# THE EFFECTS OF PROGRESSIVE RESISTANCE WEIGHT TRAINING ON THE PERFORMANCE OF MIDDLE DISTANCE AND DISTANCE RUNNERS

Thesis for the Degree of M. A.
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Crawford Eaglesham Kennedy

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By

Crawford Eaglesham Kennedy

AN ABSTRACT OF A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
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ABSTRACT

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Statement of the Problem

To evaluate the influence of progressive weight training on the performances of middle distance and distance runners.

Methodology

Two groups of three subjects each were randomly selected from five freshmen track team candidates and one sophomore track team candidate. A random selection was again made to decide which group would be the experimental group and which would be the control group. On the experimental group were two freshmen and one sophomore, and on the control group were three freshmen. The experimental group only participated in the weight training program which consisted of wearing a wristlet, an anklet and a waistbelt three times per week. To this equipment progressive weights were added each week during

regular training. Also prior to each weight training session the experimental group performed five repetitions of a three-quarter squat at maximal load. Both groups had similar (running) training programs to go by.

The testing program consisted of a) meeting once a week for an all-out treadmill run at 10 miles per hour on an 8.6 per cent incline, b) energy cost of all-out run of first and ninth week, c) energy cost of standard run at six miles per hour with no incline.

## Conclusions

The following conclusions were drawn from the analysis presented.

1. There were no significant differences in the overall running performance of the two groups.
2. Individuals participating in progressive weight training as used in the present study run less economically.

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Thanks are extended to David Gronauer for his assistance in statistical matters. Also to the subjects who participated so willingly in this study.

Appreciation is also extended to the author's wife, Maria, for her help in the final preparation of the study.

C. E. K.

# DEDICATION

This thesis is respectfully dedicated to my wife, Maria.

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# CHAPTER I

# INTRODUCTION

In the past it has been thought that if you want to find success as a runner, then you train by running, and running, and running . . .

This is good, there is nothing like running for running. If, however, you mentioned weight training for a middle distance runner you met a volley of arguments against it. It will cause rupture, heart strain, mucle-boundness, big muscles and a few other detrimental effects. This being the case, weight training of any kind has been shunned by runners and coaches for many years.

In the last few years there has been a change in thinking. Through the success met by some great athletes and coaches weight trining is being boosted to the fore as prerequisite to top world record performances.

Weight training programs if done properly will consume a great deal of time. The author has found through experience that middle distance and distance runners usually

usually prefer to run than spend countless hours doing exercises with barbells in a weight room. The method of weight training used in this study necessitates little time being spent in the weight room. All of the program is done during the regular training period with the exception of one exercise, the three-quarter squat, which was done in the weight room.

To try and gain some insight as to what was being done in the field of weight training the author sent out letters to some seventy track coaches around the country. The majority of replies stated that they did not know too much about weight training, nor did they have the facilities to attempt anything of this nature. A few coaches sent extensive accounts of their programs while one or two came out against any kind of program because they felt it was detrimental to the runner, and quoted a few examples to prove their point.

## Statement of the Problem

To evaluate the influence of progressive resistance weight training on the performance of middle distance and distance runners.

## Need for the Study

The benefits gained, if any, from weight training for middle distance and distance runners have not definitely been established. Some runners believe that weight training is beneficial, and some say that they owe their success to this type of training. However, so far there has been no proven right way to go about weight training. There are many ideas on what to do, but so far it cannot be stated definitely that any method is better than another or even that weight training really is beneficial.

This study was undertaken to shed some light on the subject and to provide the middle distance and distance runner with a method of acquiring weight training without spending laborious hours in a weight room.

## Limitations of the Study

The limitations of the study were as follows:

1. Psychological factor. It cannot be determined whether the subjects actually were running "all-out" on the treadmill.
2. Experimental group. It was felt that the group may not have worked maximally with the weights on.

3. Subjects. The five freshmen and one sophomore may not have been experienced in intensive training.
4. Length of study. The experiment ran for a period of nine weeks. Weights were still being added when the study had to be concluded.

## Definitions

The following are defined briefly for use in this study.

Progressive Resistance Weight Training. In this study the term refers to gradual increasing of resistance by addition of weights on various selected areas of the body.

Middle Distance Runner. A runner whose race distance is in the area of 440 yards to three-quarters of a mile.

Distance Runner. A runner whose race distance is in the area of one mile, two miles and on up.

Performances. This includes actual races, time trials, all-out treadmill runs, and standard treadmill runs.

All-out Treadmill Runs. Running on the treadmill at 10 miles per hour on an 8.6 per cent incline to a point of complete exhaustion.

Standard Run. Running on the treadmill at 6 miles per hour on the flat for 15 minutes.

## CHAPTER II

## REVIEW OF THE LITERATURE

### Weight Training in the Distance Runners Program

Weight training is a relatively new trend that is gaining momentum in the track and field world. Up until a year or two ago weight-training was encouraged only for field event men, and even then many coaches continued to cast a wary eye on it. When the coach thought of weights, into his mind came the picture of someone with an over-developed body and a large physique.[1, 2] Neither the coach nor the runner wanted anything to do with big muscles so as a result the use of weights has been banned from the training program until this recent trend began. Still, however, there are many who are

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[1] Otis Chandler. Scientific Weightlifting Designed for Track and Field Events. (Mimeograph material) Los Angeles Times.

[2] Percy W. Cerutty. My Views on Weight-Conditioning for Athletes. (Mimeograph material. Through courtesy of Hugh McCreath, Toronto)

dubious about the idea of using them. One only has to look at the literature on track and field techniques and training methods to see how recent weight training is. Of the more than thirty books on track and field in the Michigan State University library only one, that being Modern Athletics by the Achilles Club, mentions anything about weight training. The article was written for this book by W. B. Palmer, a British shot-putter, who took up weight training after talking with Parry O'Brien, the great U. S. shot putter.[3]

What is Weight Training?

At this point it would seem best to clarify what weight training is, and most important what it is not. The confusing of weight training with weight-lifting and body-building is probably the main reason for the difficulty it is having in being accepted. First, it is not weight-lifting, which is a competitive sport in which weights are lifted according to strict rules. The lifters are divided into various weight classes and they are interested strictly in strength. It also is not body-building.

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[3]Achilles Club, Modern Athletics. (London: 1958) pp. 135-46.

The body-builder uses weights to develop big muscles. He wants to look good and does not care if the muscles he builds up perform for him. Weight training, on the other hand, is a system of exercise in which muscular development is gained by employing weights to increase the resistance to muscular contractions.[4, 5, 6, 7]

The coach should not shun the weight-lifter or the body-builder because their goals are not the same as his own. There is, however, a lack of reliable sources on weight training. By studying the basic idea behind, and the results obtained by weight lifters and body-builders the coach can find good material that he can direct toward his athletes.[8]

Pioneers in Weight Training

Professor Theodor Siebert of Germany was one of the foremost pioneers in the field of weight training. He

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[4]L. E. Morehouse and P. J. Rasch. "Weight Training" Scholastic Coach. December, 1948. p. 12.

[5]George Ewing. "Exercise by the Pound." The Athletic Journal. September, 1958. p. 84.

[6]Cerutty, op. cit. p. 2.

[7]Chandler, op. cit. p. 1.

[8]Ewing, op. cit. p. 84.

brought out the merits of progressive weight exercise through experiments with a variety of athletes and weights. In the United States, Otis Chandler, a great shot putter in his day, did a great deal of experimental work on himself and on others. He has written up weight program for most of the field events in which he had his experience. As far as runners go, he leaves them alone but suggests a few exercises for the legs and practically nothing for the upper body.[9]

Success Through Weight Training

> "The upper body, containing as it does the heart and the lungs, when added to great upper body strength can be considered the engine, the source of power. The legs are seen as the wheels and the tires of this powered mechanism."[10]

This is the way Percy Cerutty, the Australian coach, sees the situation. He is very strongly in favor of weight training and the athletes he advises have met with success after being on a weight program. Cerutty states that running is done on the legs rather than with the legs.

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[9] Ray Van Cleef. International Track and Field Digest. (D. Canham, Ann Arbor, 1956) p. 209.

[10] Percy W. Cerutty. Running with Cerutty. (Track and Field News, Los Altos, California, 1959) p. 6.

The vital organs of the body are contained in the upper part of the body, yet runners do nothing about developing this area. They insist on basing all of their training around the legs.[11]

Kranz, points out that the arms and shoulders are not used very strenuously in many sports, also that there is no sport, with the exception of weight-lifting, that sets up developmental exercises.[12] Morehouse and Wilkinson have similar thoughts along this line. They state that usually the sport itself is not sufficient to develop the muscle group involved to their greatest extent.[13, 14] All three men feel that another source must be found to supplement the athletic event being participated in. Wilkinson believes that weight training is the answer to this. Weight training calls all of the muscle fibers in a muscle into use and makes them work at maximum effort which will in turn build up reserve strength.[15]

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[11]Cerutty, Ibid.

[12]Achilles Club. op. cit.

[13]L. E. Morehouse, "The Physiology of Athletics." Scholastic Coach. 10:25, September, 1940.

[14]D. Wilkinson, "The Importance of Weight Training to the Athlete." Track and Field, (Australia) August, 1958 p. 4.

[15]Ibid.

Palmer found that he improved tremendously after being on a weight program. He maintains that many athletes do not realize the value that can be gained from weight training in developing weaker areas of the body. One way that he benefited was in obtaining a stronger more relaxed performance. Palmer is convinced that it is not the weight or resistance that is against the athlete but his own awkward frame which is ill-timed and muscularly uncoordinated. To correct this he advocates a weight program selected to fit each individual athlete. In his mind the distance runner is in fact more in need of development of the upper body than anyone.[16]

Elliott, the Villanova University coach, states that his weight program benefited his athletes in three main ways. One, it developed stamina. The lifting caused the point of fatigue to set in later because the heart had had the opportunity to work at peak or capacity loads more often, hence adjusting to the situation. The circulatory and respiratory systems also had the opportunity to remove the lactic acid under capacity loads. Two, it increased strength. Through the program the athletes built up a progressive resistance

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[16] Achilles Club, op. cit.

to force until they had reached and increased their capacity. Three, it increased speed. The reason for this being the program removed the obstacles to it, fatigue, muscle resistance and resistance in the joints.[17]

Chui studied the effects of a weight training program on students in a physical education class. Both the expeimental and control group participated in the class with the experimental group also performing weight training. The groups consisted of twenty-two and twenty-three subjects. The results showed the experimental group increased in power much more than did the control group.[18]

Cureton has the following to say concerning the lifting of weights:

> More recently, an enormous wave of interest has been observed in weight lifting by the bar-bell method. Competiton has added interest. However, as yet, there is little research on the mechanics of weight lifting and its value is doubted because in the extreme stage of effort it raises the blood pressure to a very high level and would be dangerous for older men. It is unquestionably a good body-builder for young men but seems to be

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[17]James Elliott. Weight Training at Villanova. (Mimeograph material. Through courtesy of Paul Poce, Toronto)

[18]Edward Chui. "The Effects of Systematic Weight Training on Athletic Power." Research Quarterly. 21:188-94, October, 1950.

> worth very little for the improvement of cardiovascular condition of agility.[19]

When Wilson studied the effects of weight training on the physical fitness of young men he found the quality of endurance was lowered and the cardiovascular system was effected very little. However the training did effect the quality of fitness of the experimental group with main emphasis on strength and power.[20]

Training with weights has been a standard practice at the University of California for the last twenty-five or thirty years. The Department of Physical Education there, has offered a regular class in weight training for as long as twenty years. They have no real set program for the student to follow. The instructor examines the student, learns what he desires to do in the way of building strength and the purpose of his urge for strength. A program to fit the needs of the student is then set up by the instructor. They believe, that a strong well trained muscle is better

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[19] T. K. Cureton. Physical Fitness Appraisal and Guidance. (St. Louis: M. V. Mosby Company), 1947. p. 359.

[20] Arthur L. Wilson. "The Effect of Weight Training on the Physical Fitness of Young Men." Unpublished Master's Thesis, University of Illinois, 1947.

able to function than a well trained weak muscle.[21] Palmer is in full agreement with this point. He feels that something more than hours of discipline spent acquiring techniques and habits of style is needed to gain perfection in an athletic movement.[22]

The program at the University of California stresses an overall development of the body. They do not advocate the development of one muscle group to the exclusion of all others. For example, the javelin thrower should not develop his throwing arm and neglect his other arm and legs.[23] Morgan has similar thought along this line. He also feels that a weight program should take into consideration total body development. He points out that the weight events are concerned mostly with the upper body, but as he puts it: "It would be ridiculous to develop the superior aspect of the transverse plane and neglect the foundation."[24]

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[21] Personal Correspondence of the Author, letter from Charles Pease, Supervisor of Physical Education, University of California, February 16, 1960.

[22] Achilles Club, op. cit.

[23] University of California, op. cit. p. 19.

[24] Bill Morgan, "Weight Training for the Weight Events." Scholastic Coach. February, 1960. p. 44.

Does Weight Training Cause Muscleboundness?

The "musclebound" concept along with other factors such as rupture, heart strain and slowness were, and sometimes still are, obstacles that have slowed down the acceptance of the use of weights by athletes and their coaches.[25, 26] However there seems to be no scientific evidence to support the theory that weight training develops muscleboundness.[27, 28]

Capretta conducted a study on this subject. He found that no one knew for sure just what it was. Forty-eight questionnaires were sent out by him to leading physiologists to find out what they thought it was. Only twenty-two answered and of those only seven ventured to give any definite statement of what being musclebound consisted of.

Capretta's opinion of their attitudes toward

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[25]University of California. op. cit. p. 19.

[26]E. K. Capen, "The Effect of Systematic Weight Training on Power, Strength and Endurance." Research Quarterly. 21:83-93. May, 1950.

[27]Ibid.

[28]K. G. Wilkins, "The Effect of Weight Training on the Speed of Movement." Research Quarterly. 23:361-9. October, 1952.

muscleboundness is as follows:

> "The outstanding opinion seems to be that the condition of muscle-bound is associated with hypertrophy, and is a condition of overgrowth or excessive development of the muscles. It is seen commonly when training is associated with severe muscular strain. The excessive development results in a condition of fibrosis resulting in a proponderance of fibrous linen in muscle bundles due to the amount of stress and strain to which the muscle is subjected."[29]

As for the athlete losing flexibility, agility, elasticity or large muscle co-ordination through the use of weights, studies seem to prove other-wise.[30] Morehouse feels that increases in strength through exercise are not usually accompanied by decreases in flexibility or elasticity and the danger of becoming muscle-bound is very slight.[31]

Zorbas and Karpovich studied the effect of weight training on the speed of muscular contractions. Six hundred men, between the ages of eighteen and thirty, were used. The control group consisted of three hundred men

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[29]John Capretta. "The Condition Called Musclebound." Journal of Health and Physical Education. 3:43, February, 1932.

[30]J. E. Counsilman. "Does Weight Training Belong in the Program?" Journal of Health, Physical Education and Recreation. January, 1955. p. 17.

[31]Morehouse, op. cit.

who never indulged in weight training, the experimental group consisted of three hundred men who participated in a weight training program for a minimum of six months and still were engaged in this activity. Rotary movement of the arm was tested and it was concluded that the weight-lifting group was faster in speed than the non-lifters.[32]

Chandler writes that proper supervision of the program is essential. The athlete will not decrease speed, coordination or timing and will definitely not become musclebound or "tied-up" if he is properly supervised in his weight training.[33]

Counsilman found that weightlifting did not create a loss in flexibility, agility or large muscle coordination. He tested three weight-lifting champions and fifteen other competitive weight-lifters. The opposite result was found, the weight-lifters improved and were all above average on the tests.[34]

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[32]W. S. Zorbas and P. V. Karpovich. "The Effect of Weight Lifting upon the Speed of Muscular Contractions." Research Quarterly. 22:145-48. May, 1951.

[33]Chandler, op. cit. p. 1.

[34]Counsilman, op. cit.

Progressive Resistance Exercise in Weight Training

The basic prinicple of this technique is that muscle power is better developed by exercising a muscle a few times at its maximum capacity. This technique has been found to be much better than the other technique where the muscle repeats an exercise many times against less resistance, which produces a quality of endurance.[35]

DeLorme states that each of these two ways of exercising the muscles are incapable of producing the results obtained by the other. However a powerful muscle can be given endurance building exercises and likewise a muscle with great endurance can attain power through power building exercises.[36]

The idea behind progressive resistance is not something new that developed recently. One can go back in history and find examples of it, practiced by the early peoples of the world. Children in Central parts of America walked around with packs containing stones on their

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[35] J. R. Gallagher and T. L. DeLorme. "The Use of the Technique of Progressive Resistance Exercise in Adolescence." Journal of Bone and Joint Surgery. 31:847-58. 1949.

[36] T. L. DeLorme. "The Restoration of Muscle Power by Heavy Resistance Exercise." The Journal of Bone and Joint Surgery. 27:645-67. October, 1945.

backs. As they increased in strength more stones were added. The success of this method of increasing strength was shown by the tremendous loads carried by mature Indians.[37]

It is believed that progressive resistance originated in Greece before the birth of Christ. Milo of Krotona is the supposed originator. He was the man who carried a bull-calf everyday until it reached maturity. As the calf increased in weight, Milo increased in strength. He demonstrated his great strength by carrying a full grown bull twice around the ancient Olympic arena at the games.[38]

Kusinitz and Keeney ran an eight week program of progressive weight training on adolescent boys. The results of the tests showed that there was an improvement in the circulatory-respiratory function and also in strength of the experimental group. The experimentals also improved as much or more than the control group in speed of movement, agility, and flexibility.

After the program was completed the experimentals were put through a medical examination to try and find out if the

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[37]Robert Hoffman, How to be Strong, Healthy and Happy. (York, Pennsylvania: Strength and Health Co., 1938), p. 288.

[38]*Ibid*., p. 293

weight program had been harmful to them. The examination found nothing to qualify this.[39] A definite increase in strength was found by Capen when he studies four programs consisting of heavy resistance exercises.[40]

W. B. Palmer used progressive weight training in his training program for the shot put. He found that maximum performances require maximum development. To obtain maximum development more resistance than that of the body must be used if one is to activate that body with maximum power and efficiency.[41]

The War Department manual on "Physical Reconditioning" states the case this way:

> "If a man is to improve his physical fitness as rapidly as possible, he must exercise to the limit of his tolerance and train for tasks of greater severity than those normally to be face. He must progressively run faster, lift or carry heavier loads or speed up to the tempo or the conditioning drills."[42]

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[39] I. Kusinitz and C. E. Keeney, "The Effects of Progressive Weight Training on Health and Physical Fitness of Adolescent Boys." Research Quarterly. 29:294, 1958.

[40] E. K. Capen, "The Study of Four Programs of Heavy Resistance Exercise for the Development of Muscular Strength." Research Quarterly. 27:132, 1956.

[41] Achilles Club. op. cit.

[42] War Department Technical Manual, "Physical Reconditioning." December, 1944. p. 4.

Cerutty strongly points out that weight training must be progressive to be of any benefit. Strength is relative to resistance and if the resistance is not progressive there can be no increase in strength. It is up to each individual to find the starting weight suitable for himself, then increase from that weight as he gains in strength.[43]

The effects of systematic weight training on coordination and the speed of movement were studied by Masley, Hairabedian and Donaldson. They used three groups in their study; a beginning weightlifting class, a volleyball class and a sports lecture class. It was found that the weightlifting class improved in speed, strength and coordination over the other two groups with no harmful effects to the subjects.[44]

Various programs of progressive resistance have been tried all showing favorable results. Most of the authorities in this area seem to be in general agreement that ten

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[43]Percy W. Cerutty. "Strength Building by Lifting Weights." (Mimeograph material. Through courtesy of Hugh McCreath, Toronto).

[44]J. W. Masley, A. Hairabedian and D. N. Donaldson, "Weight Training in Relation to Strength, Speed and Coordination." Research Quarterly. 24:308-15, October, 1953.

repetitions of any exercise should be the maximum. If the athlete finds that he can do more than ten repetitions he should then increase the weight to the extent that he can only lift it less than ten.[45, 46]

Walters found that ten to twelve repetitions with heavy weights was superior to twenty-two repetitions with light weights. He divided the ninety-four subjects who volunteered for the seven week experiment, arbitrarily into Group A, consisting of forty-eight subjects, and Group B, consisting of forty-six subjects. The final tests showed that the weight training program that employed ten to twelve repetitions made superior gains in strength and endurance of the arms.[47]

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[45] S. J. Houtz, A. M. Parrish and F. A. Hellebrandt. "The Influence of Heavy Resistance Exercise on Strength." Physiotherapy Review. 26:299-304. 1946.

[46] T. L. DeLorme and A. L. Watkins. "Techniques of Progressive Resistance Exercise." Archives of Physical Medicine. 29:263-73. May, 1948.

[47] B. R. Walters. "The Relative Effectiveness of High and Low Repetitions in Weight Training Exercise on Strength and Endurance of the Arms." Unpublished M. A. Thesis, State University of Iowa. 1949.

# CHAPTER III

# RESEARCH METHODS

This study was undertaken to determine the effect of progressive weight training on endurance performance. The methods of assessment are presented in this chapter.

## Weight Training Program

In the early stages of planning this study the basic idea was to put the experimental group through a program of extensive weight training using the weight room and all the equipment in it. However, when the author finally decided on the exercises to be covered in the program, it was seen that it would take a great deal of time, daily, to get through his program.

The method decided upon required weights to be attached to the runners wrists, ankles and waist while he performed his regular training program. Weekly, these weights would be increased to a point where it was felt a maximum had been reached. Also prior to each weight training session the experimental group performed five repetitions of a three-quarter squat at maximal load.

The advantages of this method were that it would not require a great deal of time in the weight room by the participants in the program. The weights on the wrists would bring into use muscle groups in the upper body that were not used excessively in the actual running movement. The weights on the ankle would develop the leg return but not the leg drive as the foot is stationary on the ground during the driving movement. Therefore, the three-quarter squat was added to the program to develop the leg drive.

Selection of the Starting Weight

The problem came up as to how much weight should be used in the equipment during the first week of the study. This was arrived at by the author taping various lead weights to his wrists, ankles and waist, and running with them. The result of this was that four ounces seemed to be the best weight of the wrist and ankles. On the waist it was decided, also, to have four ounces. This was because it was felt that some sort of balance should be kept throughout.

The addition of weights was selected arbitrarily by the author. It was decided to increase the weights every

Monday by adding four ounces more, and to keep adding until it was felt maximum had been reached.

Design of Equipment

The wristlet, anklet and waitbelt used to hold the weights were designed after the starting weight and increases had been decided upon. The McGregor Co., makers of sports equipment, had an anklet in the form of a spat with five pockets on either side to take lead slugs. The author used this as a base for his anklet but lined it on the inside with a soft felt material so as to be more comfortable on the runner. The wristlet was also lined to prevent chaping, and was fastened around the wrist by two straps. It had pockets into which the lead slugs would fit. The waistbelt had four pockets of a canvas type material into which square four ounce slugs would fit.

Selection of Subjects

The selection of subjects was limited to a small group of freshmen and sophomore runners. Two groups of three subjects each were randomly selected from five freshmen and one sophomore track team candidates. A random selection was again made to decide which group would be the experimental group and which would be the control group.

On the experimental group were two freshmen and one sophomore. On the control group were three freshmen.

## The Experimental Factor

The experimental group only participated in the weight training program. The program consisted of wearing a wristlet on each wrist, an anklet on each ankle and a waistbelt. Also prior to each weight training session they performed five repetitions of a three-quarter squat with a maximal load. This program was carried out three times per week, on Mondays, Wednesdays and Fridays. On the first Monday of the experimental period four ounces were added to the equipment. On the Monday of each week following this, up to the ninth week, four ounces were progressively added.

The control group did not participate in any weight training program but performed their regular training program as usual.

## Testing Procedure

a) The basic test consisted of meeting once a week, on Mondays, for an all-out treadmill run. The treadmill was set at an incline of 8.6 per cent and run at a speed of ten miles per hour. The runner had to run to complete exhaustion before coming off the mill. Spotters were stationed on either side of the mill in order to help the exhausted runner off the mill.

The timing of the all-out runs was done by using two stop watches, accurate to one-tenth of a second. They were started when the runner's foot came in contact with the mill at the start of the run and were stopped when the runner's foot left the mill at the end of the run.

b) Energy cost of all-out treadmill run studied after the first and ninth run.

c) Energy cost of standard run studied after the first and ninth weeks.

## Statistical Techniques

The statistical techniques used in this study were the analysis of variance and the "t" test of significance.

## CHAPTER IV

## PRESENTATION AND ANALYSIS OF THE DATA

### Treatment of the Data

The data has been segmented into two parts. The first part deals with the comparison of the all-out runs with respect to individual and group times. The second part deals with the comparison of the energy cost requirements of the experimental and control groups. Both of these comparisons were taken from the all-out and standard runs during the first and ninth week.

The analysis of the first group was made in the following manner. A comparison was made on the basis of time using analysis of variance analyzing the all-out run times of the groups, individuals, runs, and the groups times runs interaction.

The energy cost data were analyzed using the "t" test to determine the significance of the difference in improvement of the control group and the experimental group for both the standard and all-out runs. In calculating the differences between the experimental and control groups the results of the first run were subtracted from the results of the second run. In the "t" analysis the experimental group value was subtracted from the value obtained for the control group. This procedure resulted in positive and negative "t" values. A negative "t", therefore, shows a greater effect (larger difference) upon the experimental group and a positive "t" a greater effect upon the control group.

Presentation of the Data

a) Test Results. The results of the analysis of both groups are presented in Tables I and II and in Figure I-V. The raw data are presented in Appendix A-D.

b) Discussion. The analysis of variance of the all-out runs indicated that there was no significant difference between the performance of individuals. These differences can be attributed in the most part to limitations of the study already mentioned. There also was a significant difference in the comparison of runs. This would be expected for both groups due to the implementation of the regular training program. Also there is clearly no significant difference in 'groups times runs' interaction which means that the groups responded similarly in all-out run performances through the training program.

TABLE I

RESULTS OF THE ENERGY COST ANALYSIS

| | All-out Run | Standard Run |
|---|---|---|
| Exercise Ventilation | 0.050 | -0.648 |
| Exercise Oxygen Intake | 4.375* | -4.281* |
| Exercise Intensity | 1.336 | 2.691 |
| Exercise Respiratory Quotient | ----- | 1.857 |
| Gross 15 Minute Debt | -2.209 | -6.564** |

*P=.05 **P=.01

TABLE II

ANALYSIS OF VARIANCE OF ALL-OUT RUNS

| | D.F. | S.S. | M.S. | F. |
|---|---|---|---|---|
| Groups | 1 | 676 | 676.00 | 1.52 |
| Individuals | 4 | 15,894 | 3,974.50 | 8.95* |
| Runs | 8 | 25,682 | 3,210.25 | 7.23* |
| Groups x Runs | 8 | 4,192 | 524.00 | 1.18 |
| Error | 32 | 14,215 | 444.22 | |
| Total | 53 | 60,659 | | |

*P=.01

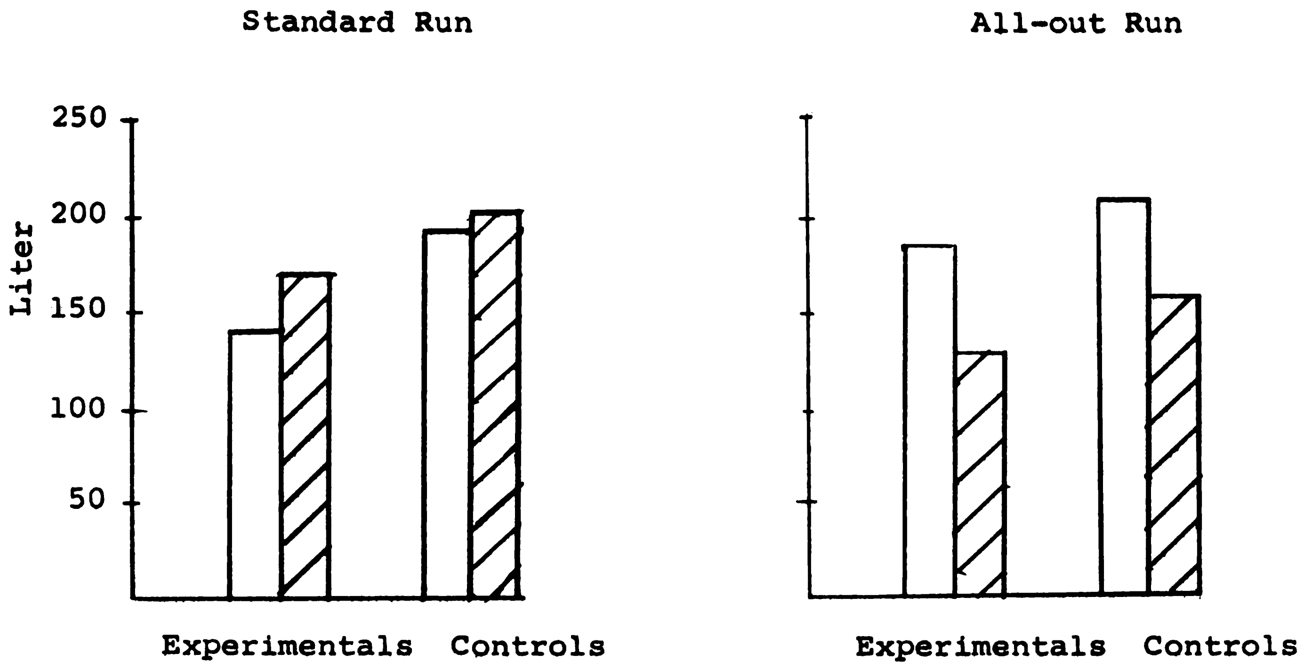


Figure 1. Exercise Ventilation

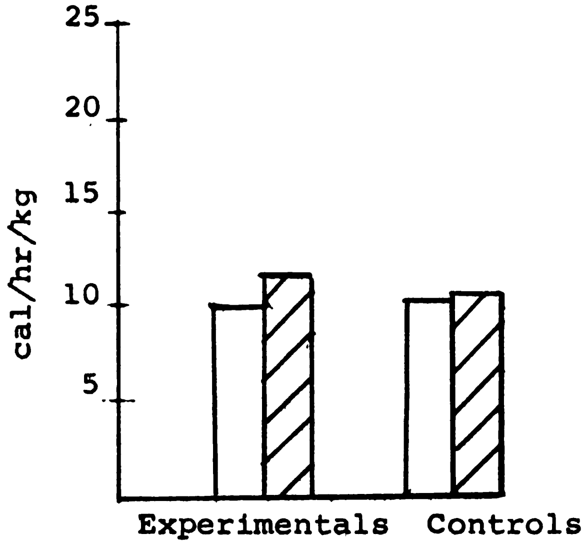


Figure 2. Exercise Intensity

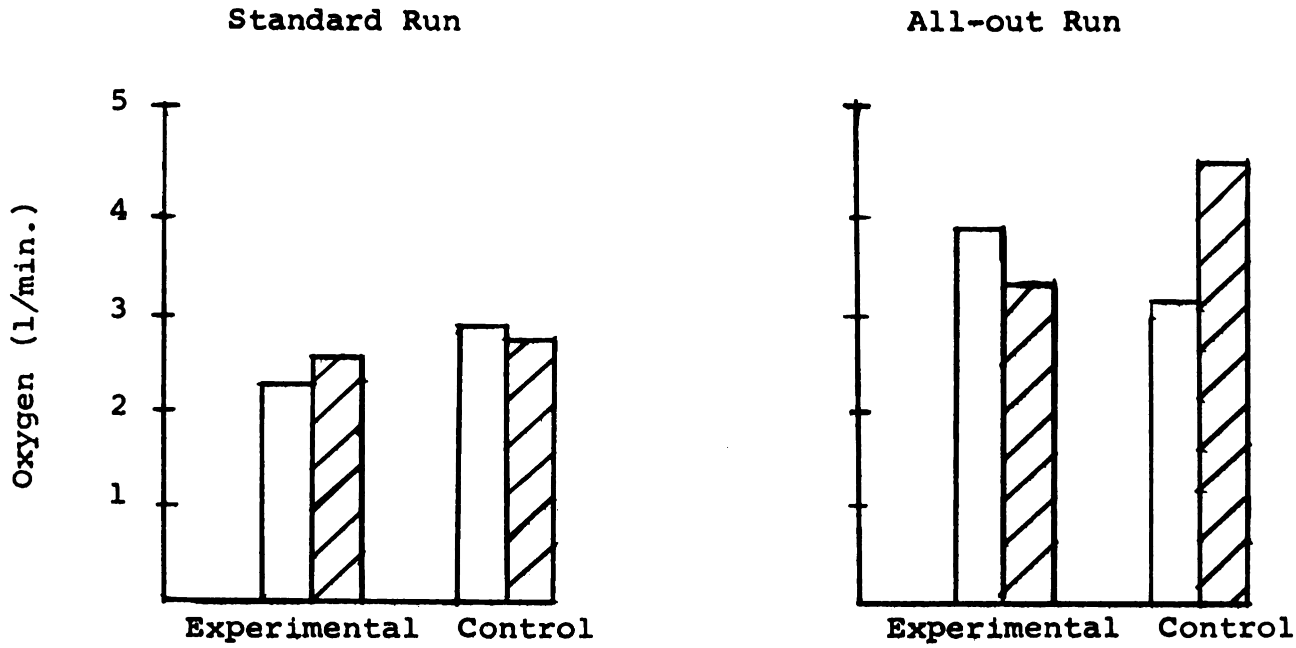


Figure 3. Exercise $O_2$ Intake

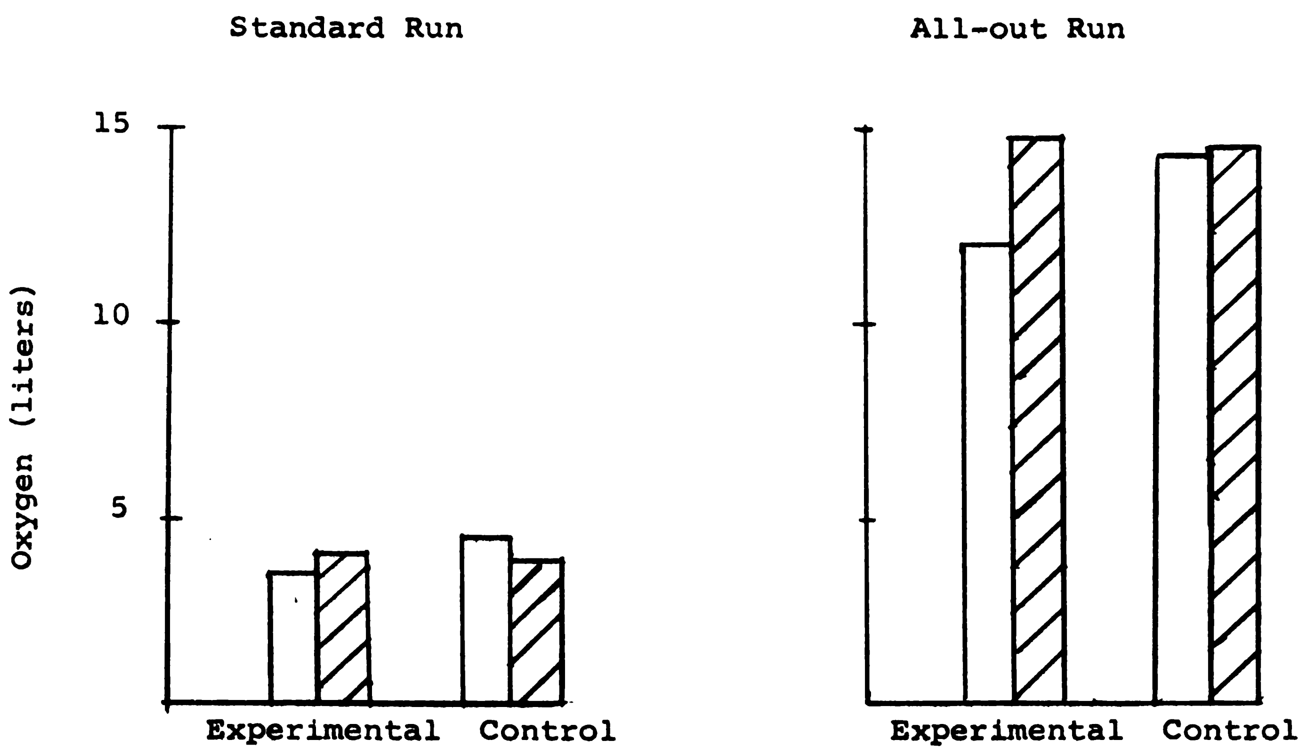


Figure 4. Gross $O_2$ Debt (15 Minutes)

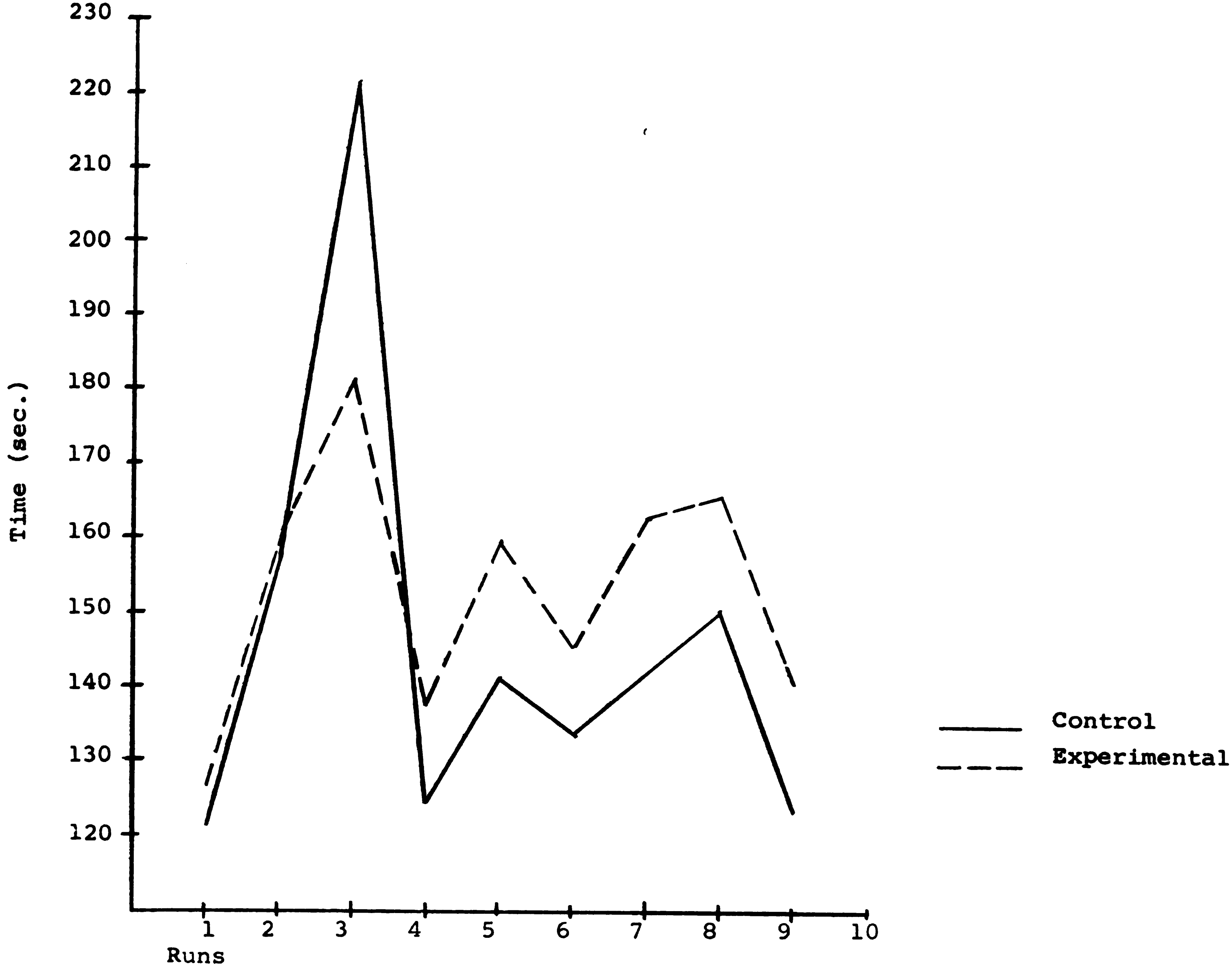


Figure 5. All-out Runs

The significant differences found in the energy cost study were found in the Oxygen uptake, fifteen minute debt of the standard run and in the Oxygen uptake of the all-out run. The negative "t" shown for the gross oxygen uptake and fifteen minute debt indicates a significantly greater energy expenditure for the experimentals in the standard run. It may be that because the experimental group took part in the weight training program they developed new muscle patterns. These new muscle patterns could have required an increase in the need for more oxygen which resulted in a greater oxygen intake and debt than that of the controls. This shows that the experimental group was less economical than the control group. This interpretation is further confirmed by the significant decrease in Oxygen uptake during the all-out run and the slightly greater debt of the experimentals. There may be some localized impairment of circulation in the muscle but unfortunately this was not studied.

## CHAPTER V

## SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

### Summary

The purpose of this study was to evaluate the influence of weight training on the performances of middle distance and distant runners.

Two groups of three subjects each, randomly selected, were used. The experimental group consisted of two freshmen and one sophomore track team candidates. This group participated in a weight training program. The program consisted of training three times a week wearing a pair of wristlets, a pair of anklets, and a waistbelt to which weights were progressively added. Also included in the program was a three-quarter squat performed maximally for five repetitions.

The control group consisted of three freshmen track team candidates. This group did not participate in the weight training program.

All subjects were timed every Monday of each week for all-out runs. During the first and ninth weeks the energy cost tests were run.

The data are presented graphically and tested statistically using the analysis of variance and the "t" test of significance.

Conclusions

The following conclusions were drawn from the analysis presented.

1. There were no significant differences in the over-all running performance of the two groups.

2. Individuals participating in progressive weight training as used in the present study run less economically.

Recommendations

The recommendations of this study are as follows:

1. It is recommended that a similar study be set up and run in such a manner that will enable the experimenter to study just how much weight can be added, as the maximum was not reached in this study.

2. Due to the small number of subjects used, it is recommended that this study be repeated with more subjects.

3. It is recommended that another test, other than the all-out run, should be used. The author feels that after the first three all-out runs it was questionable whether

some of the subjects were running to exhaustion on the treadmill.

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# APPENDIX

## APPENDIX A RAW DATA

### Inital Test

| | Resting R.Q. | Resting $O_2$ Intake | Exercise Ventila-tion | Exercise $O_2$ Intake | Exercise Intensity (cal/hr/kg) | Exercise R.Q. | R.Q. Rec. # 1 | R.Q. Rec. # 2 |
|---|---|---|---|---|---|---|---|---|
| **Control Group All-out Run** | | | | | | | | |
| F.W. | .69 | .369 | 241.5 | 3.784 | 14.288 | .87 | 1.22 | .91 |
| R.L. | .73 | .305 | 178.5 | 2.078 | 8.707 | .93 | 1.43 | .99 |
| R.H. | .78 | .351 | 202.75 | 3.207 | 12.02 | 1.20 | 1.55 | 1.20 |
| Means | .73 | .341 | 207.58 | 3.023 | 11.67 | 1.00 | 1.40 | 1.03 |
| **Experimental Group** | | | | | | | | |
| O.L. | .74 | .373 | 210.36 | 3.877 | 11.628 | .95 | .97 | .97 |
| W.G. | .79 | .377 | 183.08 | 3.699 | 17.85 | 1.00 | 1.10 | .90 |
| R.B. | .81 | .261 | 150.43 | 3.892 | 16.77 | .91 | 1.39 | .92 |
| Means | .78 | .337 | 181.29 | 3.812 | 15.41 | .95 | 1.15 | .93 |
| **Control Group Standard Run** | | | | | | | | |
| F.W. | .75 | .379 | 183.6 | 2.791 | 9.97 | .75 | .73 | ---- |
| R.L. | .58 | .432 | 200.2 | 2.54 | 10.064 | .75 | .75 | ---- |
| R.H. | .83 | .388 | 204.35 | 2.812 | 9.947 | .75 | .87 | ---- |
| Means | .72 | .399 | 196.05 | 2.714 | 9.993 | .75 | .78 | ---- |

## APPENDIX A (Continued)

| | Resting R.Q. | Resting $O_2$ Intake | Exercise Ventilation | Exercise $O_2$ Intake | Exercise Intensity (cal/hr/kg) | Exercise R.Q. | R.Q. Rec. # 1 | R.Q. Rec. # 2 |
|---|---|---|---|---|---|---|---|---|
| Experimental Group | | | | | | | | |
| O.L. | .69 | .396 | 143.38 | 1.844 | 9.219 | .77 | .76 | ---- |
| W.G. | .75 | .276 | 147.81 | 2.246 | 9.385 | .70 | .76 | ---- |
| R.B. | .69 | .299 | 149.77 | 2.546 | 10.430 | .71 | .73 | ---- |
| Means | .69 | .323 | 146.98 | 2.212 | 9.648 | .72 | .75 | ---- |

## APPENDIX B RAW DATA

### Initial Test (Continued)

| | Gross Debt # 1 | Gross Debt # 2 | Gross 15 Min. Debt | Net 15 Min. Debt | Gross $O_2$ Cost | Net $O_2$ Cost | Gross Calorific Cost | Net Calorific Cost |
|---|---|---|---|---|---|---|---|---|
| Control Group All-out Run | | | | | | | | |
| **F.W.** | 6.966 | 7.627 | 14.593 | 9.058 | 27.08 | 20.33 | ---- | ---- |
| **R.L.** | 6.937 | 7.929 | 14.866 | 10.018 | 23.84 | 18.57 | ---- | ---- |
| **R.H.** | 6.576 | 6.473 | 13.049 | 5.265 | 22.03 | 15.78 | ---- | ---- |
| **Means** | 6.826 | 7.343 | 14.169 | 8.263 | 24.31 | 18.22 | ---- | ---- |
| Experimental Group | | | | | | | | |
| **O.L.** | 7.413 | 5.997 | 13.41 | 8.188 | 25.54 | 19.16 | ---- | ---- |
| **W.G.** | 6.198 | 6.664 | 12.862 | 7.262 | 21.55 | 15.01 | ---- | ---- |
| **R.B.** | 5.249 | 5.057 | 10.306 | 6.391 | 18.52 | 14.05 | ---- | ---- |
| **Means** | 6.286 | 5.907 | 12.192 | 7.262 | 21.87 | 16.07 | ---- | ---- |

## APPENDIX B (Continued)

| | Gross Debt # 1 | Gross Debt # 2 | Gross 15 Min. Debt | Net 15 Min. Debt | Gross $O_2$ Cost | Net $O_2$ Cost | Gross Calorific Cost | Net Calorific Cost |
|---|---|---|---|---|---|---|---|---|
| | | | Control Group | Standard Run | | | | |
| F.W. | ---- | ---- | 3.939 | 2.044 | 45.804 | 38.224 | 216.97 | 181.05 |
| R.L. | ---- | ---- | 3.554 | 1.39 | 41.654 | 33.014 | 197.39 | 156.49 |
| R.H. | ---- | ---- | 4.407 | 2.72 | 42.180 | 39.827 | 221.88 | 183.88 |
| Means | ---- | ---- | 3.966 | 2.051 | 43.21 | 37.02 | 212.08 | 173.80 |
| | | | Experimental Group | | | | | |
| O.L. | ---- | ---- | 2.821 | .84 | 30.481 | 22.561 | 145.17 | 110.06 |
| W.G. | ---- | ---- | 2.334 | 1.38 | 36.024 | 30.504 | 168.96 | 142.82 |
| R.B. | ---- | ---- | 3.447 | 1.952 | 41.637 | 35.657 | 195.36 | 167.34 |
| Means | ---- | ---- | 2.867 | 1.390 | 36.04 | 29.57 | 169.83 | 140.07 |

# APPENDIX C RAW DATA

## Final Test

| | Resting R.Q. | Resting $O_2$ Intake | Exercise Ventila-tion | Exercise $O_2$ Intake | Exercise Intensity (cal/hr/kg) | Exercise R.Q. | R.Q. Rec. # 1 | R.Q. Rec. # 2 |
|---|---|---|---|---|---|---|---|---|
| Control Group All-out Run | | | | | | | | |
| F.W. | .74 | .415 | 156.6 | 5.490 | 20.73 | .83 | 1.15 | .79 |
| R.L. | .70 | .314 | 128.83 | 3.422 | 14.358 | .94 | 1.35 | .92 |
| R.H. | .70 | .309 | 176.05 | 4.650 | 18.410 | .94 | 1.16 | .85 |
| Means | .71 | .346 | 153.82 | 4.520 | 17.83 | .90 | 1.22 | .85 |
| Experimental Group | | | | | | | | |
| O.L. | .88 | .360 | 162.53 | 3.914 | 20.175 | 1.04 | 1.34 | .94 |
| W.G. | .73 | .297 | 143.06 | 3.314 | 16.542 | .95 | 1.33 | .86 |
| R.B. | .73 | .190 | 72.98 | 2.154 | 9.297 | .73 | .85 | .93 |
| Means | .78 | .282 | 126.19 | 3.127 | 15.33 | .90 | 1.17 | .91 |
| Control Group Standard Run | | | | | | | | |
| F.W. | .79 | .371 | 227.6 | 2.724 | 9.92 | .82 | .81 | ---- |
| R.L. | .80 | .322 | 206.85 | 2.606 | 10.543 | .85 | .86 | ---- |
| R.H. | .77 | .359 | 182.29 | 2.697 | 9.654 | .76 | .75 | ---- |
| Means | .78 | .350 | 205.58 | 2.675 | 10.039 | .81 | .80 | ---- |

## APPENDIX C (Continued)

Experimental Group

| | Resting R.Q. | Resting $O_2$ Intake | Exercise Ventilation | Exercise $O_2$ Intake | Exercise Intensity (cal/hr/kg) | Exercise R.Q. | R.Q. Rec. # 1 | R.Q. Rec. # 2 |
|---|---|---|---|---|---|---|---|---|
| O.L. | .78 | .292 | 157.2 | 2.295 | 10.969 | .64 | .78 | ---- |
| W.G. | .78 | .310 | 194.6 | 2.724 | 13.128 | .80 | .88 | ---- |
| R.B. | .84 | .347 | 161.33 | 2.645 | 10.819 | .73 | .64 | ---- |
| Means | .80 | .316 | 171.04 | 2.554 | 11.638 | .72 | .76 | ---- |

# APPENDIX D RAW DATA

## Final Test (Continued)

| | Gross Debt # 1 | Gross Debt # 2 | Gross 15 Min. Debt | Net 15 Min. Debt | Gross $O_2$ Debt | Net $O_2$ Debt | Gross Calorific Cost | Net Calorific Cost |
|---|---|---|---|---|---|---|---|---|
| **Control Group All-out** | | | | | | | | |
| F.W. | 7.711 | 6.592 | 14.303 | 8.078 | 22.76 | 15.895 | ---- | ---- |
| R.L. | 6.884 | 7.012 | 13.896 | 9.186 | 28.254 | 22.885 | ---- | ---- |
| R.H. | 8.384 | 6.898 | 15.282 | 10.647 | 25.281 | 19.982 | ---- | ---- |
| Means | 7.659 | 6.834 | 14.493 | 9.303 | 24.76 | 19.58 | ---- | ---- |
| **Experimental Group** | | | | | | | | |
| O.L. | 6.812 | 7.343 | 14.155 | 8.755 | 23.159 | 16.931 | ---- | ---- |
| W.G. | 7.106 | 6.442 | 13.548 | 9.093 | 20.872 | 15.761 | ---- | ---- |
| R.B. | 9.871 | 7.267 | 17.138 | 14.333 | 18.901 | 15.649 | ---- | ---- |
| Means | 7.929 | 7.017 | 14.947 | 10.727 | 20.97 | 16.11 | ---- | ---- |

**APPENDIX D (Continued)**

| | Gross Debt # 1 | Gross Debt # 2 | Gross 15 Min. Debt | Net 15 Min. Debt | Gross $O_2$ Cost | Net $O_2$ Cost | Gross Calorific Cost | Net Calorific Cost |
|---|---|---|---|---|---|---|---|---|
| Control Group Standard Run | | | | | | | | |
| **F.W.** | ---- | ---- | 3.068 | 1.205 | 43.928 | 36.508 | 208.12 | 172.60 |
| **R.L.** | ---- | ---- | 3.167 | 1.557 | 42.257 | 35.817 | 205.53 | 174.63 |
| **R.H.** | ---- | ---- | 3.334 | 1.539 | 43.789 | 36.609 | 208.04 | 173.84 |
| **Means** | ---- | ---- | 3.189 | 1.433 | 43.32 | 36.41 | 207.23 | 173.69 |
| **Experimental Group** | | | | | | | | |
| **O.L.** | ---- | ---- | 2.724 | 1.264 | 37.149 | 31.309 | 174.31 | 146.43 |
| **W.G.** | ---- | ---- | 3.269 | 1.72 | 44.129 | 37.929 | 212.17 | 181.17 |
| **R.B.** | ---- | ---- | 3.482 | 1.747 | 43.157 | 36.217 | 203.33 | 169.69 |
| **Means** | ---- | ---- | 3.158 | 1.577 | 41.47 | 35.151 | 196.60 | 165.76 |