABORATORY SOFTWARE

LABORATORY METABOLIC CALCULATION SHEET

Subject______________________Date________Age______Surface Area______________Sq.M.

Temp.___________degrees C. Barometric Pressure________mm Hg. Corr. Factor_______

SITTING (Non basal)

1. Oxygen %______ CO_2%______ True O_2______ R.Q.______ (from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_}{10}$ Kym mm. = _________ x 1.332 = _________ l/Min
3. Corr. Vent. = Vent. x Corr. Factor = _________x_________ = _________ L/Min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\_\_\_\_\text{x}\_\_\_\_}{100}$ = _________ L/Min
5. S.M.R. = $\frac{\_\_\_\text{x5 x60}\_\_\_}{\text{sq. M. S.A.}}$ = ______________ Cal/Hr. Sq. M.

EXERCISE:

SPEED_____________ HEIGHT_____________ TIME_____________

1. Oxygen %_______ CO_2%_______ True O_2_______ RQ_______ (from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_}{10}$ KYM mm. = _________ x 1.332 = _________ L/Min
3. Corr. Vent. = Vent. x Corr. Factor = _________ x +_________ = _________ L/Min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\_\_\_\_\text{x}\_\_\_\_}{100}$ = _________ L/min
5. EMR = $\frac{\_\_\_\text{x5 x60}\_\_\_}{\text{Sq. M. SA}}$ = _____________ Cal. hr/ Sq. M.

EXERCISE:

SPEED_____________ HEIGHT_____________ TIME_____________

1. Oxygen %_________ CO_2%_________ True O_2_________ RQ_________(from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_}{10}$ kym mm. = _________ x 1.332 = _________ L/min
3. Corr. Vent. = Vent. x Corr. Factor = _________ x _________ = _________ L/min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\_\_\_\_\text{x}\_\_\_\_}{100}$ = _________ L/min.
5. EMR = $\frac{\_\_\_\text{x5 x60}\_\_\_}{\text{Sq. M. SA}}$ = _____________ Cal/ hr. / Sq. M.

EXERCISE:

SPEED_____________ HEIGHT_____________ TIME_____________

1. Oxygen % _________ CO_2%_________ True O_2_________ RQ_________(from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_}{10}$ kym mm = _________ x 1.332 = _________ L/min.
3. Corr. Vent. = Vent. x Corr. Factor = _________ x _________ = _________ L/min.
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\_\_\_\_\text{x}\_\_\_\_}{100}$ = __________ L/min.
5. EMR = $\frac{\_\_\_\text{x5 x60}\_\_\_}{\text{Sq. M. SA}}$ = _____________ Cal/ hr./ Sq. M.

Treadmill Results

NAME ______________________ AGE ________ SEX ________ DATE ____________

Resting: Heart Rate Blood Pressure Cat. ____________

Supine ____________ ______/______

Standing ____________ ______/______

3.4 mph

Grade	METS / 02		Heart Rate	BP	EKG Comments
0	3.4	11.2			
2	4.2	14.5			
3	4.7	16.5			
4	5.1	18.0			
5	5.7	20.0			
6	6.1	21.5			
7	6.6	23.0			
8	7.1	24.5			
9	7.5	26.5			
10	8.0	28.0			
11	8.5	29.5			
12	9.0	31.5			
13	9.4	33.9			
14	9.9	34.5			
15	10.3	36.0			
16	10.8	37.5			
17	11.2	39.0			
18	11.7	41.0			
19	12.2	43.0			
20	12.7	44.5			21-32 cont. on back

Recovery: HR BP

3 min. ____________ ________/________

5 min. ____________ ________/________

8 min. ____________ ________/________

Reasons for Stopping: Anxiety ☐ Dyspnea ☐ Nausea ☐ Dizziness ☐ Chest Pain ☐
Leg Weakness ☐ Claudication ☐ Gen. Fatigue ☐
Hypotension ☐ EKG Changes ☐ Hypertension ☐
Other ______________________________

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Underwater Weighing Record

Name: ____________________

Date: ____________________ Ht.: __________ Age: __________

Nude Weight: __________lbs. __________oz. oz.=tenths of lb.__________

A. Scale reading with seat and harness

Subject's weight readings in water:

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

B. Highest reading obtained at least two times __________

C. Underwater Weight (UW) - difference between A and B __________

D. Net weight in water = UW + 2.86 (2.2 for females) __________

E. Specific Gravity (SG) = $\frac{\text{Wt. in air}}{\text{Wt. in air-net wt. in water}}$ __________

F. Percent of Body Fat = 100 (4.201/SG---3.813) __________

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Name____ Age________ Sex________

Date____

Anthropometric:

Ht. ______in. ______cm. Wt. ______lbs. ______kg. B.S.A. ____________sq. m.

Skinfold Measures:

Tri	________	Chest	________	Σ 3 % Fat	________________
Bi	________	Abd	________	Σ 4 % Fat	________________
Ill	________	Thigh	________	Nomogram %	________________
Back	________			% Fat Used	________________
Σ 4 Total	________	Σ 3 Total (Men)	________	% Fat Residual ±	________________
				Pounds Fat Residual ±	________________
				Suggested Ideal Weight	________________

Motor Area:

Grip Strength: Rt. 1. __________ Lt. 1. __________ Strong______________

2. __________ 2. __________ Weak______________

Flexibility: ________________

Pulmonary Function:

	Predicted Value	Measured Value	% of Pred.	
VC	__________		________	VC
FVC	__________		________	FVC
MVV	__________		________	MVV
FEF 25%-75%	__________		________	FEF 25%-75%
FEF 75%-85%	__________		________	FEF 75%-85%

ANALYSIS OF BODY BUILD

Name______________________Wt.______lbs.______kg. Ht.______in.______dm.

(1) Body Segment	(2) Circumference L.	R	Av.	(3) Male K Value	(4) Female K Value	(5) d Value	(6) Equiv Wt(kg) d^2 X H
1 Shoulder				55.4	52.0		
2 Chest				45.9	44.5		
3 Abdomen				40.6	38.7		
4 Buttocks				46.7	50.8		
5 Thighs				27.4	30.1		
6 Biceps				15.4	14.4		
7 Forearm				13.4	13.0		
8 Wrist				8.2	8.2		
9 Knee				18.3	18.8		
10 Calf				17.9	18.4		
11 Ankle				10.8	11.1		
Σ							
M							

Predicted Ideal Wt. as Mean of Equiv. Wts. (col. 6) ________________

Predicted Ideal Wt. as $\frac{C}{K}$ = $\frac{\text{Sum (col. 2)}}{300}$ ________________

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VITA

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Candidate for the Degree of

Doctor of Education

Thesis: THE EFFECTS OF PHYSICAL CONDITIONING PROGRAM ON SELECTED PHYSIOLOGICAL VARIABLES OF COLLEGE AGE WOMEN GYMNASTS

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