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A COMPARISON OF RACQUETBALL AND JOGGING TRAINING PROGRAMS AND THEIR EFFECTS ON CARDIORESPIRATORY FITNESS

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A COMPARISON OF RACQUETBALL AND JOGGING TRAINING PROGRAMS AND THEIR EFFECTS ON CARDIORESPIRATORY FITNESS

by

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STATEMENT BY AUTHOR

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Signed Sherry Annette Stokke

APPROVAL BY THESIS DIRECTOR

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ABSTRACT

Alterations in various cardiorespiratory fitness parameters subsequent to 10-wk training programs of jogging (J) and racquetball (RB) were investigated. Twenty-four college females completed the study. Members of the J group (n=8) and the RB group (n=8) exercised 3 d/wk, for 40 min/d, at 65-85% capacity based on Karvonen's THR formula. Cardiorespiratory measures were determined before and after training by a run to exhaustion on a motor-driven treadmill. An ANOVA revealed significant pre- to post-test improvements in absolute $\dot{V}O_2$ max (7.4%) and $\dot{V}_E$ (8.7%) for the J group. The RB group showed significant increases in $\dot{V}_E$ (6.8%). Between-group differences were noted for absolute $\dot{V}O_2$ max and $\dot{V}_E$ as both J and RB groups were significantly different from sedentary controls (n=8) following training. It was concluded that racquetball is an activity which, under the conditions of this study, was unable to maintain the necessary intensity to produce cardiorespiratory improvements but could possibly be effective in maintaining fitness once optimal levels had been achieved.

CHAPTER I

INTRODUCTION

With the current emphasis on improving health and fitness, increasing numbers of people are becoming concerned with the quality of their lives. The fact that Americans spend over $30 billion a year on such things as fitness club memberships, sports clothes and equipment, exercise books, and numerous fitness-related gadgets (67) seems to indicate that many individuals are looking toward exercise as a means of improving their physical and mental health status. Aerobic exercise programs have been shown to improve fitness by producing positive physiological changes in cardiorespiratory function and body composition (1,18,36,52,56,59,74). Although no cause-effect relationship has been shown, lack of exercise is often implicated in such major health problems as coronary heart disease (CHD) and obesity (11,30,43,49,53). Researchers have also documented the positive value of exercise as a method of stress relief (5).

In prescribing an exercise program, frequency (33,38,59,63), intensity (10,26,58,70), duration (29,46,61,69), and mode (6,8,13,51,60,82) must all be considered. Because adherence is often a problem (1,61), mode of exercise seems to be a very critical factor. The traditional method of improving cardiovascular fitness has been the walk/jog program (9,29,46,56,63,65,71,77,83). Drawbacks of this type of program include initial disinterest, lack of motivation, boredom, and orthopedic complications, with resulting high dropout rates (1,61). Therefore it is important to determine alternative modes of exercise which will both produce physiological benefits and have strong appeal to the participant.

Racquetball is one possible alternative. Because it is an activity which is easy to learn without excessive training, it has rapidly become a very popular recreational activity. Studies indicate that heart rate responses, and therefore possible physiological benefits, are similar to those produced while jogging (27,47,66). Thus, the potential contribution of racquetball to cardiorespiratory fitness needs to be evaluated.

The purpose of this study was to compare racquetball and jogging as training modes, evaluating resultant changes in cardiorespiratory fitness following a 10-wk training program.

CHAPTER 2

REVIEW OF THE LITERATURE

Cardiorespiratory fitness, defined as the maximal ability of the heart, blood vessels, and lungs to supply oxygen to body tissues, is commonly considered to be the most important health-related component of fitness. Aerobic activities are those activities which require large relative amounts of oxygen as the primary source of energy and are considered to be the best form of activity for improving cardiorespiratory fitness.

This section will be concerned with the effects of endurance training programs on various measures of cardiorespiratory fitness, with the maximal oxygen uptake ($\dot{V}O_2$ max) representing the best laboratory measure of cardiorespiratory fitness. First, the definition and quantification of an endurance training program will be established. Second, various modes of training will be reviewed focusing on racquetball. Finally, the expected adaptations to endurance training will be discussed. This section will conclude with expected responses of women to exercise.

Quantification of an Endurance Training Program

An endurance training program, as defined by Pollock (56), is constituted by a mode of exercise involving large muscle masses and is performed continuously for sufficient duration, frequency, and intensity to stimulate the development of the cardiorespiratory system. Thus, duration, intensity, frequency, and mode of exercise are the primary components of an exercise prescription.

Duration

With duration of exercise defined as the length of time spent in each exercise session, researchers have analyzed benefits consequent to training sessions of from 5 min to more than 60 min in length (17,50,65,71). A positive relationship between duration of exercise and improvements in cardiorespiratory fitness has been a consistent finding.

Shephard (71) looked at cardiorespiratory responses to an exercise program of treadmill running at various frequencies, intensities, and durations. Although durations of 5, 10, and 20 min/d were considered to have only a marginal effect on training results, it was concluded that cardiorespiratory fitness is better increased by at least 20 min of vigorous exercise.

Milesis et al. (46) looked specifically at the effects of different durations of training on cardiorespiratory fitness. The conditioning program consisted of running/walking for either 15, 30, or 45 min/d for 3 d/wk. It was found that subjects training 15 min/d made significant improvements over a sedentary control group in measures of treadmill performance time, $\dot{V}O_2$ max, and maximal oxygen pulse (max O_2 pulse), with the 30-min group making even greater improvements. Although researchers did not recommend 45 min sessions for beginners due to a greater percentage of injuries, it was concluded that a relationship does exist between the duration of each exercise session and the amount of improvement in cardiorespiratory fitness or aerobic capacity.

Wilmore et al. (83) reported results similar to those of Milesis, with subjects in this study trained for either 12 or 24 min per exercise session. Increasingly significant improvements were found in $\dot{V}O_2$ max, O_2 pulse, and vital capacity with increasing duration of exercise, all other factors being equal.

Many other studies have investigated duration of the training session and have been recently summarized in a position paper by the American College of Sports Medicine (1). It can generally be concluded that the longer the training session the greater the improvement in cardiorespiratory fitness or aerobic capacity.

In addition to duration of the training sessions, duration of the training program itself is an important consideration for the researcher. In designing a program, one must have an understanding of the amount of time required to elicit a training response in the cardiorespiratory system. Pollock (56) suggested that sedentary individuals often require several weeks to adapt to the initial stress of training and that significant changes are not typically identified unless the training program is of 10 or more weeks in duration. Thus, the length of a training experiment can be a critical factor in evaluating the magnitude of change in the various fitness components being studied.

In the aforementioned study by Wilmore et al. (83) in which subjects trained for 10 wks, researchers postulated that even greater differences would have been shown with additional weeks of training. Fox et al. (29) compared 7- and 13-wk training programs of varying frequency. Significant increases in $\dot{V}O_2$ max and decreases in maximum heart rate (HR max) were found for all groups with a trend for greater gains after 13 wks.

Many researchers (10,20,40,65,69) suggest that the total amount of work accomplished is the important criterion; i.e., it is the combination of duration and intensity that will determine changes in cardiovascular fitness. Sharkey (69) looked at the ability of different combinations of intensity and duration to elicit a training response. Subjects worked at various heart rate intensities on a bicycle ergometer until a given amount of work was completed.

For the groups training at lower intensities, a longer duration of work was necessary to perform the same total amount of work. Analysis of the data did not reveal any significant interaction between treatments indicating that duration is not so imporant in itself, but must be considered in combination with the intensity of exercise.

<u>Intensity</u>

Heart rate is the typical measure used to define intensity of exercise. Two common methods of calculating the training heart rate are found in the literature. The first uses a fixed percentage of HR max or the heart rate equivalent to a fixed percentage of $\dot{V}O_2$ max as the criterion for defining intensity. The second method is based on work by Karvonen, Kentala, and Mustala (39) and considers a chosen percentage of the difference between an individual's maximal and resting heart rate (HR reserve). Training heart rate is then determined by adding this percentage of the HR reserve to the resting heart rate value. The second method was validated by Davis and Convertino (21) and found to provide an accurate prediction of exercise intensity.

Since Karvonen's classic study in 1957, the issue of intensity of the exercise session has received much attention. The major question has been whether or not there exists a "threshold level" below which no training occurs. Karvonen suggested there is. In his study, subjects trained 30 min/d for 5 wks on a motor-driven treadmill at heart rates of 135 beats per minute (bpm) and 153 bpm. Finding significant increases in measures of $\dot{V}O_2$ max for the latter group, and no significant increases for the former, he concluded that intensity of at least 60% HR reserve was necessary to reach a significant training threshold.

Gledhill and Eynon (35) compared the effects of training on a cycle ergometer at three different heart rates. Finding no significant improvements in aerobic capacity in the group training at 120 bpm, they concluded that the intensity of training had to be strenuous enough to elicit heart rates of at least 135 bpm. However, when subjects were divided into low and high initial fitness levels, the low fit group training at 120 bpm showed significant increases in $\dot{V}O_2$ max while the high fit group did not. This would indicate that low fit individuals may have a lower threshold for obtaining significant improvements in aerobic capacity.

Sharkey and Holleman (70) and Crews and Roberts (14) also found no significant training effects for young men who trained on a motor-driven treadmill at 120 bpm for 6 to 7 wks although subjects were not differentiated by fitness level. Both of these studies propose that heart rates of 150 bpm are necessary to elicit improvements in measures of cardiorespiratory fitness. Faria (26) had subjects train by bench-stepping until they attained a desired heart rate. He estimated a threshold level of less than 140 bpm for the men in his study.

Pollock et al. (58) also supported the threshold concept. Information obtained in a pilot study indicated that most men had a difficult time jogging slowly enough to keep heart rates at 60 or 75% of their HR max. Subjects training at 80 and 90% of their HR max both showed significant improvements in cardiovascular function with no apparent differences between the two groups.

In an earlier study, Shephard (71) looked at the effects of training sedentary men on a treadmill at intensities of 39, 75, and 96% of $\dot{V}O_2$ max. Groups trained either 1, 3, or 5 d/wk for 5, 10, or 20 min/session. It was concluded that frequency and duration both affect the training response, but the main factor influencing the extent of training achieved was the intensity of effort relative to aerobic power. The fact that all groups showed some improvement in $\dot{V}O_2$ max provides no evidence of a training threshold. However, the author pointed out that a more vigorous level of activity would probably be required to elicit changes in initially higher-fit individuals.

Shephard's study was criticized by Davies and Knibbs (20) because of a lack of subject habituation and the use of predicted rather than actual measures of $\dot{V}O_2$ max. These investigators designed a similar study in an attempt to avoid these weaknesses. Their subjects trained on a cycle ergometer at intensities of 30, 50, and 80% of $\dot{V}O_2$ max for a period of 8 wks. Contrary to Shephard's findings, subjects training at or below 50% of their $\dot{V}O_2$ max showed no improvement in performance suggesting that a threshold of intensity possibly does exist.

Kearney et al. (40) looked at responses of women to training. In this study, subjects trained 3 d/wk for 9 wks at 50 or 65% HR reserve. Both groups showed significant improvements in $\dot{V}O_2$ max and O_2 pulse at $\dot{V}O_2$ max. For each of these variables, the absolute gains in the 65% group were greater than those made by the 50% group, but these differences were not statistically significant.

Edwards (23) also looked at the effects of intensity in training sedentary college women. Subjects trained on a treadmill 15 min/d for 4 wks with heart rates maintained at 125 or 145 bpm. These values would correspond to 47 and 63% of Karvonen's HR reserve. It was concluded that even the lower levels of training intensity elicited a training response as indicated by increases in $\dot{V}O_2$ max. Although this study conflicts with previous research (14,39,69), it supports the contention that low fit individuals require a lesser training stimulus to achieve improvements.

Additional research in the area of intensity has been summarized in a recent position paper by the American College of Sports Medicine (1). In general, improvements in $\dot{V}O_2$ max are directly related to the intensity of exercise with the minimal threshold level for improvement being approximately 60% of the maximum heart rate reserve (or 50% of $\dot{V}O_2$ max). Findings also indicate that a lower threshold is required to stimulate a training effect in low fit individuals.

Frequency

Frequency can be evaluated by either of two methods. In the first, frequency is determined by number of training sessions per week for a limited number of weeks. In the second, the definition is based on the total number of training sessions.

Pollock, Cureton, and Greninger (59) compared two groups that trained for 20 wks. One group trained 2 d/wk and the other 4 d/wk. Both groups showed improvements in $\dot{V}O_2$ max, maximum ventilation ($\dot{V}_E$ max), max O_2 pulse, and heart rate response to submaximal work. However, the group training 4 d/wk showed significantly greater improvements in most variables.

In another 20-wk training program, Gettmen et al. (33) looked at cardiovascular responses of men to training 1, 3, and 5 d/wk. Improvements in treadmill performance time, $\dot{V}O_2$ max, max O_2 pulse, and $\dot{V}_E$ max were found to increase in direct proportion to the frequency of training.

Jackson, Sharkey, and Johntson (38) trained 20 college-age men on a motor-driven treadmill for 10 min/d, 1, 2, 3, or 5 d/wk. At the end of the 5-wk training session, three different tests were used to assess $\dot{V}O_2$ max. The 5-d group was found to be superior on the Balke treadmill test, while the 2- and 3-d groups showed greater improvements on the submaximal Astrand-Rhyming step test and the Buskirk treadmill test. Investigators concluded that training 2 to 3 d/wk may have been as beneficial as a 5-d/wk program. The position paper published by the American College of Sports Medicine (1) makes reference to this "plateau" phenomenon by stating that the amount of improvement in $\dot{V}O_2$ max tends to level off when frequency of training is increased above 3 d/wk.

Work by Crews and Roberts (14) also seems to support the plateau concept. In looking at the interaction of frequency and intensity of training, six groups trained for 7 wks at heart rates of either 120 or 150 bpm and at a frequency of 1, 3, or 5 d/wk. Results showed no significant interaction between the variables. Although both 3- and 5-d groups showed greater improvements than the 1-d group, there were no significant differences between the 3- and 5-d groups.

Fox et al. (29) compared 7- and 13-wk training programs of 2 d/wk to training programs of 4 d/wk. After training, investigators found significant increases in $\dot{V}O_2$ max and HR max of both frequency and duration. The only response significantly related to increased frequency was a decrease in heart rate response to submaximal work.

Pollock (56) would criticize these last few studies on the short duration of the training program. He suggested that length of the training experiment may be a critical factor in evaluating training regimens and pointed out that it can take several weeks before adaptation to training takes place, especially with sedentary subjects. Thus, there may be limitations in interpreting results from investigations conducted over such short time spans. In a subsequent study, Pollock et al. (63) reviewed a series of six training investigations conducted over a period of 7 yrs. Each study was 20 wks in length. Data was combined to look at effects of frequency on cardiovascular function. All frequencies had a significant effect on $\dot{V}O_2$ max and resting heart rate. However, changes in $\dot{V}O_2$ max were similar for the 2- and 3-d/wk groups and significantly greater for 4-d/wk groups. These results generally favor greater improvements with increased frequency of training.

When the total number of training sessions is considered, studies generally show no differences in performances with frequency of training. Two such studies were conducted by Shephard (71) and Davies and Knibbs (20), and both studies concluded that frequency is a less important stimulus than either intensity or duration.

Sidney, Eynon, and Cunningham (73) also compared frequency of training relative to total work performed. These authors compared training groups that met 1, 2, or 4 d/wk. Measures of $\dot{V}O_2$ max, physical work capacity (PWC_{170}), and exercise heart rate were taken at the end of a 4-wk training program and again after all groups had completed an equal number of training sessions on a cycle ergometer. Analysis of the data showed results that conflicted with earlier studies (20,71). After 4 wks, when the 4-d group had performed twice as much work as the 2-d group, results showed improvements proportional to frequency of training. When total work was held constant, the nonsignificant difference between the two groups was also proportional to frequency. The 1-d group showed only slight improvements in most measures and, in fact, exhibited decreases in measures of $\dot{V}O_2$ max. Authors concluded that frequency is the important factor, even when performance of work is held constant, and suggested that the optimal frequency for training is something greater than once a week.

Mode of Training

The final component of an endurance training program is the mode of exercise. The American College of Sports Medicine guidelines recommend that the activity chosen should use large muscle groups in a continuous manner and should be rhythmical and aerobic in nature (1). Many studies have demonstrated the cardiorespiratory benefits of walking and jogging programs (14,23,29,40, 62,63,65,70,77,83). Since this study deals with a comparison of two modes of training, this review section will look first at studies comparing two or more modes of training, and finally at studies involving racquetball as a method of training.

Comparative Mode Studies. Pollock et al. (60) compared the training effects of walking, running, and bicycling in middle-aged men. All groups trained 3 d/wk for 20 wks at 85 to 90% of HR max. Results showed significant improvements of equal magnitude in $\dot{V}O_2$ max and body composition measures across the three modes of exercise. The investigators concluded that improvement in the experimental groups was independent of the mode of training.

In a study of 22- to 55-year-old men, O'Brien (51) compared cross-country bicycling and jogging as modes of training. During the 20-wk program, subjects exercised 3 d/wk, 30 min/d, at an intensity of approximately 75% of HR reserve. Post-test results demonstrated significant increases in $\dot{V}O_2$ max which were similar for both groups. It was concluded that both modes were equally effective in improving cardiorespiratory fitness. Buccola and Stone (8) conducted a similar study with older men, aged 60 to 79. At the end of the 14-wk program, these authors also concluded that comparable training effects could be achieved through walk/jog and cycling programs.

Berryhill, Corbin, and Olree (6) investigated running, treadmill walking, and exercise on a cycle ergometer as modes of training. Twenty college-aged men trained 5 d/wk, 20 min/d, for 10 wks at heart rates of approximately 150 to 160 bpm. In general, the running and cycling groups showed similar improvements in cardiorespiratory measures, and these improvements were greater than those found in the walking group. These results would agree with those of previously reported studies, except for the walking group. It is possible that this discrepancy was due to differences in intensity, i.e., walking for college-aged men would be less strenuous than for middle-aged and older men.

Wilmore et al. (82) compared cardiorespiratory and body composition changes consequent to 20-wk conditioning programs in which each of three training groups exercised 3 d/wk for 30 min/d. Bicycling, tennis, and jogging were the modes of exercise. Results for the cycling and jogging groups were compared by O'Brien (51) as discussed earlier in this review. In contrast to the first two training groups, improvements in $\dot{V}O_2$ max shown by the tennis group were not statistically significant. In measures of $\dot{V}_E$ max, substantial increases were noted for all groups with improvements in the cycling and jogging groups being the greatest. The authors suggested that changes in $\dot{V}O_2$ max for the tennis group may have been underestimated due to the fact that the 30-min exercise session was only 30 to 50% of a typical time period for playing tennis. It was also noted that the tennis group trained at an intensity of 64.7% HR max, compared to 85.8 and 83.2% for the jogging and bicycling groups respectively.

Harper, Billings, and Mathews (37) studied the effects of two programs of physical conditioning on cardiovascular fitness. One training mode utilized an Army conditioning program of calisthenics and marching. The second used a running interval training program. A third group, which served as a control, participated in recreational activities. All groups met 5 d/wk for 7 wks. Only the running group showed significant improvements in $\dot{V}O_2$ max. However, the fact that intensity was not quantified makes it difficult to compare the different modes.

Roberts and Morgan (68) studied the effects of training mode and frequency of participation on measures of cardiorespiratory fitness. Subjects were assigned to eight different exercise groups representing four modes of training. There were three running groups. One group ran 2 d/wk, a second group 3 d/wk, both on an indoor track, and the third group ran on a treadmill 3 d/wk. Two cycling groups trained 3 d/wk, one riding cross-country, and the other on a cycle ergometer in the laboratory. Two swimming groups trained either 2 or 3 d/wk. One group participated in circuit weight training (CWT) 3 d/wk. All individuals exercised at a THR equal to approximately 85% of an age-predicted maximum heart rate. Duration of the activity ranged from approximately 30 min/session to only 15 min/session for the laboratory exercise sessions. After 6 wks, the three running groups and the 3-d/wk swimming group all showed significantly greater gains in estimated $\dot{V}O_2$ max than non-exercising controls. The cycle ergometer group showed the next greatest cardiorespiratory improvements and were followed by the CWT group, the cross-country cycling group, and finally by the 2-d/wk swimming group. Although improvements in these last four training groups were not as great as the other four, differences among the eight activity groups were not statistically significant.

More extensive reviews relative to exercise mode have been conducted by Pollock (56), and the American College of Sports Medicine (1). It is generally concluded that training results are independent of the mode of aerobic activity, as long as frequency, intensity, and duration are similar. Thus, a variety of activities may be used to elicit a training effect.

Racquetball. It has been suggested that racquetball can make significant contributions to cardiovascular fitness. However, few studies have been done to substantiate this claim. One group of researchers (18) combined a training program of 30 to 50 min of running with 30 min of handball or squash (activities which are similar to racquetball) to look at cardiovascular changes in middle-aged men. Although $\dot{V}O_2$ max was shown to increase in the experimental group, it is difficult to say whether this was a result of one or the combination of both of the activities.

Most researchers studying the benefits of racquetball (or squash) assume that high intensity equates with aerobic benefits and have simply looked at the heart rate responses during exercise in an effort to determine the intensity of play. Montgomery, Malcolm, and McDonnell (48) compared heart rate responses of 10 subjects, who were both recreational runners and squash players, during 45 min of each activity. Results showed that subjects maintained an averge intensity of 84% HR max while running and 80% HR max when playing squash against a partner of equal ability and fitness level. Authors concluded that the similar heart rate responses of the two activities would indicate similar aerobic benefits.

Blanksby, Elliot, and Bloomfield (7) used radiotelemetry to study heart rate responses to squash during a normal game. Twenty-five men in each of three groups (middle-aged sedentary, middle-aged active, and younger "A" grade squash players) were monitored for 25 min of play. Analysis of the results showed that heart rate responses of the middle-aged sedentary group were significantly higher than the other two groups. Intensity of play averaged 97, 85, and 83% of age-predicted HR max for sedentary, active, and "A" grade players respectively.

Porr and Burkett (66) also used radiotelementary in looking at heart rate responses of 24 intermediate to advanced racquetball players. Subjects were 21 men and 21 women, ages 17 to 56 years. Results indicated that heart rates of 75 to 80% of maximum were reached after 3 min of play and were maintained for the entire 21 min of play.

Montgomery (47) monitored heart rate responses of nine male racquetball players as they played against opponents of varying ability. Results showed average intensities of 87, 70, and 90% HR reserve when the monitored player was equal, higher, and lower in ability compared to his opponent. The author indicated that this may be an overestimation of actual intensity of exercise as the arm work involved tends to elevate heart rate more than just leg work alone. It was also noted that an average of 83% of the rallies were less than 10 sec in length, and the ball was in play only 44% of the total game time regardless of opponent abilities. However, total match time for players of equal ability was 50 min compared to only 34 min when partners were unmatched. It was concluded that persons seeking to use racquetball to develop and maintain cardiovascular fitness should select a partner of similar skill and fitness level.

Studying the metabolic response to playing racquetball, Faria and Lewis (27) found results similar to those of Montgomery. They concluded that racquetball should be classified as a high-intensity, short-term, intermittent game.

The Exercise Prescription

Recognizing the importance of duration, intensity, frequency, and mode, the practitioner will use a combination of these four components as a starting point in developing an exercise prescription. In addition to a general knowledge about the contributions and importance of each of these variables, it is important to have some knowledge about the individual for whom the exercise is prescribed. Consideration of individual likes and dislikes, initial fitness level, level of fitness to be attained, and facilities available make it possible to personalize the exercise program and, hopefully, to develop an optimal training stimulus for each individual trainee.

Expected Physiological Adaptations to Training

General Adaptations

Maximal oxygen uptake ($\dot{V}O_2$ max) is widely accepted as the primary determinant of cardiorespiratory endurance capacity (1,25,56,72,79). Investigations have shown improvements in $\dot{V}O_2$ max subsequent to various cardiorespiratory endurance training programs, ranging from 7% to more than 30% (9,13,36,40,51,58,62,82,83). Data on ventilation at maximum workload have shown that maximum ventilation ($\dot{V}_E$ max) will generally improve 10 to 20% as a result of various endurance training programs lasting for 9 wks or more (34,40,58,62,82). Other studies have shown no significant changes in $\dot{V}_E$ max with training, even with substantial increases in $\dot{V}O_2$ max (6,83). A reduction in heart rate at maximum workload (HR max) has been evident in studies where the initial levels are above 180 bpm (25,28,59,73,83). When initial values are lower than 180 bpm, HR max values often remain unchanged or increase slightly (9,40,62). Additional cardiorespiratory alterations have also been associated with endurance training programs. These include decreased resting heart rate (HR rest) and blood pressure; decreased heart rate and $\dot{V}O_2$ at submaximal work; increased O_2 pulse, increased blood volume, increased cardiac output and stroke volume at maximal workloads; and increased vital capacity (2,11,56).

Adaptations in Women

Much of the literature has focusd on cardiovascular adaptations of men to various training programs. This section will review studies involving female subjects in an effort to determine if there are differences between the sexes in their response to endurance training.

Burke (9) compared the physiological effects of endurance training in men and women. Running programs for the two groups were similar, i.e., each group ran 3 d/wk for 8 wks at an intensity between 75 and 85% of HR max, with each group running the same total distance. Results showed a significant increase in $\dot{V}O_2$ max and $\dot{V}_E$ max for both exercise groups, with males increasing 17% and females 24%. The difference between the sexes was significant. Burke noted that the greater increases for females may have been a reflection of their lower starting levels. It was concluded that the average female can expect relative improvement in aerobic power similar to that of a male following a period of systematic training.

Sparling (78) conducted a statistical analysis to try to integrate the findings of a large number of studies comparing training effects of men and women. In quantifying the differences in $\dot{V}O_2$ max, he concluded that there is a difference between men and women in values of $\dot{V}O_2$ max obtained, but pointed out the need to consider activity and conditioning levels as well as general biological differences when making comparisons between the sexes.

The importance of considering conditioning levels also became apparent in a review by Wilmore (80) who compared men and women in measures of strength, endurance, and body composition. In measures of endurance, the average untrained college-aged female generally had a $\dot{V}O_2$ max between 30 and 44 $ml \cdot kg^{-1} \cdot min^{-1}$, while the average untrained college-aged male had values between 45 and 53 $ml \cdot kg^{-1} \cdot min^{-1}$ on the same measurement. However, when looking at the female's potential endurance capacity, the differences were much smaller. Highly-trained female endurance athletes exhibited average $\dot{V}O_2$ max values of 55 $ml \cdot kg^{-1} \cdot min^{-1}$, with values as high as 71.1 $ml \cdot kg^{-1} \cdot min^{-1}$. While this is still lower than the $\dot{V}O_2$ max of the highly trained male, it indicates an endurance capacity that is 25% greater than sedentary males of the same age.

Kilbom (41) looked at the effects of a short term training program, 7 wks in length. Forty-one Swedish females were divided into two training groups. For one group, training consisted of 3 min of work alternated with 2 min of rest on a cycle ergometer, for a total of 30 min, at an intensity of 70% $\dot{V}O_2$ max. The second group trained at 50% of $\dot{V}O_2$ max either on a cycle ergometer or by walking at a predetermined speed. When the women were divided into three age groups, 19 to 31, 34 to 48, and 51 to 64 yrs of age, results showed that changes were inversely related to age, were greater for women with lower initial aerobic capacity prior to training, and were greater at the 70% training level. Kilbom concluded that females are able to profit from physical training in a manner similar to the average male.

Kearney et al. (40) found significant increases in $\dot{V}O_2$ max, $\dot{V}_E$ max, and max O_2 pulse for 27 sedentary college women who exercised on a motor-driven treadmill at either 50 or 65% HR reserve. Although gains in the 65%

group were greater than gains in the 50% group, the differences were not significant.

Flint, Drinkwater, and Horvath (28) studied women's reponses to exercise following a 6-wk program of walking on a treadmill 3 d/wk at 75 to 80% of HR max. For three women tested before and after training, a 12% increase in $\dot{V}O_2$ max (predicted from the Åstrand-Rhyming nomogram and corrected for overestimation) was reported. Investigators noted that this falls within the range of values reported for men and concluded that physiological responses to submaximal work following training are similar for both sexes.

Smith and Stransky (77) compared the effects of two different intensities of exercise on women's responses to submaximal work. Using steady state heart rate responses to workloads of 450 and 600 kpm, it was found that groups training at 80 to 85% HR max exhibited significantly greater decreases in steady state heart rate than a group training at 70 to 75% HR max.

In these studies and others (22,56), the physiological differences between men and women have been recognized. Although women will generally show lower initial levels of cardiorespiratory function than men, evidence seems to indicate that adaptations to endurance training programs will be similar for both sexes. Therefore, the general findings relative to quantifications of and responses to endurance training programs as described in this review are considered applicable to women.

CHAPTER 3

METHODOLOGY

This chapter will detail, in the following sections, the procedures used in this study for recruitment, training, and testing of the subjects.

Subjects

Subjects for this study were female volunteers from the University of Arizona. In order to enhance the possibility of finding cardiorespiratory improvements after training, it was necessary that the subjects selected were not regular participants in any aerobic activity. Participation in normal college recreational activities including physical activity classes and/or intramurals did not preclude participation in the study. An initial $\dot{V}O_2$ max level greater than 45 $ml \cdot kg^{-1} \cdot min^{-1}$ excluded the subject from participation. The protocol and procedures for this study had been previously approved by the Human Subjects Committee at the University of Arizona before any recruitment or testing of subjects occurred.

Sixty prospective subjects, ages 17 to 35 yrs, responded to a questionnaire (Appendix A) regarding their physical activity levels. Sixteen additional women were approached about the possibility of participating in the study. Of these potential subjects, 63 were qualified for the study and were asked to take part in the project. Sixteen women elected not to participate because of time constraints. Five more were scheduled but failed to appear for initial testing.

Forty-two women were given an initial series of treadmill tests to determine their cardiovascular endurance capacity. Before testing, the nature and purpose of the study and the risks involved were explained verbally and given to each subject in written form (Appendix B), and informed consent was obtained. Subjects also completed the Pre-Exercise Personal Inventory (Appendix C) to determine if their participation was contraindicated due to health problems. Two women did not complete the initial series of tests and were therefore not assigned to any group. The remaining subjects were assigned to one of three groups: racquetball (RB), jogging (J), or control (C). Assignment was not randomized as it was necessary for the RB group to have a basic knowledge of and ability to play the game. These subjects had either completed a first-semester beginning racquetball class at the University of Arizona or had equivalent experience.

Thirteen subjects who completed inital testing were assigned to the RB group. One failed to complete the study due to injury (non-racquetball origin), three discontinued their participation because of time conflicts with school and jobs, and one dropped out because of lack of interest. Of the 16 subjects originally assigned to the J group, two dropped out due to injury, two because of school conflicts, one lost interest, and two were unavailable for final testing. One additional subject was eliminated upon completion of the study to provide equal numbers of subjects per group for statistical purposes. This was done by a random drawing. Eleven subjects were assigned to group C, and three of these subjects were unavailable for final testing.

The physical characteristics of those subjects who completed the study are presented in Table 1.

Table 1. Subject Descriptive Data

	Jogging (n=8)		Racquetball (n=8)		Control (n=8)	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Age, yrs	25.2	5.4	21.5	2.8	19.5	1.8
Wt, kg	53.8	8.1	59.9	9.1	55.1	9.3

Testing Procedures

Each of the 24 subjects who participated in the study through its entirety were tested for cardiorespiratory fitness both prior to and after completion of the 10-wk training program. All testing was conducted in the Exercise and Sport Sciences Laboratory at the University of Arizona.

For each test session, the subject was weighed in running clothes but without shoes on a Homs beam scale. A single lead (CM 5) electrocardiogram (ECG) was used to monitor heart rate (HR). ECG's were recorded on a Hewlett-Packard ECG monitoring system before the test and for the last 10 sec of each minute during the test. The maximum heart rate (HR max) was also recorded when the subject reached peak exertion.

Cardiorespiratory fitness was assessed by a continuous walk/run to exhaustion on a Quinton motor-driven treadmill. Metabolic and respiratory function were monitored continuously with data printed every 30 sec during exercise by the Beckman Metabolic Measurement Cart (81). The resulting data were used for determination of maximal oxygen consumption ($\dot{V}O_2$ max), maximal pulmonary ventilation ($\dot{V}_E$ max), and respiratory exchange ratio (R). The treadmill performance time (TT) at exhaustion was also recorded.

The test protocol consisted of walking at 3 mph, 0% grade, increasing to 4 mph and 6 mph at 3 and 5 minutes respectively. After the sixth minute, grade was increased by 2% at the beginning of each subsequent minute throughout the remainder of the test. Subjects were instructed to run to the point of volitional fatigue and were verbally encouraged throughout the test to continue working as long as possible.

The pre-training treadmill tests were administered to each subject on two separate occasions at least 48 h apart to determine test reliability and to negate any learning effect produced by the initial experience with a treadmill test. These initial tests had to demonstrate reproducibility of $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) to within $\pm$ 2 ml. If this criterion was not met, a third treadmill test was given, and the two closest values averaged for the initial pre-training values. Post-testing was conducted in exactly the same manner except that each subject was tested only once.

Training Program

Following the initial pre-test battery, subjects assigned to the RB and J groups began a 10-wk training program. Both groups performed 10 min of warm-up and 40 min of jogging or racquetball three times per week. Intensity was maintained in the 65 to 85% range with each individual training heart rate range (THR) determined by Karvonen's formula (39) of THR = HRrest + (%)(HRmax - HRrest). The peak HR obtained on the treadmill test was assumed to be the maximal value, and resting HR was taken from the quiet rest period with the subject seated. During training, subjects were instructed to use the palpation technique (45,58) to monitor their own exercise HR for 10 s after the 10th, 20th, 30th, and 40th min of each session. All exercise sessions were supervised by the investigator who directed warmup activities, assisted in heart rate monitoring, and recorded attendance, duration of exercise, and attainment of THR.

The J group trained on a combination of paved and grassy terrain. Subjects were free to choose their own course, with the distance covered determined by each individual's capabilities. This was done to simulate a self-motivated program in an effort to make the training as realistic as possible. The

RB group played on the University of Arizona's racquetball courts. Subjects were instructed to attempt to pair up according to similar ability levels. The investigator blew a whistle at 10 min intervals to indicate that HRs should be checked at the next point break.

Subjects in the C group were asked to continue their normal daily activities and were requested not to participate in any type of aerobic conditioning program.

Statistics

A Student t-test on dependent samples was used to analyze reliability of test-retest data obtained during pre-testing. Pearson product-moment correlations were also calculated. The 0.01 level was accepted as significant.

Resultant training data were analyzed by a 3 x 2 analysis of variance with repeated measures. Interaction effects were determined using a Tukey Post Hoc test. Significance was reported at the 0.05 level.

CHAPTER 4

RESULTS

Training Program Characteristics

The subjects' responses to the 10-wk program for both training groups are presented in Table 2. The mean target heart rate for both training groups was 159.8 bpm. Exercise intensity between 65 to 85% of Karvonen's HR reserve formula was maintained by the J group for 100% of their exercise sessions and for 87.7% of the sessions by the RB group.

Session duration for both groups was similar and adhered closely to the prescribed duration of 40 min/session. The J group averaged 39.4 min/session while the RB group averaged 40.4 min/session. Attendance was noticeably lower for the joggers. This group averaged 91.7% attendance, while the RB group averaged 97.5%.

Reliabiliy of Pre-test Measures

During the initial pre-training testing, it was required that measures of $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) demonstrate reproducability to within ± 2 ml. A third test was required of eight women when this criterion was not met. For these subjects, the tests with the two closest values were used as test one (T_1) and test two (T_2) measures for the initial pre-training values.

Table 2. Group Responses to the Training Program

Variable	Jogging (n=8) $\bar{X}$	Jogging (n=8) SD	Racquetball (n=8) $\bar{X}$	Racquetball (n=8) SD
THR[a] (bpm)	159.8	2.49	159.8	7.46
Time in THR range (%)	100.0	0.00	87.7	6.27
Min/Session	39.4	0.83	40.4	0.86
Attendance (%)	91.7	3.73	97.5	2.21

a. THR = 0.75(HRmax - HRrest) + HR rest

Reliability of this pre-test data was analyzed through the use of a Student t-test on the dependent variables. T_1 and T_2 values for $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$), $\dot{V}O_2$ ($l \cdot min^{-1}$), $\dot{V}_E$ max, R, HR, and TT were compared. Results showed that differences between T_1 and T_2 on all measures were not statistically significant at the 0.01 level of significance. Correlations and t-ratios are presented in Table 3.

Cardiorespiratory Alterations with Training

Graphic representations of pre- and post-test measures of cardiorespiratory responses to maximal exercise are presented in Figures 1 through 6. Mean and standard deviation values for all parameters are found in Table 4, and the analysis of variance results computed on the dependent variables are presented in Table 5.

Significant pre- to post-test changes in the J group were noted in measures of absolute $\dot{V}O_2$ max, which increased 169 $ml \cdot min^{-1}$ (7.4%), and for $\dot{V}_E$ max, which increased 8.1 $l \cdot min^{-1}$ (8.7%). Significant pre- to post-test changes in the RB group were found only in $\dot{V}_E$ max, which increased by 6.3 $l \cdot min^{-1}$ (6.8%). No changes were noted in absolute or relative $\dot{V}O_2$ max for the RB group. R, HR max, and TT remained essentially unchanged for all groups.

Between-group differences were analyzed using the Tukey Post Hoc test. A significant difference between the RB group and the C group in initial measures of absolute $\dot{V}O_2$ max was demonstrated. Post test results indicated that both training groups were significantly different than the control group in measures of absolute $\dot{V}O_2$ max and $\dot{V}_E$ max (although the difference in $\dot{V}O_2$ max between RB and C groups was not due to improvements by the RB group, but rather because of initial differences).

Table 3. Reliability of Test/Retest Measures for the Overall Group (n=24)

	T_1		T_2			
Variable	$\bar{X}$	SD	$\bar{X}$	SD	t-value*	$r_{T_1T_2}$
$\dot{V}O_2$ max $(ml \cdot kg^{-1} \cdot min^{-1})$	40.5	3.8	40.2	3.8	1.036	0.94
$\dot{V}O_2$ max $(l \cdot min^{-1})$	2.27	0.40	2.25	0.41	1.460	0.98
$\dot{V}_E$	90.8	11.3	91.9	12.4	-0.869	0.87
R	1.17	0.07	1.18	0.07	-1.804	0.78
HR max	189.2	5.9	188.2	6.4	1.450	0.86
TT	9.33	0.90	9.55	0.86	-2.389	0.87

*a t-value of 2.807 is needed for significance

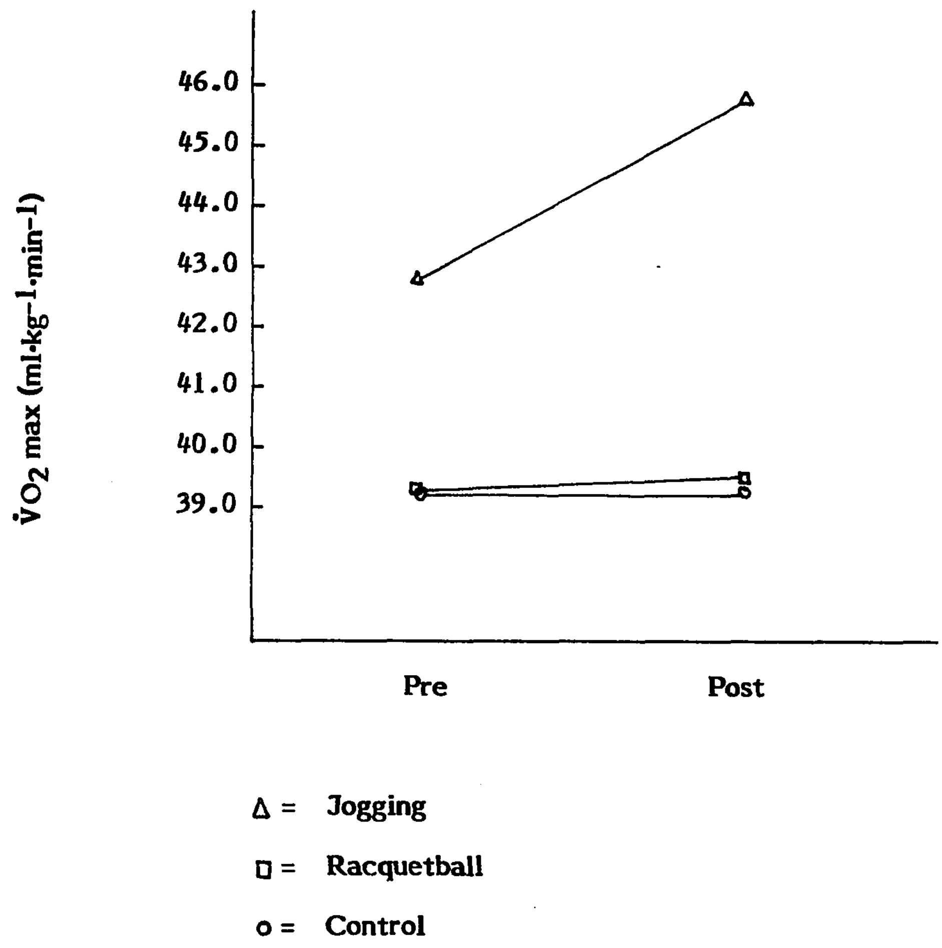

Figure 1. Pre- to post-test changes in $\dot{V}O_2$ max (ml·kg^{-1}·min^{-1}).

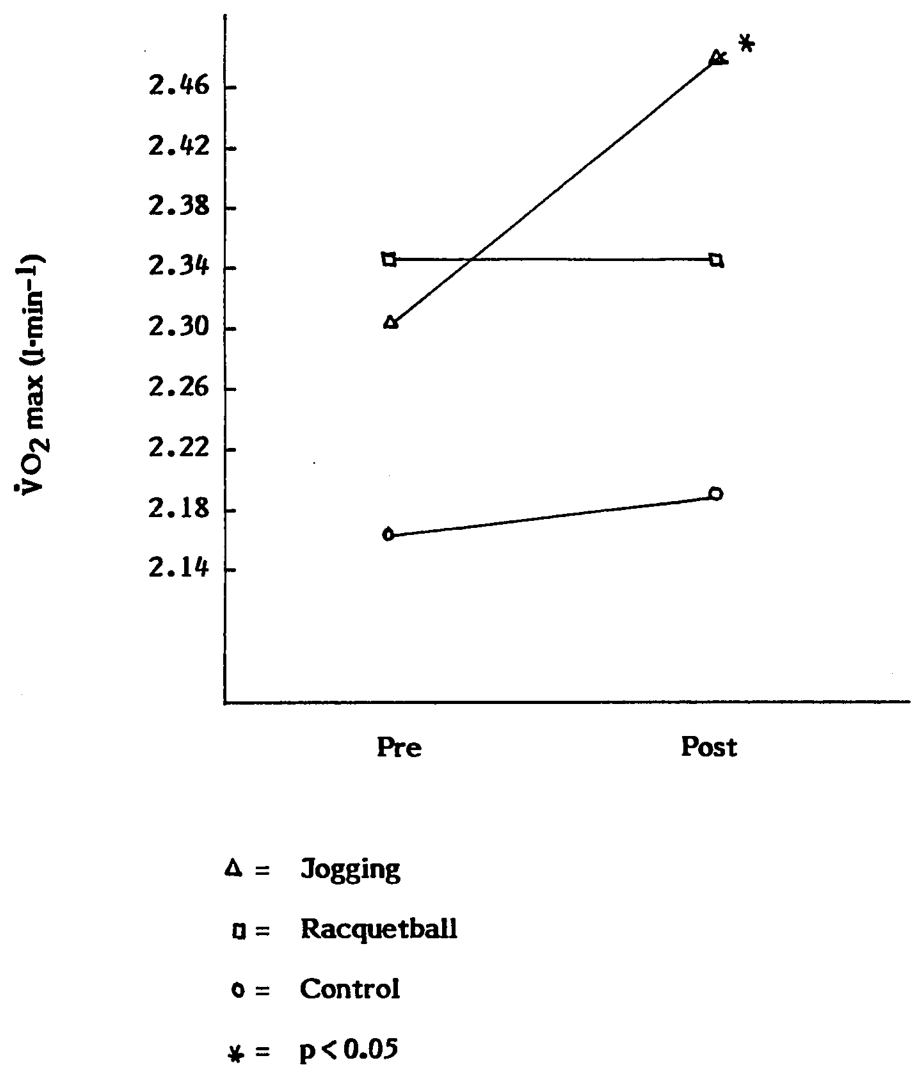

Figure 2. Pre- to post-test changes in $\dot{V}O_2$ max (l·min^{-1}).

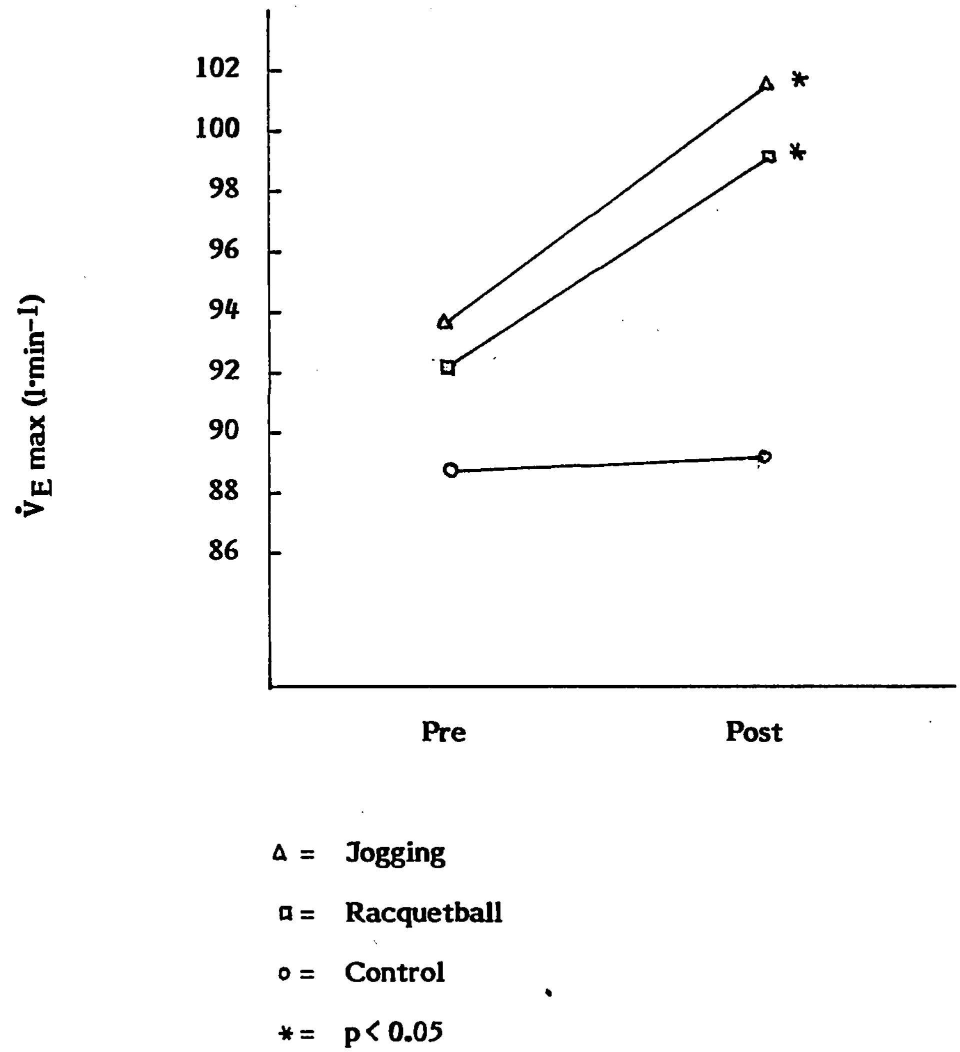

Figure 3. Pre- to post-test changes in maximal ventilation.

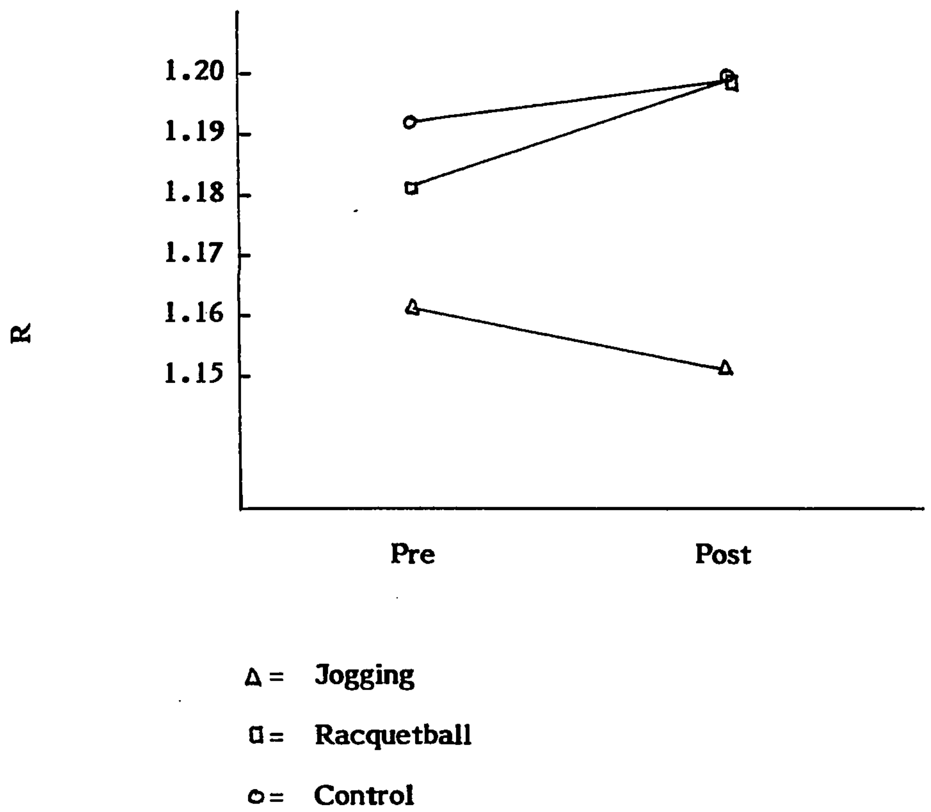

Figure 4. Pre- to post-test changes in respiratory exchange ratio at maximal exercise.

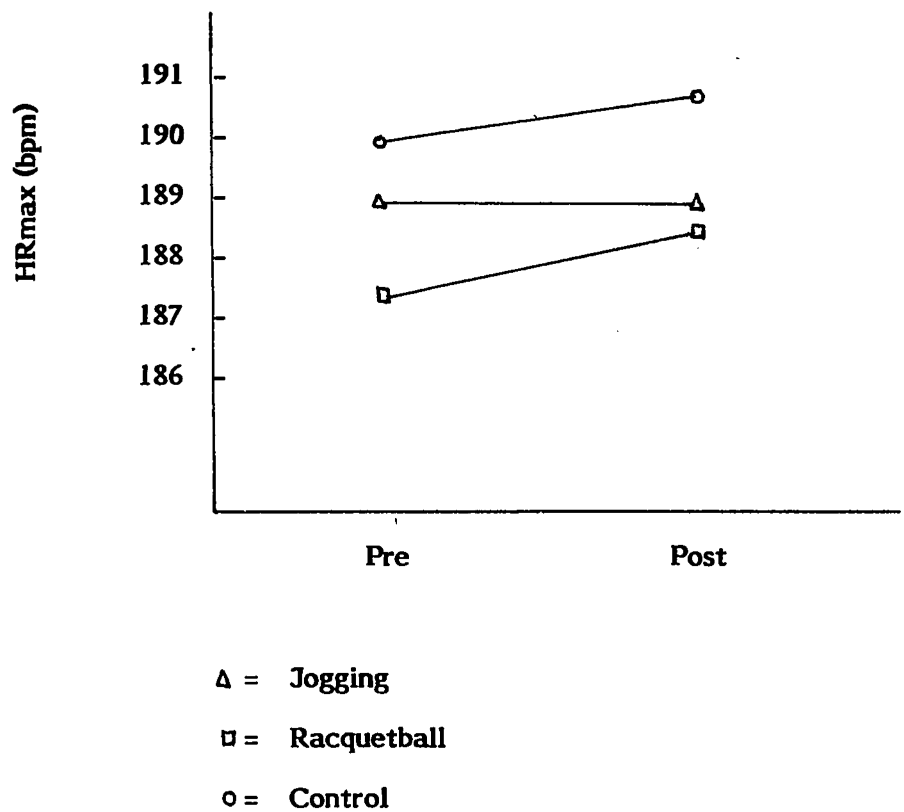

Figure 5. Pre- to post-test changes in HR max.

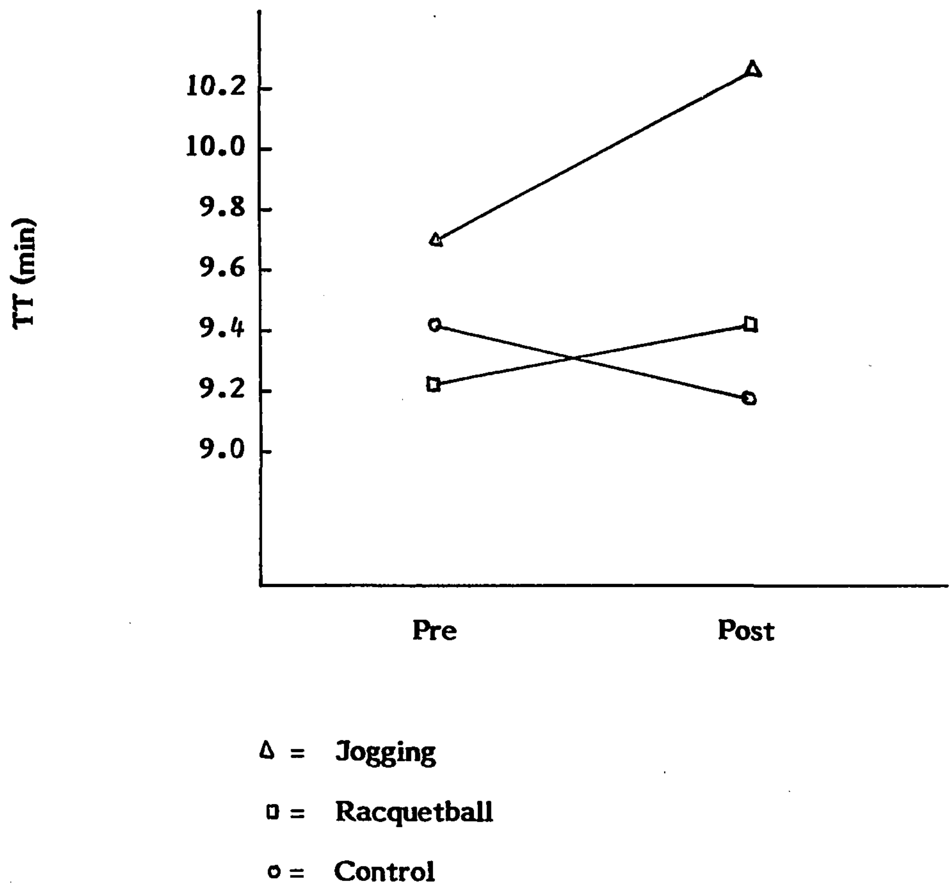

Figure 6. Pre- to post-test changes in treadmill performance time.

Table 4. Alterations in Cardiorespiratory Parameters Subsequent to Jogging and Racquetball

Variable	Jogging $\bar{X}$	Jogging SD	Racquetball $\bar{X}$	Racquetball SD	Control $\bar{X}$	Control SD
$\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$						
Initial	42.8	1.5	39.2	4.6	39.2	3.6
Final	45.7	2.6	39.3	4.0	39.2	6.0
Δ	2.9		0.1		0.0	
%Δ	6.9		0.1		0.0	
$\dot{V}O_2$ $l \cdot min^{-1}$						
Initial	2.30	0.37	2.34+	0.41	2.16	0.46
Final	2.47+	0.34	2.34+	0.35	2.18	0.52
Δ	0.17*		0.00		0.02	
%Δ	7.4		0.0		0.9	
$\dot{V}_E$ $l \cdot min^{-1}$						
Initial	93.4	11.9	92.0	9.5	88.3	13.4
Final	101.5+	13.9	98.3+	10.9	88.4	11.5
Δ	8.1*		6.3*		0.1	
%Δ	8.7		6.8		0.1	
R						
Initial	1.16	0.045	1.18	0.075	1.19	0.073
Final	1.15	0.029	1.20	0.059	1.20	0.073
Δ	-0.01		0.02		0.01	
%Δ	0.9		1.7		0.8	
HR bpm						
Initial	188.9	4.0	187.4	7.5	189.8	6.2
Final	188.9	5.0	188.1	7.8	190.2	9.0
Δ	0.0		0.7		0.4	
%Δ	0.0		0.4		0.2	
TT min						
Initial	9.7	0.6	9.2	1.1	9.4	0.7
Final	10.2	0.6	9.4	1.1	9.2	1.3
Δ	0.5		0.2		-0.2	
%Δ	5.2		2.2		-2.3	

* significant pre-to-post changes (p 0.05)
\+ significantly different from the control group

Table 5. Summary of ANOVA Statistics

	df	Mean Square	F
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), pre-to-post	1	12.02	3.32
between group	2	133.18	4.70*
$\dot{V}O_2$/group interaction	2	11.53	3.19
$\dot{V}O_2$ ($l \cdot min^{-1}$), pre-to-post	1	0.047	5.27*
between group	2	0.208	0.62
$\dot{V}O_2$/group interaction	2	0.034	3.82*
$\dot{V}_E$, pre-to-post	1	278.79	15.62*
between group	2	361.82	1.35
$\dot{V}_E$/group interaction	2	71.02	3.98*
R, pre-to-post	1	0.0005	0.17
between group	2	0.0085	1.80
R/group interaction	2	0.0006	0.80
HR, pre-to-post	1	1.88	0.41
between group	2	20.26	0.23
HR/group interaction	2	0.69	0.15
TT, pre-to-post	1	0.30	0.40
between group	2	2.50	2.70
TT/group interaction	2	0.50	0.60

* $p < 0.05$

The Tukey Post Hoc analysis revealed treatment/group interation in measures of relative $\dot{V}O_2$ max. In the J group, pre- to post-test measures of this parameter showed an increase of 3.0 $ml \cdot kg^{-1} \cdot min^{-1}$ (6.9%). This value approached but did not reach statistical significance. Although there were no significant differences between groups on the pre-test measures of relative $\dot{V}O_2$ max, the J group was obviously at a higher initial fitness level than the other two groups. This fact would elevate the pre-test mean and possibly mask a significant pre- to post-test increase for the J group in this parameter. This is also suggested by the significant post-test differences between the J group and both of the other two groups in measure of relative $\dot{V}O_2$ max.

CHAPTER 5

DISCUSSION

This chapter will focus first on the criteria commonly recognized as indicators of a valid maximal exercise test. Secondly, between-mode differences in the relative contributions of jogging and racquetball to improvement in cardiorespiratory fitness as a response to training will be discussed.

Indications of a Maximal Exercise Test

There are three common indices of achievement of maximal exertion, i.e., $\dot{V}O_2$ max in exercise testing. $\dot{V}O_2$, R, and HR all exhibit specific characteristic responses to maximum effort. Each of these will be discussed.

The first index of the attainment of $\dot{V}O_2$ max relates to the oxygen consumption response during graded exercise. At submaximal levels of exercise, an increase in workload generally shows a corresponding increase in $\dot{V}O_2$. However, when an increase in workload fails to elicit a significant increase in $\dot{V}O_2$, or results in a drop in $\dot{V}O_2$, the highest value obtained is considered $\dot{V}O_2$ max. Taylor, Buskirk, and Henschel (79) have quantified this response and suggest a change of less than 150 ml for two successive measures of $\dot{V}O_2$ with increasing workload as an indication of the achievement of aerobic capacity.

In tests conducted for this study, an increase in workload produced a resultant change in $\dot{V}O_2$ of less than 150 ml in 65% of the cases, while 28% of the tests actually showed a decrease in $\dot{V}O_2$. Five tests did not meet either of these criteria and showed increases of 160 ml (two tests), 190 ml, and 300 ml (two tests) with the final increases in workload. McArdle, Katch, and Katch (44) indicate that this is not uncommon and that the highest $\dot{V}O_2$ values are often recorded during the last minute of exercise. They suggest the use of R and HR max as other reasonable indicators of near maximal oxygen consumption.

The R value represents the ratio of CO_2 produced to O_2 consumed. At rest and submaximal exercise, before the break in ventilation, this ratio gives an indication of substrate metabolism at the cellular level. Values range from approximately 0.70 to 1.00 depending on the substrate source of energy.

During exhaustive exercise, as a person reaches capacity for aerobic resynthesis of ATP, exchange of O_2 and CO_2 at the lungs no longer reflects the oxidation of specific foods in the cells. Additional work is accomplished through anaerobic energy sources which results in the formation of lactic acid. The body responds to this acidosis by buffering the acids. The neutralization process ultimately results in CO_2 being "blown off" at the lungs so that the amount of CO_2 produced is greater than the amount of O_2 consumed. Thus, an R value greater than 1.00 has been used as an indication of achievement of maximum aerobic capacity (44). In this study, R values greater than 1.00 were demonstrated in every test for all subjects. Values ranged from 1.06 to 1.34, with a mean of 1.18.

Heart rate is a third indicator of maximal exertion. It has been found that the maximal achievable heart rate is not affected by a person's state of health or level of fitness, but only by the person's age. The formula HRmax = 220 - age gives an approximate value of maximum heart rate. When an average standard deviation of ± 12 to 15 bpm for each age increment is allowed for individual variation, an even better estimate is obtained.

In this study, all but four women exhibited HRmax values in the expected range. The four who did not fall within this range all showed a deviation of 20 to 25 beats from their age-predicted values. However, considering the shape of the normal curve, these values are not unrealistic.

In all tests conducted for this study, responses of $\dot{V}O_2$, R, and HR during exercise were each evaluated to determine whether or not the test was a "true" max. In no instance was it necessary to reject a test as invalid based on these criteria.

Cardiorespiratory Improvements with Training

Responses to Maximal Exercise

Pre-test values for $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) in this study were higher than those found in earlier studies (13,23,31,32,40) with young sedentary females. However, the values do fall in the range of 30 to 44 $ml \cdot kg^{-1} \cdot min^{-1}$ reported in review articles (22,80) for the average untrained college-age female.

The 6.9% increase in $\dot{V}O_2$ max noted at the conclusion of the training program in the J group of the present study falls within a range of values reported by Pollock (56) who stated that endurance training for ten weeks results in a 4 to 14% improvement in $\dot{V}O_2$ max. The present value is lower, however, than the range of 15 to 20% reported elsewhere (2,36) as the general improvement in relative $\dot{V}O_2$ max resulting from endurance training programs.

It has been suggested in other reviews (25,35) that individuals with the lowest aerobic capacity may be expected to have the greatest percentage increases in cardiovascular fitness as a result of training. For example, Edwards' subjects (23) began their training program at a relative $\dot{V}O_2$ max level of 26.7 $ml \cdot kg^{-1} \cdot min^{-1}$. After only 4 wks of training, 15 min/d, for 5 d/wk, this group showed a 29.7% improvement in $\dot{V}O_2$ max. Fringer and Stull (32) found a 35.5% improvement for low-fit subjects with initial values of 33.8 $ml \cdot kg^{-1} \cdot min^{-1}$ for relative $\dot{V}O_2$ max, following 10 wks of training, 3 d/wk.

Conti (13) investigated cardiorespiratory responses to training programs of jogging and circuit weight training. Subjects in his jogging group also trained 3 d/wk for 10 wks with initial values of relative $\dot{V}O_2$ max which were nearly identical to those of Fringer and Stull (32). However, at the end of this group's training program, $\dot{V}O_2$ max improved only 14.6% over the initial values.

Atomi and Miyashita (4) found average improvements similar to Fringer and Stull following 44 wks of training. However, when individual results were considered, the authors noted an inverse relationship between initial $\dot{V}O_2$ max and the percent of increase following training. In their study, two subjects with pre-training $\dot{V}O_2$ max values of 42 $ml \cdot kg^{-1} \cdot min^{-1}$ showed improvements of 10 to 15% whereas two subjects with initial values of 35 $ml \cdot kg^{-1} \cdot min^{-1}$ improved 35 to 40%.

Joggers in the present study had an average initial $\dot{V}O_2$ max value of 42.8 $ml \cdot kg^{-1} \cdot min^{-1}$. The smaller relative improvement by the J group was similar to the results of Atomi and Miyashita (4) and may be due to the initially high level of fitness. Even though the improvements shown by the J group were relatively small compared to other studies, the increases were significant and substantially greater than those seen for the RB group. The lack of improvement for racquetball players in the present study would seem to indicate no physiological benefits for this group.

A summary of findings from previous studies involving female subjects is presented in Table 6. The wide range of responses noted between various endurance training programs makes the data somewhat confusing. While differences in initial level of fitness may account for some of the discrepancies, age, mode of training, frequency, duration, and intensity are other possible sources of variation.

Some researchers (36,56) have reported increases in maximal pulmonary ventilation as a result of endurance training. Others have found no significant changes (6,83). Increases shown by the training groups of the present study were 8.7% for joggers, and 6.8% for racquetball players. These changes were significant and approach the range of 10 to 20 % reported by Pollock (56) as an expected response to endurance training.

Maximal heart rate did not change significantly in either training group. Previous studies indicate that HRmax may be reduced as a result of endurance training (25,28,59,73,83), or the values may remain the same or increase slightly (9,40,62).

Differences Between Modes

The two training programs in this study were equated with respect to frequency, duration, and intensity, with mode being the only variable under consideration. Therefore, this section will examine cardiorespiratory responses in terms of mode of training used in the exercise prescription.

Table 6. Comparison of Maximal Oxygen Uptake Changes with Training in Women

Investigator	Age yrs	N	Prescription wks	days	mode	$\dot{V}O_2$ max $ml \cdot k^{-1} \cdot min^{-1}$ pre	post	%
Atomi et al. (3)	18-20	40	8	2-4	bike	33.6	40.2	19.6
Atomi, Miyashita (4)	23-40	7	44	2-4	bike	29.4	39.4	34.0
Burke (9)	18-25	8	8	3	run	31.7	39.8	24.0
Conti (13)	20	9	10	3	run	33.9	38.2	14.4
Conti (13)	21.3	7	10	3	CWT	33.8	36.3	7.6
Cunningham et al. (16)	18-25	10	12	4	bike	36.7	41.1	12.0
Cunningham, Hill (15)	21-48	17	9	4	R/W	26.0*	35.2*	34.0
Cunningham, Hill (15)	21-36	6	52	2	R/W	38.4*	40.6*	5.7
Daniels et al. (19)	17-21	26	6	5-6	run	46.0	49.7	7.9
Edwards (23)	17-21	12	4	5	run	26.7	34.7	29.7
Eisenman, Golding (24)	18-21	8	14	3	run	38.1	44.8	17.6
Flint et al. (28)	23-49	7	6	3	walk	36.3*	40.6*	12.0
Franklin et al. (31)	29-47	13	12	4	R/W	34.4	38.5	11.9
Franklin et al. (31)	29-47	23	12	4	R/W	26.6	31.6	18.8
Fringer, Stull (32)	17-28	44	10	3	bike	33.8	45.8	35.5

Table 6. Continued

Investigator	Age yrs	N	Prescription wks	days	mode	$\dot{V}O_2$ max ml·k^{-1}·min^{-1} pre	post	%
Kearney et al. (40)	17-22	13	9	3	run	38.4	45.6	18.7
Kilbom (41)	19-31	12	7	3	bike	36.8	40.8	10.9
Patton et al. (55)	17-25	57	7	7	ACP	36.9	39.3	6.5
Sinning (75)	19	14	14	5	BB	44.8	42.9	-4.2
Sinning, Adrian (76)	19-22	7	9	3.5	BB	34.4	38.7	12.5
Wirth et al. (84)	19-23	17	10	3	bike	34.6	38.9	12.4
Withers (85)	18-30	7	12	6	lacs	44.0	52.9	20.2
Yeager, Brynteson (86)	18-22	18	6	3	bike	36.7*	43.3*	18.0
Present Study	17-35	8	10	3	run	42.8	45.7	6.9
	17-35	8	10	3	RB	39.2	39.2	0.1

* = predicted values
ACP = army conditioning program: run, march, cal.
BB = basketball
bike = cycle ergometer
CWT = circuit weight training
lacs = lacrosse
RB = racquetball
R/W = run, walk

Åstrand and Rodahl (2) explain that central adaptations to training may be dependent on the mass of the peripheral muscles used during the exercise. Pollock et al. (64) have shown that the $\dot{V}O_2$ of arm work is approximately 58% of leg work at similar heart rates. In his study, Montgomery (47) pointed out the high amount of arm work involved in racquetball. Faria and Lewis (27) made a similar observation. In conjunction with Pollock's findings, this could indicate that the activity of racquetball does not involve a large enough muscle mass to stimulate central adaptations to training, i.e., changes in $\dot{V}O_2$ max would not be expected.

The fact that the RB group showed an increase in $\dot{V}_E$ independent of an increase in $\dot{V}O_2$ max suggests the possibility that there may have been cardiorespiratory improvements produced by racquetball play which were unrelated to $\dot{V}O_2$ max. Treadmill performance time would be one indication of improved cardiorespiratory endurance. Analysis of TT revealed 2.2% and 5.2% improvements for the RB and J groups respectively. Although these figures suggest a slightly greater increase in endurance for the J group, the size of the improvements and the differences between the groups were not statistically significant.

Specificity of training and testing is another concept that may explain $\dot{V}O_2$ max differences between the groups. Testing done on the treadmill would favor the J group since the action of testing is similar to that of training (12,42,54).

Another possible explanation for discrepancies in $\dot{V}O_2$ max changes between the groups is related to the nature of the workout itself. Faria and Lewis (27), finding the ball in play only 39% of playing time, classified racquetball as a high-intensity, short-term, intermittent game. Montgomery (47) also discovered that the ball is actually in play less than 50% of the time during a racquetball match. The intermittent nature of the game would result in less actual work time for the racquetball players as compared to the joggers who worked continuously during the exercise session. For the joggers who could not maintain 40 min of continuous running, periods of vigorous walking were interspersed. However, this did not interrupt the continuity of the exercise, and training heart rates were still maintained.

Because of the nature of the game of racquetball, it was not possible to control intensity for this group as well as with the J group, and this warrants consideration. Subjects were instructed to try to maintain heart rates within a range of 65 to 85% HR reserve. Racquetball players, however, found it difficult to maintain heart rates in this training range and only recorded heart rates above the minimal prescribed level 87.7% of playing time. Thus it is difficult to explain why a training effect was shown in the J group but not in the RB group.

Finally, even though heart rate responses to racquetball and jogging have been shown to be similar (27,47,66), heart rate may not be an accurate indication of what happens metabolically. Montgomery (47) and Faria and Lewis (27) suggest that activities involving a high amount of arm work would have a tendency to produce elevated heart rate responses. Therefore, the two activities could not be expected to elicit similar physiological benefits.

CHAPTER 6

SUMMARY

Increasing numbers of people are recognizing the benefits of a lifestyle which includes physical activity. Since physical inactivity is often associated with such major health problems as obesity and CHD, exercise is widely accepted as one means of improving one's physical and mental health. The problem then lies in determining what mode of exercise will provide the best stimulus for improving cardiorespiratory fitness.

In the past, the walk/jog program was the traditional method of exercise. Since this program is not acceptable to everyone, it is important to identify alternative modes of exercise which will stimulate cardiorespiratory improvements. The present study has investigated the alteration of various cardiorespiratory parameters resulting from a racquetball training program as compared to a jogging program of similar frequency, intensity, and duration.

Since racquetball has been shown to produce heart rate responses similar to jogging, it has been hypothesized that the aerobic benefits of the two activities would also be similar. In this study, cardiorespiratory improvements shown by the jogging group in measures of $\dot{V}O_2$ max and $\dot{V}_E$ were as expected. However, this investigation failed to find improvements in either absolute or relative $\dot{V}O_2$ max for the group using racquetball as a training mode. It is possible that this was due to the fact that an appropriate intensity, as measured by heart rate, was not maintained during exercise. No significant changes were noted in HR, R, or TT for any group. Therefore, it is concluded that a regular program of jogging can result in cardiorespiratory improvements, while racquetball is an activity which cannot effectively maintain the necessary intensity to produce these improvements. Further investigation would be beneficial to determine if racquetball could be effective in maintaining fitness once optimal levels had been achieved.

APPENDIX A

From: Sherry Stokke--Graduate Assistant--University of Arizona

To: Prospective Research Subjects

Subject: Physical Activity Participation Questionnaire

Name:

Age:

Date:

The following questions will be used to determine your past and present level of physical activity. Please answer each question as accurately as possible.

1. In what sports or activities have you been a participant in the last two years?

2. In what sports or activities are you currently active?

3. How many days per week do you participate in the activity (activities)?

   How many hours?

4. Would you be willing to participate in a Physical Education research project? The time commitment would entail 10 weeks in the second semester, 3 days per week, one hour per day. (For control subjects, the time commitment would be approximately 3 hours: 2 hours near the beginning of the semester for testing and one hour ten weeks later for a post test.)

5. If yes, please list your local address and phone number. This information will remain confidential.

   Address:

   Phone:

APPENDIX B

SUBJECT'S CONSENT

I understand that I am being asked to voluntarily participate in a project entitled "A Comparison of Racquetball and Jogging Training Programs and their Effects on Cardiorespiratory Fitness."

The project is a Master's thesis intended to compare physiological changes in heart and lung function resulting from a prescribed racquetball training program with those resulting from a similar jogging program. All subjects will be female volunteers, age 17-35, enrolled at the University of Arizona, who will be assigned to one of three groups: racquetball, jogging, or control. The project will last for 10 weeks, with exercise sessions 3 days per week, 50 to 60 minutes per session. The racquetball group will meet at 6:30 a.m. on Mondays, Wednesdays, and Fridays at the racquetball courts in McKale Center. The jogging group will also meet on these days at a designated time northeast of the McKale Center by the Chi Omega Steps. The control group will continue their regular activities and will be asked only to refrain from any new physical activity.

I understand, as a part of this project, that I will be involved in some tests to determine my fitness level. A continuous walk/jog test on a treadmill will be given to determine the maximum amount of oxygen used by my body during exercise and also my maximum heart rate. The test will be given twice before and once after the 10 week training program. These tests will be administered at the Exercise and Sport Sciences Laboratory in McKale Center by trained technicians. As a subject, I will also be asked to fill out a Physical Activity Participation Questionnaire as well as a Pre-Exercise Personal Inventory Questionnaire to indicate my activity and health histories.

I understand that there may be some discomforts that occur as a result of testing and training. For the treadmill test, my skin will be prepared for placement of three electrodes by cleansing the area with alcohol and rubbing with an abrasive pad. This may cause slight stinging at the electrode sites, but will last only a few seconds. There is a slight chance that I may experience muscle fatigue or dizziness during the test and/or mild muscle soreness between 24 to 48 hours afterwards as a result of the treadmill test to exhaustion.

As a subject in this study, there will be no cost to me and no monetary compensation. The only benefits to me are the knowledge of my fitness level and the possible improvement of it. Knowledge about the effects of racquetball as a form of exercise may also benefit society. In the event of physical injury resulting from research procedures, financial compensation for wages and time lost and the cost of medical care and hospitalization is not available and must be borne by me, the subject.

I understand that this consent form will be filed in areas designated by the Human Subjects Committee with access restricted to the principal investigator or authorized representative of the particular department. All information obtained in testing will be treated as privileged and confidential. My name will be known only to the principal investigator; to all others I will be identified by a number. I will receive a copy of my individual results and a set of norms so I may compare my results with others in the measurements used. Results of the study will be used for statistical or scientific purposes only. Group data may be published in professional journals, always with my right of privacy retained.

I have read the "Subject's Consent" form. The nature, demands, risks, and benefits of the project have been explained to me. A copy of this consent form is available to me upon request. Furthermore, I understand that my participation is completely voluntary and that I am free to ask questions and/or to withdraw from the project at any time without affecting my university standing or incurring any ill will. If at any time I have any questions related to this study, I am free to contact Sherry Stokke (Physical Education Building, Room 3, phone: 626-3407, or home phone: 795-3275).

Subject's Signature Date

I have carefully explained to the subject the nature of the above project. I hereby certify that the subject signing this consent, to the best of my knowledge, understands clearly the nature, demands, benefits, and risks involved in participating in this study.

Investigator's Signature Date

Witness' Signature Date

APPENDIX C

PRE-EXERCISE HEALTH HISTORY

Name: Date:

Please answer the following questions by responding as follows:
(x) Yes - place x ( ) No - leave blank (?) Unknown - place ?

HAVE YOU EVER HAD ...

( ) Rheumatic fever
( ) Heart murmur
( ) High blood pressure
( ) Any heart trouble
( ) Disease of the arteries
( ) Lung disease
( ) Arthritis
( ) Asthma
( ) Migraine headaches
( ) Operations - describe

( ) Injuries - describe

HAVE YOU RECENTLY HAD ...

( ) Chest pain
( ) Shortness of breath
( ) Heart palpitations
( ) Cough on Exertion
( ) Back pain
( ) Swollen, stiff, or painful joints
( ) Foot problems
( ) Muscles cramping

HAVE ANY OF YOUR RELATIVES HAD ...

( ) Heart attacks (under age 55)
( ) High blood pressure
( ) Diabetes
( ) Congenital heart disease
( ) Cholesterol (260 or higher)

DO YOU NOW ...

( ) Drink coffee - tea
cups/day
( ) Drink cola, tabs, etc.
cans/day
( ) Drink beer
cans/week
( ) Drink wine
oz./week
( ) Drink alcohol
oz./week (1 shot = 1 oz.)
( ) Smoke cigarettes
cigarettes/day
( ) Take prescription medicine
if yes, list:

HAVE YOU EVER ...

( ) Smoked cigarettes
If yes, how long ago did you quit?
_____ months
_____ years

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