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It was the purpose of this study to determine if groups of female subjects with diverse initial muscular endurance levels differed in amount and rate of muscular endurance development, and to determine the relationship between the initial level of muscular endurance and the amount of muscular endurance development during a four-week conditioning program.

Twenty-seven women from the freshman physical education major class at The University of North Carolina at Greensboro participated in the four-week conditioning program on the bicycle ergometer. The subjects were divided into three groups (high, medium, low) based on their initial riding time.

Analyses of variance were used to determine if there were any significant differences between the mean changes in pedaling time of the three groups for each week. Also, for each group of subjects, t-tests were calculated using the initial pedaling time scores and the fourth week mean pedaling time scores to determine if there were significant changes in pedaling time during the four-week training program. Correlation coefficients were calculated using the initial pedaling time scores and the difference between the initial pedaling time scores and the mean scores of each week for the entire group of subjects to see if there were any relationships between the initial scores and the improvement scores for each week.

There were no significant differences between the groups at the 5 percent level of confidence in relation to changes in

muscular endurance after one, two, three, and four weeks. In addition, there were no significant correlation coefficients between the initial scores and the mean scores for each week.

Within the limitations of this study the following conclusions are proposed:

1. There is no significant difference between the initial level of muscular endurance and improvement in muscular endurance after one, two, three, and four weeks of high resistance bicycle ergometer training.
2. There is no significant relationship between the initial muscular endurance and improvement in muscular endurance after four weeks of high resistance bicycle ergometer training.

THE DEVELOPMENT OF MUSCULAR ENDURANCE IN WOMEN
PHYSICAL EDUCATION MAJORS WITH DIVERSE
INITIAL MUSCULAR ENDURANCE SCORES

by

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Approved by

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APPROVAL PAGE

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Endurance has long been recognized as an important part of many physical education activities and it can be classified in two ways: cardio-respiratory and muscular. Usually one type of endurance compliments the other. When a great deal of muscular endurance is required, cardio-respiratory endurance comes into play and vice-versa.

Considerable research has been done on both cardio-respiratory and muscular endurance. Researchers have attempted to determine the best methods for developing endurance. Studies have been concerned with isotonic and isometric training, distance running, treadmill conditioning, weight training, and bicycle ergometer workouts. Although the information on endurance training and development is abundant, it is unfortunate that very little of this research has employed women as subjects. Thus, there is limited statistical data available concerning the performance of women during endurance workouts.

There have been indications that muscular endurance is related directly to strength. It has been stated that stronger individuals have less room for improvement than do individuals with less strength. Suggestions have also inferred that individuals with higher levels of strength are generally considered to be closer to their physiological limit than are individuals with less strength; thus, individuals with more initial strength have less chance to improve equally as much as individuals with less initial strength. Perhaps, then, if strength and endurance are directly related the same would be true for endurance.

The bicycle ergometer is one instrument often used to test for endurance development. Not only is the bicycle a good instrument for measuring cardio-respiratory endurance, it is also valuable in measuring muscular endurance of the lower extremeties. By setting the resistance sufficiently great enough and at a moderately rapid cadence, it is possible to develop and measure muscular endurance of the legs. This measure of endurance can be calculated, by measuring to the nearest second, the length of time the subject can continue pedaling at a predetermined rate and tension.

Due to the lack of information about the capabilities of women in relationship to strength and endurance, it has become important and necessary to obtain research data. The growth of interscholastic and intercollegiate sports for women has further increased the interest of physical educators and coaches as to the best methods for developing endurance in women. This much needed data could offer greater insight into the capabilities of women in relationship to endurance levels and help instructors better condition and coach women for various activities. The effect on teaching and coaching methodologies for women and the improvement in the overall caliber of performance should be enhanced by information on the endurance capabilities of women.

STATEMENT OF PROBLEM

The purpose of this study was to determine if groups of female subjects with diverse initial muscular endurance levels differ in amount and rate of muscular endurance development, and to determine the relationship between the initial level of muscular endurance and the amount of muscular endurance development during a four-week conditioning program.

LIMITATIONS OF STUDY

The following are considered to be limitations of this study:

1. All subjects were between the ages of eighteen and nineteen years of age.
2. All subjects were freshman physical education majors.
3. Training was conducted for a four-week period only.
4. The experimenter was unable to control factors of diet, rest, and/or psychological stressors.

BASIC ASSUMPTIONS

The following are considered to be basic assumptions of this study:

1. Exercises that cause exhaustion in less than two minutes are considered to be muscular endurance exercises.

2. High resistance pedaling times on the bicycle ergometer can be used to evaluate quantitative measures of muscular endurance.
3. High resistance pedaling times on the bicycle ergometer can be used as training stimulus to develop muscular endurance.

DEFINITIONS

The following operational definitions were selected for this study:

Muscular exhaustion - inability to continue work at a resistance of five kiloponds at a pace of 120 pedal strokes per minute.

Kilopond - a unit of measure in relationship to the pull of gravity on one kilogram; one kilopond is equal to one kilogram; (a kilopond meter moves one kilogram one meter; one kilogram is equal to 7.233 foot-pounds).

Muscular endurance - the ability to endure intense physical activity (up to two minutes) which involves high anaerobic power or requires high anaerobic capacity.

Maximum effort - a work load of sufficient intensity to cause muscular exhaustion of the lower extremities.

CHAPTER II

REVIEW OF LITERATURE

There are many factors that can affect the performance of an individual during conditioning programs or training periods requiring physical exertion. One such factor is motivation. This psychological state can be facilitated or inhibited by the individual himself or by his immediate environment. Carlson suggested that motivation was an intangible factor that had definite effects on performance. (28) The control of this factor is limited in many ways. External motivating forces can be produced or withheld, but the internal motivating forces known only to the individual himself are limiting factors that must be accepted to exist during experimental conditioning projects or training programs. Steinhaus pointed out that there are great individual variations in the ability to endure severe physical exertion. He also stated that there are measurable differences between the sexes and that "these differences impose greater limitations on women in activities of strength, speed, and endurance." (25:300)

ENDURANCE

The concept of endurance has many connotations and numerous attempts have been made to define it. Jokl defined endurance as the ability to work efficiently for an extended period of time. (5)

Scott and French defined endurance in the following statements:

> Endurance is primarily the result of a physiological capacity of the organism to continue functioning satisfactorily. Endurance may be measured by either the ability to maintain action at maximum speed for a short period of time, or the ability to maintain action at a slower rate for an indefinite period of time. (13:303)

Kilander's definition of endurance is very similar to that of Jokl. Kilander stated that ". . . endurance is the ability of the body to resist fatigue during long periods of muscular effort. . ." (7:215) Cureton's definition of endurance is more complex than that of previously quoted authors. Cureton defined endurance as "the capacity for continuous exertion, involving a severe depletion of the oxygen reserve and the development of the oxygen debt rapidly following strenuous activity." (19:70) Cureton also pointed out that "endurance has been found to be the most desirable point of emphasis in physical fitness." (2:36)

Klafs and Arnheim discussed endurance and concluded with the following statements:

> Endurance is usually defined as the ability of the body to undergo prolonged activity or to resist stresses set up as a result of prolonged activity. Endurance involves a number of elements, each of which is partially responsible for success or failure in sustaining physical performance. (8:53)

Morehouse pointed out that endurance may be improved by increasing muscular strength and improving physical condition. Morehouse also stated that an athlete with abundant endurance can sustain strenuous work for long periods of time. (11) Clarke, on the other hand, made the following statement concerning the relationship of muscular strength and muscular endurance:

> Muscular strength and muscular endurance are not the same, although they are related. Individuals with greatest muscular strength have greatest absolute endurance; however, stronger muscles tend to maintain a smaller proportion of maximum strength than do weaker muscles. (1:201-202)

Carlson stated that "individuals with a high level of strength are usually able to achieve better scores on tests of muscular endurance than individuals with less strength." (28:30) Fait felt that "since there is a relationship between muscular strength and muscular endurance, muscular strength can be estimated by determining endurance." (3:69)

McGlynn, in his study on the relationship between maximum strength and endurance of individuals with different levels of strength, concluded that there was a significant relationship between maximum strength and endurance. (23)

Tuttle, Janney, and Salzano utilized dynamometers based on the strain gauge principle for measuring the maximum strength and endurance of the back and leg muscles. The authors reported that subjects performed differently when the resistance was a percentage of strength. The weak individuals demonstrated greater muscular endurance than the strong individuals. (26)

Elbel studied the relationship between leg strength, leg endurance and other body measurements. Five hundred potential pilots were divided into four groups. Low but significant coefficients of correlation were found between leg endurance and leg strength for these groups. Data for the right leg for the group of pilots revealed significant coefficients of correlation between leg strength and leg endurance at all increments. (20)

In 1965, Martens conducted a study on the relationship of phasic and static strength and endurance. His conclusions are listed below:

1. Maximum phasic strength has no relationship to phasic muscular endurance.
2. Maximum static strength has no relationship to static muscular endurance.
3. Phasic muscular endurance and static muscular endurance are not related.
4. In no way was phasic or static strength related to phasic or static muscular endurance. (31:40)

Marten's findings are not in agreement with other literature reviewed on the relationship of maximum strength to endurance.

Start and Graham made the following statement concerning endurance:

> Isotonic endurance is in fact an ephemeral thing, requiring severe definition of conditions to be at all meaningful. Not only the load, the distance through which the load is moved, and the frequency of the movement, but also the speed with which the load is moved varies the energy expended per second. The speed of movement in a particular cadence determines the amount of rest and recovery between the movements. The cadence of 60 per minute is the same as an endurance of two minutes at a rate of 30 per minute. Or again, whether at a cadence of 30 per minute an endurance of one minute with a 20 pound load is the same endurance as two minutes with a load of 10 pounds. (24:194)

Lawther stated that exercise for endurance development should be gradually and carefully increased with the increase not too rapid and over an adequate time span. Lawther also stated that endurance is specific to an activity, and because of this, a person should train in the specific type of endurance called for by his activity. (9)

There have also been many attempts to define and/or explain muscular endurance. Singer stated that "the capacity of a muscle or a group of muscles to contract repeatedly against a moderate resistance reflects muscular endurance." (14:57) He further stated that "the individual must maintain a moderate energy output over an extended duration of time." (14:57) Start and Graham stated that muscular endurance "is related to the capacity of a muscle to maintain or repeatedly develop a certain degree of tension, and can be either isotonic or isometric in nature." (24:193)

Cureton referred to muscular endurance as being either phasic muscular endurance or static muscular endurance. (19) Adamson stated that muscular endurance is the capacity of an individual for continuous performance of relatively heavy activities which make relatively small demands on the functions of circulation and respiration before fatigue terminates performance. (16)

Swegan defined muscular endurance to be the ability to persist at a defined movement, at a predetermined rate, as measured in time. (32) Clarke stated that muscular endurance is repeatedly recognized as one of the most important factors determining success or failure in athletic contests or in performance of skills. (1)

ENDURANCE TRAINING

Endurance training involves a number of factors, one of which is the amount of resistance at which the individual works. Klafs and Arnheim defined training as "a systematic process of repetitive, progressive exercise or work." (8:50) Clarke and Stull stated that ". . . there seems to be little doubt that physical performance can be enhanced by repetitive exercise if the individual employs some sort of overload procedure." (18:19)

Wessel and MacIntyre defined and outlined overload in the following way:

> Overload is any resistance greater than that which you usually encounter in daily living. There are five techniques for applying overload in exercise programs for attaining strength, endurance and flexibility. They are to: (1) increase the number of repetitions or distance, (2) increase the duration, or length of time of the exercise, (3) increase the speed of the exercise movement, (4) increase the intensity (strength), by increasing the resistance or load (weight) to be lifted, (5) decrease the rest interval between exercises. (15:25-26)

In summary, overload seems to be generally accepted as performing at a level that is above what is normal for the individual.

When training at levels that are greater or above what is customary for the individual, it is believed that the individual will increase or improve his ability to perform, providing the training program is continued over a sufficient period of time. Once again the improvement will vary due to individual differences; the level of condition at the beginning of the training period; and the intensity of the exercise training program. (6)

Yessis made the following comments concerning training for strength and endurance:

> There appears to be no one best method for developing either /stength or endurance/. Few repetitions with maximum resistance appears to be best suited for strength development while maximum repetitions with sub-maximal resistance appears to be suited for endurance development. There appears to be some definite relationships between strength and endurance but these relationships are not clear. The relative efficaay (sic) of isometric and isotonic exercises in producing strength and/or

> endurance is also not clear. Whether strength can be entirely separated from endurance or vice versa has not been answered either. (34:60)

Yessis also pointed out that since all physical activities require some strength and endurance, it may be possible to achieve better performance more quickly and efficiently with the use of knowledge about the relationship between strength and endurance. (34)

Murray and Karpovich made the following statements concerning strength and endurance training:

> . . . in training for strength, muscles increase in size much more than in training for endurance, because strength depends on the cross-section of muscle fibers, and endurance on the addition of capillaries around the fibers. (12:37)

They also implied that it was easier for individuals with high levels of strength to develop endurance because their muscles could carry them through the necessary movements. (12)

Walters suggested that strength and endurance could only be obtained through a program which applied the overload principle and all out performance bouts. (27) McCloy discussed the effects of overload on muscular endurance; he implied that overload for muscular endurance was commonly held to result in the development of a more adequate blood supply to the muscle as well as facilitate increase in strength of the muscle. McCloy felt that the greater oxygen supply brought by this increased blood supply should improve muscular endurance. (22)

MUSCULAR ENDURANCE TRAINING UTILIZING THE BICYCLE ERGOMETER

The bicycle ergometer is an instrument that has been used to measure and evaluate the isotonic endurance of the lower extremeties. Although the bicycle ergometer has been generally accepted as an instrument for evaluating cardiovascular efficiency, it has been used to assess the development of endurance of the muscles of the legs. (28)

Bolonchuk provided insight into the use of the bicycle ergometer and the types of instruments involved:

> The bicycle ergometer has become a popular instrument to quantitatively study the effect of human response to various types and intensities of exercise. This instrument may be one of two general types, a mechanical variable load type such as the Monark ergocycle or the electromagnetic constant work load type such as the Collin's Pedal Mode ergocycle. (17:845)

Bolonchuk further described the Monark ergocycle:

> The work load for the Monark ergocycle is determined by the settings for resistance in kiloponds and rpm of the pedals. One revolution of the pedal arms moves a point on the flywheel a distance of six meters. If the pedaling rate is held constant, the mechanical work load may be calculated from the following formula:
>
> $$\underset{\text{(kpms/min.)}}{\text{Work load}} = \underset{\substack{\text{(meters)} \\ \text{(rpm's x 6 m)}}}{\text{Distance}} \times \underset{\text{(kiloponds)}}{\text{Resistance}}$$
>
> (17:845)

Kaprovich also commented on the use of the bicycle ergometer:

> Most information regarding the energy cost and efficiency of bicycling has been obtained from experiments on stationary bicycle ergometers. Riding a bicycle requires not only skill but also specific training of the muscles of the legs. A beginner, for example, riding on an

> ergometer with work output of 6000 foot-pounds per minute, may last only five minutes. After several weeks of training, he may be able to continue this work output for hours. (6:99)

According to Vittorio, the "bicycle ergometer allows for controlled variation in the work load and constancy in the rate of working." (33:19) Vittorio further commented:

> Many types of ergometers have been employed for the purpose of investigating physiological problems relating to the working efficiency of the human body. The use of the bicycle ergometer has proved satisfactory in previous research studies of endurance. (33:19)

Marder, in a study assertaining effects of vigorous activity on relatively sedentary older men, noted significant changes from eight weeks of participation. Improvement in endurance, slight decrease in body weight, and decrease in pulse rate occurred. The experimeter used a bicycle ergometer at a low resistance. Eighteen of his subjects showed significant gains at better than 3 percent level of confidence. (29)

In Vittorio's study on the development of endurance during double work periods in varying age groups, the subjects were divided into three groups. Group I consisted of nine local Boy Scouts ranging in age from 12-14 years; Group II consisted of fifteen college students from physical education classes ranging in age from 18-19 years; Group III consisted of adults working at the university ranging in age from 24-70 years. The subjects trained two times per week for eight weeks. The length of time the individual could continue at the pre-established rate and tension was recorded to the nearest whole second by the use of a stop watch. The subjects rate of exercise was maintained by making sure his pedal strokes corresponded in time to the beats of a metronome.

Vittorio supplied vocal cadence when the subject had difficulty in hearing or keeping in rhythm with the metronome. The author stated that the verbal counting seemed to be particularly helpful as the subject became more fatigued. The subject rode until he could no longer continue or until he was instructed by the experimenter to stop because he was falling behind his predetermined rate of work. Vittorio concluded:

1. Individual variation under the same training procedure is very great (range in scores from an actual loss to a one hundred and eighty percent improvement).

2. Older subjects show less fluctuation from bout to bout than 12-14 year olds.

3. From mid-twenty's on much greater time is necessary for the development of endurance (25-70 year olds).

4. The second bout riding time per session approached the first. . . much more closely in advanced age group than in college men or 12-14 year olds.

5. The percent of drop off in the sessions following peak performance was great in all groups. . . a week or more was needed before a new peak could be attained.

6. College students employing the single and double bouts per session improved 53% and subjects riding two all-out bouts per session improved 90%.

7. The young adult is at the best age for endurance development ($t = 4.74$).

12-14 year old	58.4	$t = 4.74$
18-19 year old	129.0	significant .01
24-70 year old	93.0	

(33:54-55)

Karpovich studied inmates in a jail during a fourteen-week endurance experiment using the bicycle ergometer. He observed marked fluctuation in endurance by subjects as well as extreme fall-off after exceptionally severe exertion. (21)

Scannel conducted a study to determine the effect of "all-out" workouts once per week or once every other week, upon a newly attained level of endurance. Forty-nine undergraduates enrolled in the required physical education program served as subjects and trained on the bicycle ergometer for twelve sessions (three times a week) over a five-week period. Resistance was set at a constant tension of thirty-eight pounds on the brake belt at 160 pedal strokes per minute in cadence with a metronome. Pre-training and post-training tests were administered before and after the training period. At the end of the five-week period, the subjects were divided into three groups. Group I exercised once every week for ten weeks; Group II did the same type of exercise once every two weeks; and Group III served as a control group and exercised once at the end of eight weeks. Scannel concluded from his study that: (1) it is possible to achieve large gains in endurance with only a few all-out bouts; (2) there was no statistically significant loss in newly developed endurance, and (3) there appeared to be a great deal of individual variation and many factors that affect the maintenance of new levels of endurance. (29)

In conclusion, Ziegler conducted a study in an attempt to find the most favorable frequency for the development of endurance. Maximum performance bouts (one, two, and three times per week) were used to determine the development of endurance. Fifteen subjects from the physical education major program rode the bicycle ergometer over an eighteen-week period. The subjects were divided into three groups and rode the bicycle ergometer with a resistance of forty-five pounds at a rate of 176 pedal-strokes or 88 flywheel revolutions per minute. Ziegler concluded that all three groups made significant gains in endurance at the end of the training period, regardless of the frequency of their workouts. (35)

CHAPTER III

PROCEDURES

The purpose of this study was to determine if groups of female subjects with diverse initial muscular endurance levels differ in amount and rate of muscular endurance development; and to determine the relationship between the initial level of muscular endurance and the amount of muscular endurance development during a four-week conditioning program using a bicycle ergometer.

TESTING PROCEDURES

Equipment

Bicycle ergometer. The Monark bicycle ergometer was selected for this test because it was a simple apparatus to operate and understand. By turning the resistance control screw, the belt was adjusted to cause the desired resistance against the wheel. The bicycle ergometer resistance was calibrated in kiloponds. One kilopond is equal to one kilogram (7.233 foot-pound), thus five kiloponds equals approximately 36.165 foot-pounds.

Metronome. The metronome was an electric type with a flashing light and an audible tick. The pace range of the metronome was from 40 to 208 beats per minute.

Stop watch. A stop watch was used in this experiment to record the riding time to the nearest whole second.

Pilot Study

A pilot study was conducted to determine a sufficient resistance and cadence at which the bicycle ergometer and metronome should be set in order to produce a work load of not more than two minutes duration for freshman women physical education majors. The writer felt that a maximum two-minute time limit would be necessary in order to prevent cardio-respiratory endurance from becoming a factor. The writer, a graduate student, and an undergraduate student participated in the pilot study.

The study was conducted over a two-week period. During the first week of the pilot study, the group met to experiment with various resistances and various cadences. These resistances ranged from four kiloponds to six kiloponds. The metronome cadences ranged from 100-144 beats per minute. The group rode until exhausted or until they could no longer maintain pace with the metronome. A five to fifteen-minute rest was taken before attempting to ride again. After three days of experimenting with various resistances and cadences, two resistance loads were chosen and three cadences were selected for further experimentation during the second week of the pilot study.

During the second week of the pilot project, work centered around metronome paces of 100, 108, and 120 pedal strokes per minute and resistance loads of four kiloponds and five kiloponds.

At the end of this work session, it was decided that a resistance of five kiloponds would be the resistance load for the testing program. Further work centered on metronome paces of 100, 108, and 120 pedal strokes per minute. At the end of this work session, the decision was made that a metronome pace of 120 pedal strokes per minute would be used for the testing program.

Based on the findings of the pilot study, the author concluded that a pace of 120 pedal strokes per minute with a resistance of five kiloponds would provide a work load that should be sufficient to enable all subjects in the testing program to pedal for at least fifteen seconds but not more than two minutes.

Subjects

Twenty-eight students from the freshman physical education major class at The University of North Carolina at Greensboro volunteered to participate in this study. Only twenty-seven subjects completed the testing program because one student had to be dropped during the second week of testing due to illness. Thus, all statistical calculations were made in reference to twenty-seven subjects. The author purposefully attempted to find a group of major students who were exposed to the same physical education activity offerings and who, for the most part, were engaged in the same kind of class routine and activity participation. If major students had been selected from all four of the major classes (freshmen, sophomores, juniors, seniors), this control would not have been possible because students would be engaged in different physical education activities, each requiring different physical demands. The freshmen majors seemed the best major group available for testing due to several other factors: (1) they had no student teaching responsibilities; (2) they had no observation or assisting commitments in the public schools; (3) they had not been involved with previous thesis testing programs to the degree and extent of other physical education major classes.

Preliminary Arrangements

Permission was secured from the freshmen major class advisor for the author to seek freshman major students as volunteers for this study. The author met with the majors at the end of an activity class to discuss the thesis and testing procedures and to ask for volunteers. The majors were told that the bicycle ergometer would be used and the work load would be set at five kiloponds with a pace or cadence of 120 pedal strokes (60 revolutions) per minute. They were also told that hopefully each girl would be able to ride for at least fifteen seconds but not more than two minutes. It was further explained that the resistance and pace would remain constant throughout the testing period. The subjects were told they would be tested four days a week for four weeks and that the testing program would be concerned with improvement gains over maximum effort on the first riding.

At this point, the experimenter asked for volunteers. Women participating in another experiment of this nature or women participating in varsity sports during the spring were asked not to volunteer. Twenty-eight women volunteered to participate. All volunteers were asked to fill out a class schedule and to indicate additional times that they could not meet for testing. The class schedules were used to set up times for each student to come to the research laboratory to ride the bicycle ergometer. The subjects were informed that a preliminary meeting would be held in the research laboratory to allow each subject to become familiarized with the bicycle ergometer and the testing procedures.

The student class schedules were used to make out a master time schedule. No more than four subjects were scheduled to come to the laboratory at the same time; a ten-minute span was allotted between groups. The ten-minute span allowed for extra time in case any subject was late. All subjects were scheduled for testing between the hours of 10:00 A.M. and 1:40 P. M. with no subjects coming between 11:00 A.M. and 12:00 noon.

On April 14, the experimenter met with the subjects again and passed out master time schedules for testing. Corrections and/or adjustments were made on the master schedule at this time. An outline of the testing schedule can be found in the Appendix. The subjects were reminded to meet in the research laboratory on Thursday, April 15.

All subjects came to the research laboratory at their scheduled time to familiarize themselves with the laboratory, the bicycle ergometer, and the beat of the metronome. Each subject pedaled the bicycle with no resistance until they could pedal with the beat of the metronome. After the desired pace was attained, resistance was gradually raised over a fifteen second span until five kiloponds of resistance was reached. Each subject pedaled no more than fifteen seconds and then was stopped.

Questions asked by the subjects were answered by the experimenter. Subjects were asked not to participate in any activity for the purpose of improving their ability to ride the bicycle ergometer. Subjects were told to continue participating in the activities that were part of their daily routine. Subjects that were scheduled to ride in the afternoon were asked to allow fifteen to thirty minutes between eating and riding times. All subjects were reminded of their testing time on Monday, April 19, and encouraged to be on time.

<u>Score Sheet</u>

One master score sheet was devised with the names of all subjects listed down the left hand side of the page and the daily scores listed across the page. This score sheet was present each day of testing for the subject to see. A copy of this score sheet may be found in the Appendix.

<u>Research Laboratory Environment</u>

The research laboratory at The University of North Carolina at Greensboro is relatively small in size. In an attempt to reduce the number of distractions in the laboratory, the equipment for this experiment was set up near the front entrance to avoid conflict with a treadmill experiment being conducted in another area of the laboratory. The bicycle was placed in a position so that each subject faced the laboratory entrance and had her back toward the treadmill experiment. The room temperature and relative humidity in the laboratory remained relatively constant during the entire testing program due to air conditioning.

The Test

The bicycle ergometer conditioning program was conducted to determine the development and improvement of muscular endurance in the legs of freshman women physical education majors. The testing program began with twenty-eight subjects reporting to the research laboratory at their scheduled appointment times. The seat on the bicycle was adjusted for each individual so that there would be only a slight bend in the leg at the knee joint.

The metronome was turned on as soon as the subject was ready to ride. Approximately ten seconds were allowed for the subject to pick up the pace and pedal with the beat of the metronome (120 pedal strokes per minute). As soon as the pace was correct, the experimenter started the stop watch and used five seconds to increase the resistance from zero to five kiloponds. Each subject was encouraged to keep pace with the metronome. These five seconds did not count toward the total riding time for the subject. Each subject rode until she could no longer keep pace with the metronome or until she was exhausted (fatigued) to the point that she stopped. During the riding time, the experimenter used verbal cadence if the subject started to fall behind the beat of the metronome. The stop watch was visible to each subject at all times and the metronome could be seen and heard during the entire riding time. The verbal cadence and the visibility of the watch and metronome were used as motivational factors. At every riding session, each subject was reminded of her best previous riding time and encouraged to try to surpass that time. The subject's riding time was measured to the nearest whole second.

The subjects rode once per day, four days a week for four weeks. Schedules for riding were set up Monday through Thursday, leaving Friday available as a make-up day in case a subject had to miss one of her scheduled riding times during the week. The make-up day was used at the end of the first, third, and fourth weeks.

Mid-way into the second week, a number of the subjects started to stand up to ride during the last few seconds. They were told to remain seated. After this incident, it was explained to all subjects that during the riding time they had to remain seated.

At the beginning of the third week, the experimenter attempted additional motivation by constantly encouraging the subject to continue riding as long as possible and at the designated metronome pace. When the subject showed signs of tiring, the experimenter offered stronger encouragement in order to motivate the subject to pedal for a few more seconds.

By the end of the third week and throughout the fourth week, the subjects seemed to become more competitive with themselves and with the other subjects. As the time drew closer toward the final testing period, the subjects seemed more determined to improve their riding time.

As was stated earlier, the experimenter had attempted to set the resistance for this study sufficiently great enough so that no subject would pedal less than fifteen seconds nor more than two minutes. On the first day of testing only one of the twenty-eight subjects pedaled less than fifteen seconds, and on the final day of testing only one of the twenty-seven remaining subjects pedaled longer than two minutes.

TREATMENT OF DATA

The subjects were divided into three groups based on their initial pedaling time. Groups were divided at points where there was a natural time span while keeping the groups as similar as possible.

Changes in pedaling time for each week were computed by subtracting the initial pedaling time scores from the mean pedaling time scores for all four weeks. Analyses of variance were used to determine if there were any significant differences between the groups in relation to pedaling time changes during each week. In addition, t-test for correlated samples were conducted for each group to determine if there were significant changes in pedaling time by the end of the fourth week.

Correlation coefficients were calculated for all subjects to determine if there were any relationships between initial pedaling time scores and changes in pedaling time scores for each week.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

Twenty-seven volunteers from the freshman physical education major class at The University of North Carolina at Greensboro participated in a four-week conditioning program using the bicycle ergometer. The bicycle ergometer was set at a resistance of five kiloponds and the metronome was set at 120 beats per minute. The subjects rode at this work load until they could no longer keep pace with the beat of the metronome or until exhausted to the point they had to stop. The training program consisted of riding four days a week for four weeks. The subjects were divided into three groups (high, medium, low) based on the time achieved on the first day of riding. Pedaling time was measured to the nearest whole second and pedaling time was considered as a measure of muscular endurance for this study.

Comparison of Changes in Pedaling Time Between Three Groups

Changes in the length of each subject's pedaling time were calculated by subtracting the initial time from the mean time for each week. The initial time was not figured into the mean for the first week. Analyses of variance were used to determine if there were significant differences between the mean changes in pedaling times of the three groups for each week. There were no significant differences found between the three groups (Table I). During the

TABLE I

ANALYSIS OF VARIANCE OF CHANGES IN INITIAL PEDALING TIME AND THE DIFFERENCE IN THE MEAN PEDALING TIME FOR EACH WEEK

Week	Source	SS	df	MS	f
First week	Between	69.25	2	34.62	1.13
	Within	732.86	24	30.53	
	Total	802.11	26		
Second week	Between	82.27	2	41.13	.89
	Within	1105.57	24	46.06	
	Total	1187.84	26		
Third week	Between	220.01	2	110.00	1.38
	Within	1904.73	24	79.36	
	Total	2124.74	26		
Fourth week	Between	177.00	2	88.50	.60
	Within	3516.88	24	146.53	
	Total	3693.88	26		

Significance of 3.40 needed at the .05 level of confidence.

first week of testing, two subjects from the medium group and five subjects from the high group showed losses in endurance compared to their initial scores. At the end of the second week, there was one subject from the medium group and one subject from the high group still showing an endurance loss. By the end of the third week all subjects had gained in endurance over the initial score.

Test of Significance of the Changes in the Initial Pedaling Time and the Fourth Week Mean Pedaling Time

In addition to the analysis of variance calculation the initial scores and the fourth week mean scores of each group were subjected to t-test for correlated samples to determine if there were significant changes in pedaling time during the four-week training program.

Table II summarizes the results of the t-tests conducted using the difference between the initial score and the mean score for the fourth week for all three groups. The t-test ratios indicated that all three groups showed significant increases in pedaling time at the 5 percent level of confidence.

Relationship Between Initial Pedaling Time and the Increase in Mean Pedaling Time

Correlation coefficients were calculated using the initial score and the difference between the initial score and the mean score at the end of each week for the entire group of subjects to see if there were any relationships between the initial scores and the improvement scores for each week.

TABLE II

TEST OF SIGNIFICANCE OF THE CHANGES IN INITIAL PEDALING TIME AND THE FOURTH WEEK MEAN PEDALING TIME

Group	Number	$\overline{MD}$	$\overline{SD}$	t*
Low	8	22.75	2.58	8.81*
Medium	9	28.44	3.17	8.91*
High	10	28.27	5.176	5.46*

*Significant at the .05 level of confidence.

Table III presents the results of the correlations calculated on scores for all twenty-seven subjects. The correlations indicated that there was no significant relationship between the initial pedaling time score and the improvement scores for any of the four weeks.

An additional correlation coefficient was calculated between the initial score and the final week mean score for all subjects. A correlation of .7676 was found. This correlation coefficient was significant at the .05 level of confidence showing a relationship between the initial score and the final score for the entire group.

Implications of Results

According to the results achieved by the subjects in this study, it is believed that initial muscular endurance scores will not have a bearing on the degree of muscular endurance development

TABLE III

CORRELATION COEFFICIENTS BETWEEN THE INITIAL SCORES AND THE DIFFERENCE BETWEEN THE INITIAL SCORE AND THE MEAN SCORE FOR EACH WEEK

Week	Number	r*
First	27	.2547
Second	27	-.0387
Third	27	-.0150
Fourth	27	-.2315

*A "r" of .381 was needed for significance at the .05 level of confidence.

during a four-week training program. The results of this study suggest that it is impossible to utilize a pre-training muscular endurance score to predict the changes in muscular endurance that will take place during four weeks of training. It is possible, however, that subjects can gain in muscular endurance over their initial muscular endurance score in a four-week training program of sufficient resistance.

CHAPTER V

SUMMARY AND CONCLUSIONS

It was the purpose of this study to ascertain if groups of female subjects with different initial muscular endurance levels differed in the amount and rate at which muscular endurance developed, and to determine the relationship between the initial level of muscular endurance and the amount of muscular endurance development during a four-week conditioning program using a bicycle ergometer.

The review of literature showed that data on muscular endurance training or development for women was lacking. While many studies on muscular endurance have been conducted using men subjects, no studies were found using women subjects.

Twenty-seven female subjects participated in this study. The subjects rode once per day, four days per week for four weeks. A resistance of five kiloponds and a metronome pace of 120 beats per minute was the criteria used for this training program. The pedaling time of each subject was used as the measure of muscular endurance and the pedaling time was measured to the nearest whole second.

Analyses of variance were used to determine if there were any significant differences between the mean changes in pedaling time of the three groups for each week. Also, for each group of subjects, t-test for correlated samples were conducted for each group to determine if there were significant changes in pedaling time by the end of the fourth week. Correlation coefficients were calculated for all subjects to determine if there were any relationships between initial pedaling time scores and changes in pedaling time scores for each week.

There were no significant differences between the groups at the 5 percent level of confidence in relation to changes in muscular endurance after one, two, three, and four weeks. The changes in pedaling time between the initial score and the fourth-week mean score were significant for all three groups. There were no significant correlation coefficients between the initial scores and the mean scores for each week.

Within the limitations of the study, the following conclusions are proposed:

1. There is no significant difference between the initial level of muscular endurance and improvement in muscular endurance after one, two, three, and four weeks of high resistance bicycle ergometer training.
2. There is no significant relationship between the initial muscular endurance and improvement in muscular endurance after four weeks of high resistance bicycle ergometer training.

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APPENDIXES

APPENDIX A

Master Time Schedule

MASTER TIME SCHEDULE

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY
10:00				
10:20				
10:40				
10:50				
11:00				
12:10				
12:20				
12:30				
12:40				
12:50				
1:00				
1:10				
1:20				
1:30				
1:40				

Please note your time appointments. Arrive at the time set on TIME.

If no one or only one person is scheduled the period above you, you may come a little early.

Do Not Skip a Day. It is very important that you meet your testing program four days a week for four weeks. (April 19 - May 14)

Jennifer Alley
North Spencer Annex
5531 or 5197

APPENDIX B

Master Score Sheet
(Raw Data)

TABLE IV

MASTER SCORE SHEET[a]
(Raw Data)

Sub-	April					April				May					May				
Sub-	19	20	21	22	23	26	27	28	29	3	4	5	6	7	10	11	12	13	14
ject	M	T	W	T	F	M	T	W	T	M	T	W	T	F	M	T	W	T	F
**A	40	42	45		43	55	63	58	69	71	83	84	74		87	80	70	80	
***B	19	19	20	22		17	25	25	29	27	26	30	25		29	33	24	37	
**C	35	34		36	43	47	51	50	50	51	48	55	52			54	56	60	60
*D	42	53	54	62		61	45	56	55	64	60	60	58		55	56	62	71	
**E	33	41	42	47		34	40	55	47	65	55	53	66		68	70	60	71	
***F	20	21	26	28		25	29	30	33	32	36		35	38	40	41	41	45	
**G	40	45	49	57		60	62	66	54	67	72	66	74		82	67	84	84	
***H		23	27	25	27	35	31	42	46	38	50	51	52		49	53	57	62	
*I	41	41	40	50		50	55	57	60	64	57	65	56		56	63	66	75	
*J	42	42	47	53		62	63	70	72	80	82	91	84		89	93	105	118	
**K	39	43	48	57		65	50	59	61	58	63		68	67	59	77	72	65	
*L	44	27	42		42	46	52	55	55	56	58	50	55		58	67	68	73	
*M	42	35	43	47		42	46	46	46	35	48	48	53		57	60	59	59	
*N	51	48		68	53	55	62	69	72	58	67	85	89		93	107	108	124	
*O	43	35	40	35		41	36	45	38	50	47	51	50		51	53	63	53	
**P	35	27	34	34		30	37	48	39	43	46	42	47		58	50	50	46	
**Q		32	36	45	44	47	53	54	61	61	57	52	48		54	56	56	62	
*R	48	45	49	46		56	54	57	61	64	66	65	67		69	71	70	73	
**S	32	31	35	32		42	43	48	50	53	55	57	62		64	71	71	67	
**T	34	27	32		32	23	33	36	40	38	44	43	50		53	54	40	46	

TABLE IV (continued)

Sub-ject	April 19 M	20 T	21 W	22 T	23 F	April 26 M	27 T	28 W	29 T	May 3 M	4 T	5 W	6 T	7 F	May 10 M	11 T	12 W	13 T	14 F
***U	29	34	33	34		32	33	38	43	42	36	40	37		45	52	51	54	
***V	26	28	30	35		24	38	37	39	34	44		49	51	59	45	39	50	
*W	58	46	58	47		62	64	67	71	67	72	70	77		76	72	82	84	
***X	16	15	20	24		19	22	29	32	32	26	33	32			37	26	32	38
***Y	13	17	20	23		22	22	28	24	26	24	31	34		33	35	31	38	
*Z	46	40	55	55		54	55	62	66	53	65	67	71		70	76	72	82	
***AA	26	25	25	30		39	38	43	40	38		46	42	52	55	60	63	62	

[a]Times measured to the nearest whole second.

* = High

** = Medium

*** = Low