THE EFFECTIVENESS OF TWO INTERVAL TRAINING PROGRAMS ON THE IMPROVEMENT OF SPEED IN RUNNING THE 220 YARD DASH IN YOUNG WOMEN

Thesis for the Degree of M. A.

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Eleanor Cecilia Rynda

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THE EFFECTIVENESS OF TWO INTERVAL TRAINING PROGRAMS ON THE IMPROVEMENT OF SPEED IN RUNNING THE 220 YARD DASH IN YOUNG WOMEN

By

Eleanor Cecilia Rynda

AN ABSTRACT OF

A THESIS

Submitted to
Michigan State University
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ABSTRACT

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<u>Purpose</u>

The purpose of this study was to investigate the effectiveness of two interval training programs on the improvement of speed in running the 220 yard dash in young women. Thirteen healthy college women ages 19-22 were the subjects. Two experimental groups and one control group were used. One experimental group trained by running short sprints of 60 yards four days per week; the other group trained by running 60 yard sprints two days per week and 300 yard runs two days per week. Both groups trained for five weeks. The control group did not participate in a special training program.

All subjects were tested before and after five weeks of training. The tests included: time for running 220 yards, energy metabolism and heart rate during an all-out treadmill run to exhaustion and during a standardized treadmill run of 10 minutes, and leg strength.

The results were analyzed using analysis of variance to determine the significance of the differences in mean changes among the three groups.

Conclusions

Based on the statistical data presented, the following conclusions seem justified:

1. There was no significant improvement in running speed over 220 yards for either experimental group. However, a general tendency for greater improvement of both experimental groups over the Control Group, and of experimental Group B over experimental Group A is indicated.
2. Both experimental groups improved significantly in athletic endurance performance as measured by an all-out run.
3. Experimental Group A improved significantly in the maximum ventilation reached during the all-out run.
4. No significant changes in heart rate occurred as a result of training in either group.
5. No significant improvements in leg strenth were observed. However, data seems to indicate a greater tendency for improvement in strength in experimental Group A, the sprint group, than for experimental Group B, the sprint and overdistance group.

Recommendations

The following recommendations are made as a result of this study:

1. A similar investigation using a larger number of subjects should be made.
2. The training period should be carried on for a longer period of time than five weeks. Experience and observation indicate that the subjects were just reaching the point of intensive training. An eight or nine week training program may yield different results.
3. Untrained runners who have a strong interest in running and a firm desire to improve running speed should be used as subjects.
4. Various sprint training distances should be investigated.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF APPENDICES

TABLE		PAGE

CHAPTER I

INTRODUCTION

In the quest for better race times on the track, various methods of training have been employed by coaches and athletes. Most of these training programs have been handed down from coach to athlete through the years with changes being made on a trial and error basis depending on the relative success of the performer. Quite a number of theories, ideas and schedules are being used to train runners with little scientific evidence supporting them. Recently there is a greater tendency for scientific research to become translated into practice as the basis of support for present day training methods. This is particularly true for men. Little has been done for women.

It has been the usual practice for an athlete who wishes to compete in the 220 yard dash, to train for this event by running several short distances under 220 yards and several distances longer than 220 yards. Today, with the use of interval training, it is believed that an athlete will train best for this race by running distances shorter than the 220 race distance itself, at a pace faster than the race pace, with a measured rest interval, repeating this many times during a workout. At no time in a specific interval training program does the athlete train by running the actual 220, or any distance over 220, except of course the jogging done for warmup and for tapering off at the end of the workout.

There are many approaches utilizing interval training programs. These being dependent on the ultimate speed-goal of the athlete in the particular event for which he trains.

Purpose of the Study

It was the purpose of this study to investigate the effectiveness of two interval training programs on the improvement of speed in running the 220 yard dash in young women.

Definition of Interval Training

Interval training is a system of repeated efforts in which a distance of measured length is run on a track at a timed pace alternately with measured recovery periods of low activity(22).

In this study, interval training for the sprint group consisted of repeat runs over 60 yards at a timed pace followed by a measured recovery period of walking after each run. Interval training for the sprint and overdistance group consisted of repeat runs over 60 yards for two days per week, and repeat runs over 300 yards for two days per week, at a timed pace with a measured recovery period of walking after each effort.

Need for the Study

Little scientific evidence is available concerning the comparative merits of specific interval training programs. What data does exist has been done from research with men. No data has been done in this area with women.

Limitations of the Study

1. Untrained runners were used as the subjects
   a. They had no knowledge of pace when running.
   b. A large part of success in the performance of an athlete lies in the desire to apply oneself diligently to the task at hand. It was not possible to measure this desire.
2. The psychological factor of getting an individual to go all-out in a certain criterion measure (treadmill run to exhaustion).
3. The size of the sample was limited by practical problems.
4. The sample was non-randomized and based on volunteer subjects.

CHAPTER II

REVIEW OF RELATED LITERATURE

A search of the literature on interval training revealed no previous research done with women in an interval training program for a specific event in track and field. There is considerable interest surrounding the physiological principles behind training in general. Abundant information concerning the general effect of running on physiological functions and work performance has been presented by various investigators with results that can be stated quite emphatically. However, little information exists in the literature on the comparative merits of different methods of interval training.

The review of literature presented here will deal with the evolution of interval training, statements regarding interval training practices, the physiological basis behind interval training, and pertinent studies related to physiological changes as affected by training with special emphasis on heart rate, ventilation and strength.

Evolution of Interval Training

To attempt to pinpoint the actual beginning of interval training as it is known and used today is not possible.

There is no general agreement as to exactly when and where it first began. Doherty asserts "No one person or country can be credited with the invention of Interval Training" (21, p. 177). The concept of interval training expanded from training methods that preceded it. It is believed by many as evolving from the Swedish Fartlek system where the athlete trains by running informally over unmarked areas at alternately fast and slow speeds (70). Pikhala, an outstanding Finnish distance runner, and later coach, stressed the rhythm between work and rest periods in his method of Tarrace training in the 1920's (64). His principles were applied by Paovo Nurmi, Finland's legendary long-distance runner in the twenties. Gosta Holmer, National Coach of Sweden, after studying Nurmi's methods, popularized the Fartlek system by adapting these principles to the Swedish conditions so his training involved running both in the woods and pace running on the track daily (64).

Gerschler introduced the Finnish training method to Germany. He noticed a lack of speed work in the training of Nurmi, and his theory was to increase speed without reducing endurance. His subject, Harbig, trained by running ten consecutive repetitions of 400 meters and shortly thereafter became 400 meters champion of the world (64). At that time, this number of repetitions at that distance was considered an extremely difficult and punishing workout. Questions arose concerning possible overstrain of the athlete (24).

World War II interrupted the works and ideas of Gerschler and Harbig. The great Czechoslovakian runner, Emil Zatopek, revived interest just after the war (24) by running as many as 60 repetitions of 400 meters in his training sessions with jogging intervals after each (69). His success in the 1952 Olympics, where he won three gold medals, gained much support for this method of training and it has been continued and modified by coaches and champions into what is known in present day practices as interval training.

Statements Regarding Interval Training Practices

The purpose of any conditioning program is to develop the athlete's body so that it will be able to resist fatigue (26) and the principle objective of the runner in training is "to run a specified distance as fast as possible" (25, p. 593). This then must be considered the purpose of interval training. It has become universally accepted by modern coaches as the most effective system for conditioning athletes (26). The basic principle behind interval training being "endurance through speed" (24, p. 574). This places the emphasis on quality or intensity of work rather than on quantity of work as was the custom in the past.

There is general agreement among writers as to the variables in interval training. These variables are: (1) distance of the work interval, (2) speed of the work interval, (3) number of repetitions of the work interval, and (4) length of the rest interval (22, 26, 29, 38, 70).

Doherty also includes ease as a variable in interval training and states that "one cannot be said to have mastered a given workout or task until one can do that task with relative ease, with full relaxation and certainty of willed control, despite its hardships and the pains of fatigue"(92l, p. 186). The action or activity during recovery is a further consideration according to Wilt (70). This action may be walking or jogging.

A number of opinions exist concerning each of these variables. How long should the distance of the runs be during interval training? Down writes, "the one prerequisite is that the distance chosen must be of sufficient length to create adequate stress--both physical and mental." He continues, "In general, empirical knowledge demands that the fast sectors should be long enough to bring in some sustained effort at the correct racing rhythm, but short enough to permit a little faster than racing speed" (25, p. 595).

Nett states, "the duration of the individual exertion (run) should be one minute at the most" (57, p. 200).

Hollman says the duration of effort should be relatively short and not longer than 30 seconds (64).

Heusner suggests using a single work interval of a fraction of the total race distance and chose 1/4 in proposing a hypothetical interval training program for a mile runner (38).

In training for middle and long distance, Gerschler, after experimenting over different distances, concludes that 100 or 200 meter (100-200 yards) distances are best. He added 400 meters later but reported finding that the results of 400 meter repetitions in interval training were not as good as those with the 200 meters repetitions, because the oxygen debt is partly paid off during the 400 meter run (30).

Hildreth simply says that the interval unit is usually an even distance such as 220, 440, or 660 yards which can be conveniently related in time to the pace of the runner's chosen event (39).

Regarding the second variable in interval training, speed or pace of the work interval, Gerschler says the intensity should be enough to bring the heart rate up to 170 or 180 beats per minute (65).

Hollman suggests taking the athlete's maximum performance and adding 20 per cent to it (64, as reported by Smit).

Nett states that "Intensity of the individual exertion should be such as to produce a pulse frequency of 120 to 140 at the end of the pause" (57, p. 200).

The opinion of Heusner is that the first several work intervals should be performed at a high enough work rate to bring the subject up to his oxygen debt tolerance quickly (38).

"Just decide the time the athlete should hit in his next competition, considering the athlete's ability and present condition, and multiply that time by the fraction of the race distance that is going to be run. The fraction of the race time run will be the same as the fraction of the distance run" is the suggestion by Ecker (26, p. 62).

Alford relates that the speed of the fast intervals will be a little faster than the average speed for the race of which an athlete is capable (1).

Wilt makes the following suggestions:

> Repetitions of 110 yards may be run at 1 1/2 to 2 1/2 seconds slower than your best 110 yards mark. Repetitions of 220 yards may be run 3 to 5 seconds slower than your best 220 yards. 440 yards repetitions may be run in 1 to 4 seconds faster than your average racing pace. Thus a 4:00 minute miler would run 440 yards repetitions in 59 to 56 seconds. Longer distances than 440 yards may be run at racing pace, but the distance above 440 yards should not exceed half the total racing distance at this speed (70, p. 45).

Relating to variable three, the number of repetitions of the work interval, no appreciable agreement among the writers was found as there is no scientific evidence available at the present time in this regard and decisions were made subjectively depending on fitness of the athlete. "When properly conditioned, the athlete should be able to run from one and one-half to three times his total race distance in practice without altering his pace or interval" states Ecker (26, p. 64).

Alford feels that the length of the fast intervals will be such that they entail a fair amount of sustained effort and yet short enough to enable an athlete to undertake about twice as many intervals as are found in his actual race (1).

In speaking of repetitions of 220 yards, Smit reports

> The number of times the 220 yards should be run will naturally depend on the athlete's condition, but usually the number of sprints vary from 10 to 20 with rest periods of 90 seconds after each. Then a longer rest period is introduced until the athlete is well rested. After that the whole series of 10, 12, 15, or 20 X 220 yards spurts are again repeated as above. On the whole, the series is repeated about five times during one training session" (64, p. 184).

In a conversation with Gerschler, Doherty reports that Gerschler seemed to feel that 20 repetitions was a sufficient number to produce optimum development in a single practice (22).

Wilt (70) suggests two or three times actual racing distance as a general rule, except for international-caliber and long distance runners.

In the discussion of variable four, the length of the rest interval, consideration will also be given to statements about the action or activity during the rest interval.

In working with 3,000 subjects in Germany, Gerschler and his associate, cardiologist Dr. Reindell, report that 180 beats per minute represented somewhat of a limit for heart rate in the course of physical exercise. From this 180 beats per minute, the heart is permitted 1 minute, 30 seconds to return to 120 or 125 beats per minute; if it takes longer, it is because the effort demanded was (1) either too violent, or (2) too long. When the pulse has returned to 120-125 beats per minute, the runner is able to, and ought to, begin running again even if the heart took less than 1 minute, 30 seconds to recover (65).

Wilt (70) agrees with this theory of permitting the heart rate to decrease to 120 beats per minute or less as the determining factor in length of recovery. He suggests this may be determined quickly by holding the hand over the heart for 10 seconds during which time there should be 20 beats or less. He finds recovery is twice as rapid by walking as by jogging when judged by heart rate recovery.

"It is recommended that it should never be less than 30 seconds and not more than 90 seconds" according to Hollman (In 64, reported by Smit).

Heusner's (38) subjective judgment is that the rest interval should be increased if the athlete is unable to complete at least six repetitions of the work interval at the specific rate of work desired.

Ecker (26) states that the interval of recovery may be any length of a few seconds to 30 minutes or more but it is usually two to five minutes in length. The important point being not its length, but its uniformity throughout the workout. "There should be no more rest after the tenth repeat than after the first" he says (26, p. 64).

That no uniform agreement exists as to the specific amounts of each of the variables involved in an interval training program is evident and explicit when Ecker states, "The uniqueness of this method is that it is adaptable to any athlete regardless of his capabilities or state of his development" (26, p. 16), and Doherty concludes that "The core of such values lies in its almost infinite adaptability to whatever conditions of individual need or coaching attitude may prevail" (22, p. 103).

The weakness of interval training on a cinder track is its great monotony (56). Some athletes, especially those of a nervous temperament, eventually rebel against the rigidity of a pure interval training type of program and go over to a less exacting form of Fartlek training (1). Variety can be created in an interval training program by alternating the distances run from practice to practice. During a gradual interval training program, the athlete can begin increasing speed, decreasing the interval of recovery, or increasing the number of repetitions run, but a runner should never work on more than one of these factors during any one workout (26). An interval training program used poorly can develop excellent interval trainers without developing excellent competitive runners (1, 22).

The Physiological Basis Behind Interval Training

The overload principle accounts for the general phenomenon of adaptation to stress. Whenever a stress is imposed upon the living body causing strain, the body will attempt to compensate or adapt so that future applications of the same stress will produce less strain (38).

In interval training the object is to allow as many stimulus intervals as possible to affect the heart muscle (57). Wilt (70) presents a clear, practical explanation of this principle. When running 10 miles, one of the many stresses an athlete encounters is the oxygen debt, but during this 10 mile run only one high oxygen debt is created. Each time an athlete runs fast enough or far enough to create a high oxygen debt, and thereafter recovers, he is capable the next time he runs to create and tolerate a slightly higher oxygen debt. It is known that a runner who sprints 100 yards as fast as possible creates an oxygen debt somewhat comparable to that of the runner who has just finished running 10 miles. Theoretically, then, by sprinting 100 yards, ten times in a workout, a runner gets ten times more benefit from this workout than the runner who runs one continuous 10 mile run. Many factors are ignored in this theory; however, for best results one should accept the theory of creating a high oxygen debt many times during each workout.

The writings of Smit (64) state that metabolism during interval training was first investigated by Hollmann, Venrath, Schild, Bolt, and Valantin (40). He reports of their work in which the subjects performed on a cycle ergometer and turnmill ergometer. Every subject performed a fixed work load twice; first continuously and a second time interspersed with numerous pauses. It was found that in work of average intensity interrupted by short periods of rest, the gross oxygen uptake was less than in an equal load of work performed continuously. Pyruvic and lactic acid readings in the venous blood indicated that the reaction of the lactic acid was quicker and more marked than that of pyruvic acid, and that both acids never reached the same levels during a second loading as during the first. Often they were markedly lower. The underlying physiological principles involved, as interpreted by Hollman are that: Every work starting from rest is at first performed anaerobically due to the delayed adjustment of the heart, circulation, and respiration to the increased metabolic needs. The average adaptation period being three minutes, after which time will the active muscles have recovered sufficient oxygen as required by the work if it is not too intense. In interval training, during the work (loading) phase, the reserve capillaries in the muscles are opened, and the heart rate, heart stroke volume and minute volume of ventilation are increased. Then work is stopped. On the average 60 to 80 per cent of the recovery takes place within the first one to two minutes of recovery depending on the intensity and duration of the work. A longer recovery is required the higher the intensity; however, the duration of the work is not as important for length of recovery. When a new loading phase is resumed, after 70 per cent of the recovery is completed, the heart, circulation, and respiration are still adapted to the work, i.e. the heart rate is still high, the stroke volume is still increased and the reserve capillaries are open. This permits the second loading to be resumed aerobically almost immediately. The lactic acid level in the blood has also remained relatively low so there will be less fatigue and the athlete will be able to perform a larger dosage of work in a shorter period of time than he would if the work were continuous. The total amount of work done and the numerous stimuli offered by an interval training program are important for good training effect. The continuous alternately loading and unloading stimulates the body to higher adaptations making for optimal development.

Subjecting the heart to numerous stimuli, as in interval training, results in a stronger development of the heart in a much shorter period of time than is possible in any other method of training (64). Hollman's physiological explanation of how the heart and musculature are affected in interval training is that

> during the loading phase the systolic pressure increases, whereas the diastolic pressure remains almost unchanged or, at most, shows only a slight drop. Simultaneously, the heart frequency increases steeply, only to drop sharply after a few seconds at the conclusion of the work, while the blood pressure amplitude remains relatively high. The significance of this is that, during the recovery phase the heart functions with a very large stroke volume, thereby rendering dilatation stimuli on the walls of the heart. Thus it is possible to increase the heart volume from 200 to 300 ml. in a matter of 3 to 4 weeks. At the same time this results in a strong stimulus for the development of capillaries in the skeletal musculature.
>
> In this way, the athlete attains all the advantages also for competitive running as needed in continuous work, i.e. he will have a well capillarized musculature, which is a prerequisite for endurance and a strong heart. In addition, favorable changes have taken place in the enzyme system (64, pp. 183-184).

Reindell's (64) investigations with the heart and interval training substantiate these results and explanations of Hollman.

Gerschler agrees very much with the theory of optimal development of the heart in interval training. He insists "It is the recovery effort which strengthens the heart; that is, while the pulse is returning from 180 to 120 a minute." (65, p. 151).

The pause between work intervals must not last too long is the caution of Nett (57). If it does, a backing up of the blood from the arterial into the venous system occurs with the result being that the conditions for an optimal increase in beat-volume during and immediately after the next exertion are no longer present.

<u>Pertinent Studies Related to Physiological Changes as Affected by Training</u>

Astrand (4) and her associates experimented with muscular work of an intermittent type by investigating the physiological effects of rest pauses on a non-steady-state work load. A well trained subject performed on a bicycle ergometer doing work with 0.5, 1, 2, or 3 minute periods of work and rest. Total oxygen intake, total pulmonary ventilation, total number of heart beats and blood lactic acid concentration during the work hour and during recovery were determined. It was found that when the work was performed continuously, the rate of the work was low enough so that there was little stress placed on the subject. When heavy work was split into short periods of work and rest, of thirty seconds or one minute duration, it became a submaximal load on circulation and respiration and could be maintained with little stress on the subject for one hour. With work periods of two or three minutes duration, the work output got close to the maximum limit of performance and could be completed only with great strain.

Christensen, Hedman, and Saltin (16) conducted a similar experiment by contrasting continuous running with interval running using alternate work and rest periods of 5, 10, and 15 seconds. Blood sample, gas analyses, and heart rate data were collected. They conclude that:

1. Two physically trained subjects can run continuously for 3 and 4 minutes respectively on the treadmill at a speed of 20 kms./hr. (12.4 mph), reaching maximal values for oxygen uptake and for blood lactic acid. At the end of this time they will have run a total distance of 1 and 1.3 km respectively, and they will be totally exhausted and need a long time for recovery.
2. Running at the same speed with short spells of activity and rest, the character of the work changes entirely; despite a marked decrease in oxygen uptake during the actual work periods, the work can be performed without or with only a slight increase in blood lactic acid concentration, indicating aerobic or practically aerobic work conditions. The trained subjects can stand an effective work time of 15 and 20 minutes respectively within an experimental time of 30 minutes and run a total distance of 5 and 6.67 km respectively without being totally exhausted.

The heart rate remained relatively constant at 140 to 150 beats per minute during these short runs.

Results of the experiments of Vasil'eva (68) and associates show that pulmonary ventilation increased more rapidly in trained individuals during work than in the untrained. The resting state heart rate was almost the same in both groups (70/min), but the heart rate rose steadily during the work and at the end of the last minute of a five minute run averaged 180 beats per minute in trained and 185 beats per minute in untrained subjects. From their investigations they conclude that the changes taking place in the respiratory exchange during intensive muscular activity were greater in the trained than in the untrained subjects. This facilitated the performance of work of much greater intensity.

In work done with one female and one male subject on a bicycle ergometer, Christensen (16) found that the oxygen energy cost per kpm of work or the mechanical efficiency is the same or practically the same whether the work is performed continuously for one hour with an easy load or discontinuously with a heavier load. For the high work loads the lowest heart rate was found with short spells of 30 seconds or 45 seconds of work and rest.

Knehr (45) investigated the metabolic effects of six months of training on 14 middle distance runners. There was a decrease in resting pulse rate of 5 beats per minute and in exhausting work there was an increased capacity for supplying oxygen to tissues and greater utilization of anaerobic energy reserves.

During a prolonged exercise period lasting 2 to 8 hours, Michael (48) found that ventilation volumes generally increased throughout the exercise. When the heart rate reached 140 beats per minute, the intensity of work could not be maintained for more than four hours or a rate of 160 beats per minute for more than two hours without extreme fatigue.

Brouha (12), Gemmil (28), Gray (31), and Milic (49) report that the oxygen cost of respiration is smaller in trained than in untrained individuals.

Astrand and Saltin (7) measured metabolic effects while one female and four male, well trained subjects, performed maximal work on a bicycle ergometer. With maximal work times of about 2 minutes, a heart rate average of 185 beats per minute was reached. This same range was recorded with lighter work that could be maintained for about 6.5 minutes. In the 10 minute warmup exercise, heart rate was about 140 beats per minute at the end of it. The common feature of pulmonary ventilation was a more rapid increase and also a higher maximal ventilation the heavier the work load.

A number of studies indicate that resistance exercise will, within limits, increase strength (15, 37, 71). Much of the research done in this area is concerned either with the improvement of strength through various programs of progressive resistance exercise using isotonic contractions, or strength improvement through isometric contractions.

The effects of weight training on middle distance and distance runners has been investigated by Van Huss and Kennedy (67).

Ouellette (58) studied the effect of quadriceps development on sprint running time.

Cureton (20) has shown that champion athletes scored well above the normal young men's average on the Cureton 4-Item Strength Test.

Adult males who participated in a recreational sports program were stronger than non-participants as measured by dynamometer strength in the work done by Donnelly (23).

No information is available concerning the effects of specific running programs on the development of leg strength.

CHAPTER III

METHODOLOGY

The measures in this study were obtained on thirteen healthy college women, ages 19-22, who were in the physical education majors track and field class at Michigan State University. None of the subjects were trained athletes. All subjects volunteered for the study and were placed into one of three groups, the groups being matched on a time trial in running 220 yards on a straight-away, with a standing start, on the university track. A sprint group, a sprint and overdistance group, and a control group were used.

General Procedures

The data were collected during four appointments to the Human Energy Research Laboratory, and at the university track during the track and field class. The laboratory observations consisted of pre-training and post-training metabolism and heart rate tests of the subjects during work performance on a motor-driven treadmill, and of five strength measures. At one appointment, the strength measures were taken and a practice in treadmill running was provided to familiarize the subject with procedures and equipment. At the second appointment, energy metabolism measures and heart rate data were collected during two running tests on the treadmill. For the protection of the runner, a canvas harness was strapped around the waist and fastened by a rope to an overhead frame throughout both treadmill tests.

Specific Procedures

Energy Metabolism and Heart Rate

The subject ran on the treadmill for 10 minutes at 5 m.p.h., 0 per cent grade. As soon as the treadmill belt stopped, the subject sat down on a chair placed on the treadmill, keeping the mouthpiece in place, for a 15 minute recovery period. Gas samples were gathered in Douglas bags during the middle 30 seconds of each minute during the run, and during the middle 30 seconds of the first five minutes of the recovery. Single 5 minute recovery gas samples were collected for minutes 5-10 and 10-15.

At the end of this 15 minute recovery period, the subject removed the mouthpiece and nose clip and was provided with an additional ten minute recovery before the next test. During this time the subject was free to walk around.

The subject then ran at 7 m.p.h., up an 8.6 per cent grade, for as long as possible (to exhaustion). Expired gas was collected for each minute of this run and for each minute of the first five minutes of the recovery. Again single 5 minute recovery samples were collected for minutes 5-10 and 10-15 of the recovery period.

All expired gas was collected in Douglas bags by the open circuit method. The amount of gas expired was measured by the Kofranyi-Michaelis Calorimeter. The temperature and humidity of the room were observed each day of the experiment. Calculations were made according to Consolazio, Johnson and Pecora, 1953. (19)

A continuous heart rate record was obtained by recording a single precordial ECG lead during the entire 10 minute run at 5 m.p.h. and the 15 minute recovery period following this run, and also during the entire time of the 7 m.p.h. run to exhaustion and the 15 minute recovery period following it. A resting heart rate was recorded two minutes prior to the first run.

Strength

Five strength measures, hip flexion, hip extension, knee flexion, knee extension and ankle plantar flexion were taken with the T5 Cable Tensiometer (Clarke, 1953). All measures were taken on the right side of the body except those involving the trunk. Measures were made at least twice at each site according to instructions outlined by Clarke (18). If the second measure differed from the first by more than 2.0 kg., additional measures were made until two of them differed by not more than 2.0 kg. The first of the two measures differing by not more than 2.0 kg. were recorded. The average uncorrected kg. amount was corrected and recorded.

220 Yard Dash Times

The pre-training and post-training 220 yard dash times were recorded at the university track, on a straightaway run, with a standing start. Following a warmup consisting of a 440 yard jog, a few stretching calisthenics, and several 40 yard sprints, the subjects ran the 220's in groups of two. Times were recorded to the slowest tenth of a second. Each subject was given three trials, one trial each on successive days. The best of the three times was used. All timing was done using a Hanhart split time stop watch.

Training Program

The subjects in both experimental groups trained four days per week for five weeks following the training schedules shown in Tables I through VII, in addition to participating in the regular class work. The control group followed the regular planned teaching-learning activities in class.

Training distances of 60 yards and 300 yards were measured on both the outdoor and indoor tracks. During inclement weather the subjects trained indoors. The training sessions usually took place either before the start of the regular class period or immediately after it. At the beginning the subjects ran as a group; however, within three to four days they were training in groups of two as their ability differed and each had progressed to a different step on the training schedule. During the last two weeks, the subjects often trained alone for this same reason.

Experimental group A, the sprint group.--This group trained by running repeat 60 yard dashes each day of training for the entire five week training period. All of the subjects started at step 1 of the schedule shown in Training Table I where the pace was set at 15 seconds and the work to rest ratio was 2 to 1. This work to rest ratio was set up by an empirical decision in view of the fact these were untrained subjects. If the subject could meet the schedule by running each dash at the pace or faster than the pace the schedule requested, progression was made to the next step on the next day of training.[1] After the first day, the 15 second pace was found to be too slow as the subjects ran with extreme ease, so the pace was raised to 13 seconds the second day and then to 12 seconds the third day to demand some effort from the subjects. During the rest interval, the subject walked.

[1]A leeway of two was permitted since all subjects were untrained and it often took them a few runs to know if they were running at the requested pace.

Experimental group B, the sprint and overdistance group --This group trained by running 60 yard dashes for two days, following the same schedule as Group A, and the other two days they ran an overdistance of 300 yards following the steps in Training Table VII. During the rest interval, the subject walked.

TABLE I

SPRINT TRAINING SCHEDULE FOR 15 SECOND PACE

Step	Distance (Yards)	Speed (Seconds)	Rest (Seconds)	Start Interval (Seconds)	Repetitions (Number)
1	60	:15	:30	:45	10
2	"	"	:25	:40	9
3	"	"	:20	:35	8
4	"	"	:15	:30	7
5	"	"	:10	:25	6
6	"	"	:05	:20	5
7	"	"	0	0	4

TABLE II

SPRINT TRAINING SCHEDULE FOR 13 SECOND PACE

Step	Distance (Yards)	Speed (Seconds)	Rest (Seconds)	Start Interval (Seconds)	Repetitions (Number)
1	60	:13	:26	:39	10
2	"	"	:22	:35	9
3	"	"	:18	:31	8
4	"	"	:14	:27	7
5	"	"	:10	:23	6

TABLE III

SPRINT TRAINING SCHEDULE FOR 12 SECOND PACE

Step	Distance (Yards)	Speed (Seconds)	Rest (Seconds)	Start Interval (Seconds)	Repetitions (Number)
1	60	:12	:24	:36	10
2	"	"	:20	:32	9
3	"	"	:16	:28	8
4	"	"	:12	:24	7
5	"	"	:08	:20	6

TABLE IV

SPRINT TRAINING SCHEDULE FOR 11.5 SECOND PACE

Step	Distance (Yards)	Speed (Seconds)	Rest (Seconds)	Start Interval (Seconds)	Repetitions (Number)
1	60	:11.5	:23	:34.5	10
2	"	"	:19	:30.5	9
3	"	"	:15	:26.5	8
4	"	"	:11	:22.5	7
5	"	"	:07	:18.5	6

TABLE V

SPRINT TRAINING SCHEDULE FOR 11 SECOND PACE

Step	Distance (Yards)	Speed (Seconds)	Rest (Seconds)	Start Interval (Seconds)	Repetitions (Number)
1	60	:11	:22	:33	10
2	"	"	:18	:29	9
3	"	"	:14	:25	8
4	"	"	:10	:21	7
5	"	"	:06	:17	6

TABLE VI

SPRINT TRAINING SCHEDULE FOR 10.5 SECOND PACE

Step	Distance (Yards)	Speed (Seconds)	Rest (Seconds)	Start Interval (Seconds)	Repetitions (Number)
1	60	:10.5	:21	:31.5	10
2	"	"	:17	:27.5	9
3	"	"	:13	:23.5	8
4	"	"	:09	:19.5	7
5	"	"	:05	:15.5	6

TABLE VII

TRAINING SCHEDULE FOR OVERDISTANCE

Step	Distance (Yards)	Speed (Seconds)	Rest (Sec)	Rest (Min&Sec)	Start Interval (Sec)	Start Interval (Min-Sec)	Repetitions (Number)
1	300	:70	140	2:20	210	3:30	2
2	"	:68	136	2:16	204	3:24	2
3	"	:66	132	2:12	198	3:18	2
4	"	:64	128	2:08	192	3:12	2
5	"	:62	124	2:04	186	3:06	2
6	"	:60	120	2:00	180	3:00	2
7	"	:58	116	1:56	174	2:54	2
8	"	:56	112	1:52	168	2:48	2
9	"	:54	108	1:48	162	2:42	2
10	"	:52	104	1:44	156	2:36	2
11	"	:50	100	1:40	150	2:30	2

Statistical Methods Employed

Initial and final measurements for each subject were used to determine the changes in 220 yard dash run times, the all-out treadmill run times, total ventilation during work performance on the treadmill, heart rate during work performance on the treadmill and strength.

Group means were compared. Analysis of variance was used to determine the significance of the differences in mean changes among the three groups.

CHAPTER IV

ANALYSIS OF DATA

Description of Subjects

Of the 15 subjects who began this study, complete data is available for only 13. Two subjects from Experimental Group A were dropped; one because of an accident that prevented the second battery of tests to be administered, and one was dropped for medical reasons.

A description of the thirteen subjects participating in this study is presented in Table VIII.

TABLE VIII

DESCRIPTION OF SUBJECTS

Characteristics	Group A Sprint	Group B Sprint and Overdistance	Group C Control
Number	3	5	5
Mean Age (Years)	21	21	21
Mean Height (Inches)	67	66	64
Mean Weight (Pounds)	139	134	131

Results and Discussion

Analysis of variance was used in the statistical analysis to compare the mean changes from T_1 to T_2 for each group. The 5 per cent level of confidence was selected as the significant level for all observed differences.

Changes in 220 Yard Dash Times

Table IX contains the analysis of variance results for the 220 yard dash times. There was no significant difference in the effect of the two training programs on

TABLE IX

ANALYSIS OF VARIANCE FOR 220 YARD DASH TIMES

Group	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F
A	Between Groups	5.22	1	5.22	
	Within Groups	8.33	4	2.08	2.50
	Total	13.56	5		
B	Between Groups	24.96	1	24.96	
	Within Groups	54.19	8	6.77	3.68
	Total	79.15	9		
C	Between Groups	.44	1	.44	
	Within Groups	53.08	8	6.63	.06
	Total	53.52	9		

the improvement of speed in running the 220 yard dash. An F of 7.71 is needed for significance at the 5 per cent level for Group A. For Groups B and C, an F value of 5.32 is needed for statistical significance at the 5 per cent level. These results seem to indicate that neither of the two training programs applied in this study will improve running speed significantly over 220 yards. It is felt that if the training programs were applied over a longer period of time significant improvement would take place.

The group means and standard deviations for the 220 yard dash are presented in Table X. Although no statistically significant improvement in running 220 yards was found, examination of Table X shows that the two experimental groups did improve their times more than the Control group. The Control group changed very little. A greater improvement is noticed in Group B.

TABLE X

GROUP MEANS AND STANDARD DEVIATIONS FOR 220 YARD DASH TIMES

Group	Means		Standard Deviation	
	T_1	T_2	T_1	T_2
A (N=3)	:35.2	:33.3	1.96	.55
B (N=5)	:36.1	:32.9	2.84	2.33
C (N=5)	:35.8	:35.4	2.60	2.50

Changes in All-Out Run Times

The all-out runs were used as a measure of athletic endurance performance. The subjects ran on a motor-driven treadmill at a speed of 7 miles per hour up an 8.6 per cent grade. Table XI contains the analysis of variance results for the all-out runs. Statistical significance was found for both

TABLE XI

ANALYSIS OF VARIANCE FOR ALL-OUT RUN TIMES

Group	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F
A	Between Groups	840.16	1	840.16	
	Within Groups	90.66	4	22.66	37.06*
	Total	930.83	5		
B	Between Groups	4202.50	1	4202.50	
	Within Groups	4216.40	8	172.35	7.97**
	Total	8418.90	9		
C	Between Groups	656.09	1	656.09	
	Within Groups	1378.80	8	172.35	3.80
	Total	2034.90	9		

*Significant at the .01 level.
**Significant at the .05 level.

experimental groups. This suggests that training through the use of an intensive running program will improve athletic endurance performance as measured by an all-out run. Data suggests that the training program followed by Group A would improve athletic endurance performance to a greater degree.

Changes in Energy Metabolism and Heart Rate

It is generally known that with training, standardized work tests are performed with greater economy, i.e., the same amount of work can be performed with less stress on the circulo-respiratory mechanism. Such adjustments were not apparent in this study. No significant changes in ventilation or heart rate during the 10 minute standardized work test (Table XII) are indicated. A general trend toward a decrease in ventilation during the standard work test is suggested upon examination of the data presented in Table XIII. Of the eight subjects who trained, six showed a decrease in ventilation during the second work test; two showed an increase. Subject C. L. showed a marked increase in both maximum ventilation reached and maximum heart rate reached (as seen in Table IV) during the second test. Reasons for this are not clear from this data. In the Control Group, two subjects showed an increase

TABLE XII

F VALUES FOR ENERGY METABOLISM AND HEART RATE MEASURES

Measure	Experimental Group A	Experimental Group B	Control Group
All-out Run Peak Heart Rate	2.13	.01	.13
All-out Run Maximum Ventilation l/min.	22.33*	3.58	.70
St. Wk. Test Total Vent. During Ex.	.10	.07	.004
St. Wk. Test Total Vent. During Rec.	1.08	.15	.65
St. Wk. Test Heart Rate Sum Ex. Min. 8-10	2.80	.64	.39
St. Wk. Test Heart Rate Sum Rec. Min. 1-3	4.32	2.39	1.71

*Significant at the .01 level.

TABLE XIII

MAXIMUM VENTILATION REACHED DURING
STANDARD WORK TEST OF 10 MINUTES

		Maximum Ventilation l/min.		Reached at Min.	
Group	Subject	Before Training	After Training	Before Training	Training
Exp. A	C. H.	68	61	9	8
	M. K	65	61	10	5
	J. R.	63	67	8	9
Exp. B	K. B	65	55	5	7
	D. D.	61	44	9	5
	C. L.	46	58	9	7
	L. N.	66	60	7	6
	S. O.	79	74	9	7
Control	S. C	52	54	10	6
	J. F.	75	71	7	6
	K. K.	61	52	6	6
	S. S.	66	66	7	10
	K S.	58	60	7	9

in ventilation, two showed a decrease, and one showed no change. It is not clear why subject K. K. in the Control Group showed a marked decrease in ventilation and a corresponding decrease in heart rate (Table XIV). One reason more marked decreases in ventilation are not apparent in the experimental groups may be accounted for by the relatively short length of the training period.

The maximum heart rate each subject reached during the 10 minute standard work test is presented in Table XIV. Although no significant changes in heart rate occurred, it is interesting to notice that all of the subjects in experimental Group A had a lower maximum heart rate during

TABLE XIV

MAXIMUM HEART RATE REACHED DURING STANDARD WORK TEST OF 10 MINUTES

Group	Subject	Heart rate/min. Before Training	Heart rate/min. After Training	Reached at min. After Training	Reached at min. After Training
Exp. A.	C. H.	192	190	10	10
	M. K.	218	184	7	10
	J. R.	194	180	6	5
Exp. B.	K. B.	212	178	10	9
	D. D.	198	180	10	7
	C. L.	180	212	5	8
	L. N.	174	174	10	10
	S. O.	194	196	10	2
Control	S. C.	194	204	4	6
	J. F.	196	194	9	10
	K. K.	196	188	9	9
	S. S.	208	198	5	8
	K. S.	180	182	8	7

the second test. In experimental Group B, two of the subjects had lower maximal heart rates, one remained the same, and two increased; one markedly. In the Control Group, two subjects showed an increase and three showed a decrease.

During the all-out runs the maximum ventilation reached during the run improved significantly for experimental Group A (Table XII). No significant changes were observed for experimental Group B and the Control Group. Data seems to indicate that training by running short distances at an intensive speed significantly improves the ability to bring increased amounts of air into the body as an adjustment to severe exercise.

No significant change in the peak heart rate reached during the all-out runs was observed in any of the three groups.

Changes in Strength Measures

Ample research (15, 71) indicates that training by the use of isotonic or isometric contractions will improve strength. Little is known concerning the effect training by running has on the improvement of strength. Table XV contains the analysis of variance of the sum of five strength measures administered to the legs and trunk of the subjects. No statistically significant improvements were made by any of the groups. However, a slight improvement was found in leg strength in all three groups (Table XVI). The two experimental groups improved more than the Control Group. Experimental Group A, the sprint group, improved slightly more than Experimental Group B, the sprint and overdistance group. It is believed (62) that any improvement in strength by running would take place

TABLE XV

ANALYSIS OF VARIANCE FOR THE SUM OF FIVE STRENGTH MEASURES

Group	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F
A	Between Groups	5460.16	1	5460.16	
	Within Groups	4850.95	4	1212.73	4.50
	Total	10311.12	5		
B	Between Groups	5267.02	1	5267.02	
	Within Groups	16780.25	8	2097.53	2.51
	Total	22047.27	9		
C	Between Groups	1556.25	1	1556.25	
	Within Groups	10315.92	8	1289.49	1.20
	Total	11872.18	9		

TABLE XVI

GROUP MEANS AND STANDARD DEVIATIONS FOR THE SUM OF 5 STRENGTH MEASURES

Group	Means		Standard Deviation	
	T_1	T_2	T_1	T_2
A (N=3)	191.58	251.91	27.25	41.02
B (N=5)	209.45	255.35	50.16	40.96
C (N=5)	220.30	245.25	34.28	37.45

during the starts and accelerations in a sprint. Since experimental Group A trained by running short sprints in every training session, their improvement should be greater than that of Group B that trained by running short sprints during one-half of the training sessions, or Group C.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

It was the purpose of this study to investigate the effectiveness of two interval training programs on the improvement of speed in running the 220 yard dash in young women. Thirteen healthy college women ages 19-22 were the subjects. Two experimental and one control group were used. One experimental group trained by running short sprints of 60 yards four days per week; the other group trained by running 60 yard sprints two days per week and 300 yard runs two days per week. Both groups trained for five weeks. The control group did not participate in a special training program.

All subjects were tested before and after 5 weeks of training. The tests included: time for running 220 yards, energy metabolism and heart rate during an all-out treadmill run to exhaustion and during a standardized treadmill run of 10 minutes, and leg strength.

The results were analyzed using analysis of variance to determine the significance of the differences in mean changes among the three groups.

Conclusions

Based on the statistical data presented, the following conclusions seem justified:

1. There was no significant improvement in running speed over 220 yards for either experimental group. However, a general tendency for greater improvement of both experimental groups over the Control Group, and of experimental Group B over experimental Group A is indicated.
2. Both experimental groups improved significantly in athletic endurance performance as measured by an all-out run.
3. Experimental Group A improved significantly in the maximum ventilation reached during the all-out run.
4. No significant changes in heart rate occurred as a result of training in either group.
5. No significant improvements in leg strength were observed. However, data seems to indicate a greater tendency for improvement in strength in experimental Group A, the sprint group, than for experimental Group B, the sprint and overdistance group.

Recommendations

The following recommendations are made as a result of this study:

1. A similar investigation using a larger number of subjects should be made.
2. The training period should be carried on for a longer period of time than five weeks. Experience and observation indicate that the subjects were just reaching the point of intensive training. An eight or nine week training program may yield different results.
3. Untrained runners who have a strong interest in running and a firm desire to improve running speed should be used as subjects.
4. Various sprint training distances should be investigated.

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APPENDICES

APPENDIX A

RAW DATA ON MEASUREMENTS

TABLE XVII

220 YARD DASH TIMES

Group	Subject	Before Training (Seconds)	After Training (Seconds)
A	C. H.	:37.5	:34.0
	M. K.	:34.2	:33.1
	J. R.	:34.0	:33.0
B	K. B.	:36.2	:32.8
	D. D.	:33.7	:30.1
	C. L.	:33.1	:31.5
	L. N.	:40.1	:36.1
	S. O.	:37.4	:34.2
C	S. C.	:39.7	:39.3
	J. F.	:33.2	:33.5
	K. K.	:37.3	:36.6
	S. S.	:35.2	:34.6
	K. S.	:34.0	:33.3

TABLE XVIII

TREADMILL ALL-OUT RUN TIMES

Group	Subject	Before Training (Seconds)	After Training (Seconds)
A	C. H.	60	91
	M. K.	60	85
	J. R.	70	85
B	K. B.	73	124
	D. D.	100	160
	C. L.	85	120
	L. N.	60	81
	S. O.	70	108
C	S. C.	45	65
	J. F.	80	86
	K. K.	60	90
	S. S.	60	75
	K. S.	80	90

TABLE XIX

RAW DATA ON TOTAL VENTILATION IN L/MIN FOR 5MPH STANDARD WORK TEST BEFORE TRAINING

Subject	Exercise Minutes										Recovery Minutes						
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6-10	11-15
C. H.	20	34	58	60	63	64	65	66	68	76	53	37	30	24	25	17	12
M. K.	35	55	59	64	54	51	63	61	61	65	38	25	20	16	14	12	9
J. R.	32	49	53	51	59	59	47	63	55	53	28	20	18	15	10	12	10
K. B.	29	54	60	57	65	63	57	65	56	61	38	23	17	14	12	14	11
D. D.	25	34	46	49	48	54	55	58	61	59	30	27	20	15	9	11	8
C. L.	26	31	42	39	40	39	40	43	46	44	32	22	11	12	11	9	7
L. N.	30	39	56	65	57	60	66	62	58	52	36	19	18	18	16	13	8
S. O.	40	53	63	58	67	63	71	76	79	78	57	33	25	27	22	19	17
S. C.	23	41	43	49	44	44	51	44	50	52	35	21	17	13	12	11	9
J. F.	35	49	62	63	68	66	75	74	72	74	47	23	14	15	15	11	11
K. K.	32	52	53	50	59	61	49	51	52	49	30	26	22	19	17	13	13
S. S.	24	41	55	59	64	60	66	64	66	57	34	27	23	18	15	13	11
K. S.	29	49	42	56	56	55	58	58	53	46	32	25	25	26	21	17	12

TABLE XX

RAW DATA ON TOTAL VENTILATION IN L/MIN FOR 5 MPH STANDARD WORK TEST AFTER TRAINING

Subject	Exercise Minutes										Recovery Minutes						
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6-10	11-15
C. H.	31	53	58	55	58	54	58	61	59	60	39	21	18	17	14	12	9
M. K.	40	57	59	59	61	56	60	53	52	47	37	24	18	13	12	10	7
J. R.	36	57	54	58	62	65	64	67	67	64	43	16	19	12	13	13	11
K. B.	32	44	45	43	52	53	55	55	52	38	37	23	13	15	8	13	11
D. D.	21	41	42	37	44	41	44	43	44	36	25	16	12	11	8	11	9
C. L.	30	38	48	51	54	51	58	58	58	57	34	20	14	14	10	10	9
L. N.	31	48	56	52	59	60	57	56	55	55	45	21	21	15	16	13	10
S. O.	43	59	68	67	68	71	74	71	72	65	44	28	23	20	13	16	11
S. C.	28	37	48	45	45	54	50	54	48	48	30	21	16	12	12	12	10
J. F.	40	56	66	66	70	71	67	66	65	64	42	30	22	18	17	14	11
K. K.	28	44	48	50	51	52	49	49	50	47	29	21	17	13	12	12	8
S. S.	28	49	54	59	52	59	61	63	59	66	40	29	22	18	13	13	10
K. S.	31	43	53	54	51	59	59	57	60	56	41	22	19	15	14	13	11

TABLE XXI

RAW DATA ON TOTAL VENTILATION IN L/MIN FOR 7MPH ALL OUT RUN

Subject	BEFORE TRAINING									AFTER TRAINING									
	Exercise Minutes		Recovery Minutes							Exercise Minutes			Recovery Minutes						
	1	2	1	2	3	4	5	6-10	11-15	1	2	3	1	2	3	4	5	6-10	11-15
C. H.	50	--	45	39	27	27	27	21	15	57	80	--	56	49	42	36	29	21	15
M. K.	45	--	42	46	31	31	21	19	13	51	74	--	51	57	39	23	25	20	14
J. R.	46	--	58	30	30	22	15	17	12	45	78	--	62	54	39	27	24	18	12
K. B.	45	59	67	42	32	26	20	21	15	40	72	--	73	60	41	36	32	22	17
D. D.	41	90	49	32	43	39	18	12	12	45	66	71	90	82	63	26	21	15	13
C. L.	38	67	48	41	32	27	24	14	8	54	78	--	68	50	37	27	31	23	15
L. N.	52	--	51	36	23	24	21	16	12	51	73	--	57	57	40	35	22	20	13
S. O.	58	--	75	54	34	34	33	21	19	63	93	--	67	43	38	33	36	23	17
S. C.	42	--	34	30	26	21	19	15	11	43	--	--	51	35	29	22	18	15	10
J. F.	48	84	49	38	42	32	23	21	13	54	54	--	86	58	44	36	33	25	16
K. K.	36	--	41	33	28	28	27	18	14	39	72	--	43	35	32	24	19	17	10
S. S.	35	--	57	37	39	23	21	16	12	43	40	--	52	42	30	23	18	16	12
K. S.	33	55	46	37	30	25	27	19	15	46	73	--	59	44	34	28	24	18	13

TABLE XXII

RAW DATA FOR HEART RATES DURING STANDARD WORK TEST, 5MPH, 0% GRADE, BEFORE TRAINING

		Exercise Minute									
Subject	Rest	1	2	3	4	5	6	7	8	9	10
C. H.	92	178	170	182	182	178	180	186	186	190	192
M. K.	80	170	188	208	206	216	216	218	214	206	210
J. R.	84	160	172	180	182	186	194	182	188	184	188
K. B.	72	140	182	202	202	192	190	190	192	192	212
D. D.	108	148	180	174	188	192	194	196	192	196	198
C. L.	111	160	158	168	168	180	178	178	174	176	176
L. N.	96	156	150	168	166	166	166	168	168	172	174
S. O.	104	176	184	184	186	184	188	184	190	192	194
S. C.	97	165	171	172	194	190	188	186	190	190	192
J. F.	95	160	180	186	188	184	188	192	192	196	194
K. K.	120	166	172	180	178	180	178	178	186	196	196
S. S.	84	168	198	202	206	208	196	194	206	200	202
K. S.	92	164	160	162	162	168	178	178	180	178	168

TABLE XXII, Continued

		Recovery Minute														
Subject	Rest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C. H.	92	172	138	124	118	118	112	114	110	106	96	108	107	103	105	105
M. K.	80	162	132	118	112	108	106	107	101	99	98	99	96	99	99	101
J. R.	84	164	120	108	104	106	104	105	101	104	104	104	100	103	101	102
K. B.	72	166	134	138	120	118	115	109	109	112	107	109	106	106	107	105
D. D.	108	160	150	134	128	126	120	121	119	120	114	117	116	119	112	112
C. L.	111	156	130	118	110	112	110	108	109	102	107	105	102	103	102	102
L. N.	96	158	122	100	110	102	98	98	96	94	98	96	92	92	94	93
S. O.	104	168	132	118	120	114	113	109	115	115	112	118	112	114	113	125
S. C.	97	176	140	126	122	112	114	111	109	113	109	108	106	106	110	114
J. F.	95	168	134	130	128	122	119	116	110	113	113	111	110	109	109	115
K. K.	120	188	146	128	124	130	110	109	107	103	106	102	103	100	101	101
S. S.	84	186	150	142	138	138	135	128	127	128	124	124	126	126	126	126
K. S.	92	134	122	122	118	114	109	115	106	108	107	111	113	108	110	107

TABLE XXIII

RAW DATA FOR HEART RATES DURING STANDARD WORK TEST, 5MPH, 0% GRADE, AFTER TRAINING

		Exercise Minute									
Subject	Rest	1	2	3	4	5	6	7	8	9	10
C. H.	102	166	180	180	186	188	180	184	188	188	190
M. K.	88	134	158	162	168	168	168	174	174	172	184
J. R.	86	146	164	168	170	180	178	176	178	180	180
K. B.	92	140	160	166	168	170	174	174	170	178	174
D. D.	108	160	174	172	172	174	178	180	178	178	180
C. L.	122	154	170	182	198	210	210	210	212	194	188
L. N.	96	140	158	164	166	170	172	170	172	172	174
S. O.	102	176	186	186	186	184	186	178	178	184	180
S. C.	104	168	178	174	192	198	204	190	192	182	186
J. F.	88	156	168	174	178	178	178	186	192	184	194
K. K.	104	160	176	184	184	182	186	186	184	188	184
S. S.	106	188	192	188	186	186	190	196	198	196	198
K. S.	92	146	162	166	170	166	176	182	178	182	178

TABLE XXIII, Continued

		Recovery Minute														
Subject	Rest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C. H.	102	161	126	113	110	108	108	106	106	108	104	111	104	106	105	109
M. K.	88	141	107	97	88	86	82	83	82	82	83	83	83	83	83	83
J. R.	86	160	107	101	100	82	88	92	90	91	94	92	97	87	90	96
K. B.	92	147	116	120	107	94	100	97	96	99	93	96	93	93	91	95
D. D	108	160	131	119	117	116	115	114	114	111	114	116	109	112	111	114
C. L.	122	153	133	132	124	119	116	113	109	110	115	107	106	110	109	111
L. N.	96	160	129	119	112	108	102	102	105	103	95	100	106	103	108	107
S. O.	102	151	115	102	101	100	113	98	93	98	94	99	101	97	96	96
S. C.	104	162	134	123	116	112	116	112	108	109	106	108	107	105	100	109
J. F.	88	152	112	110	109	110	102	107	107	107	102	102	101	97	93	99
K. K.	104	145	113	98	101	98	98	102	98	97	99	98	97	106	95	98
S. S.	106	180	153	132	129	131	125	123	122	117	117	112	114	113	117	117
K. S.	92	165	129	117	113	109	105	103	101	97	100	100	97	98	95	104

TABLE XXIV

RAW DATA ON STRENGTH MEASURES

Subject	Knee Extension		Ankle Plantar Flexion		Knee Flexion		Hip Extension		Hip Flexion	
	1	2	1	2	1	2	1	2	1	2
C. H.	45.50	53.25	35.00	40.00	41.50	43.25	27.00	36.50	23.25	35.00
M. K.	40.00	63.75	65.50	76.00	34.00	43.25	43.25	47.50	40.00	58.75
J. R.	51.50	36.50	36.50	60.75	27.75	45.50	34.00	55.00	30.00	60.75
K. B.	53.25	55.00	55.00	63.75	25.00	35.00	30.00	32.25	31.50	47.50
D. D.	78.00	80.00	41.50	55.00	30.00	45.50	60.75	72.50	38.00	49.50
C. L.	30.00	40.00	35.00	47.50	34.00	47.50	19.50	32.75	23.25	30.00
L. N.	49.50	40.00	35.00	47.50	40.00	47.50	41.50	76.00	27.75	70.50
S. O.	83.25	80.00	43.25	60.75	38.00	47.50	45.50	32.75	58.75	40.00
S. C.	55.00	47.50	60.75	65.50	30.00	36.50	30.00	45.50	32.75	38.00
J. F.	45.50	74.25	53.25	57.00	53.25	40.00	58.75	55.00	40.00	63.75
K. K.	40.00	34.00	28.50	35.00	45.50	47.50	25.00	40.00	27.00	34.00
S. S.	63.75	62.00	36.50	57.00	58.75	58.75	32.75	41.50	51.50	47.50
K. S.	68.75	62.00	45.50	53.25	34.00	30.00	43.25	53.24	41.50	47.50

NOTE: Measured in kilograms.

Rest 1 - before training. Rest 2 - after training.

APPENDIX B

INDIVIDUAL TRAINING CHARTS

TABLE XXV

GROUP A - SPRINTS

Subject: C. H.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	11.5	12.0	12.0	11.1	10.5	10.7	10.9	11.1	10.8	11.5	10.9	11.6	10.7	10.3	10.2	10.1	10.1	10.8	10.1	10.0
2	12.5	12.0	11.5	11.5	10.7	11.1	11.3	11.0	11.1	11.2	10.6	11.9	11.2	11.0	10.4	10.9	10.4	11.0	10.1	10.5
3	11.4	12.1	12.0	12.0	11.6	11.4	11.6	11.0	11.2	11.6	11.2	11.0	11.4	10.7	10.6	10.8	10.9	12.3	10.9	11.4
4	12.5	13.2	12.2	12.1	11.6	11.3	11.8	11.2	11.2	12.0	11.3	10.9	11.7	11.0	10.3	10.9	10.5	13.0	10.4	11.4
5	14.0	12.2	11.6	12.0	11.7	11.8	11.4	11.3	11.3	11.5	11.4	11.7	12.4	11.1	10.4	11.0	10.9	12.9	11.5	11.9
6	12.5	13.5	11.8	12.0	11.2	11.8	11.7	11.2	10.9	11.7	11.4	11.9	12.8	11.7	11.0	10.8	11.2	12.2	10.8	11.8
7	13.0	13.0	11.7	12.0	11.6	12.1		11.1	11.1	11.5	11.3				10.7	10.8	11.3	12.9	11.7	12.7
8	13.0	13.5	11.9	11.5	11.5			10.8	10.9	10.8					10.4	10.8	11.0			
9	13.4	12.0	11.1	11.3				11.1	11.1						11.1	10.9				
10	13.0	11.5	10.8					11.1							11.0					
Speed	15	13	12	12	12	12	12	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.0	11.0	11.0	11.0	11.0	11.0
Rest	30	26	24	20	16	12	8	23.0	19.0	15.0	11.0	7.0	7.0	7.0	22.0	18.0	14.0	10.0	10.0	10.0
Start Int.	45	39	36	32	28	24	20	34.5	30.5	26.5	22.5	18.5	18.5	18.5	33.0	29.0	25.0	21.0	21.0	21.0
Reps	10	10	10	9	8	7	6	10	9	8	7	6	6	6	10	9	8	7	7	7

Time in Seconds

TABLE XXVI

GROUP A - SPRINTS

Subject: J. R.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	14.0	10.0	10.2	10.0	10.4	10.2	9.1	9.9	10.8	9.8	11.4	10.8	9.1	10.5	9.2	9.6	9.5	8.5	8.9	9.3
2	11.5	10.5	10.3	10.3	11.5	10.5	10.2	9.7	11.2	11.2	11.7	10.4	9.5	11.3	9.4	9.3	9.3	10.1	9.5	9.9
3	15.0	12.5	10.7	10.3	13.0	10.8	10.8	11.7	11.4	10.9	11.4	10.4	9.9	11.8	11.9	11.1	11.7	10.4	10.6	10.6
4	15.0	12.0	10.0	10.7	11.7	11.8	11.6	10.5	11.3	12.3	11.7	10.8	9.5	12.1	11.0	10.5	10.5	10.2	10.2	10.5
5	14.5	13.5	10.7	10.9	11.6	11.6	11.3	10.3	11.2	10.9	11.3	10.3	10.4	11.5	11.8	11.5	10.8	10.4	10.8	10.5
6	15.0	14.0	10.3	11.0	11.9	10.4	11.7	10.5	11.1	11.2	9.7	10.8	10.1	11.3	11.1	10.6	9.9	10.4	10.0	9.9
7	15.5	14.5	11.0	11.2	12.9	11.5		10.8	10.9	11.3		10.3	11.2				10.7	10.5	10.8	10.2
8	14.0	15.5	10.2	11.3	10.5			10.1	11.1	10.9		11.0	10.4				9.8	10.7	10.4	9.7
9	14.0	13.0	10.8	10.4				11.1	10.8			10.2					10.6	10.4	10.1	10.0
10	14.0	10.0	10.5					9.6				10.0					10.0	10.1		
Speed	15	13	12	12	12	12	12	11.5	11.5	11.5	11.5	11.0	11.0	11.0	11.0	11.0	10.5	10.5	10.5	10.5
Rest	30	26	24	20	16	12	8	23.0	19.0	15.0	7.0	22.0	14.0	6.0	6.0	6.0	21.0	21.0	17.0	17.0
Start Int.	45	39	36	32	28	24	20	34.5	30.5	26.5	18.5	33.0	25.0	17.0	17.0	17.0	31.5	31.5	27.5	27.5
Reps	10	10	10	9	8	7	6	10	9	8	6	10	8	6	6	6	10	10	9	9

Time in Seconds

TABLE XXVII

GROUP A - SPRINTS

Subject: M. K.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	9.0	10.2	10.0	10.8	11.8	10.5	10.4	10.8	11.0	10.6	11.4	9.4	9.4	10.0	9.7	10.2	9.8	9.6	10.0	9.8
2	11.0	10.3	10.3	12.0	12.5	10.9	10.8	11.2	10.4	10.6	11.7	9.8	9.7	10.8	10.2	10.9	10.3	9.6	10.0	9.9
3	11.5	10.7	10.3	11.8	11.3	11.0	11.7	11.4	11.5	10.9	11.4	9.8	10.4	10.9	11.0	10.8	9.9	10.2	10.1	10.4
4	12.0	10.0	10.7	11.7	11.0	10.9	11.0	11.3	11.4	10.6	11.7	10.4	10.0	11.2	10.8	10.9	10.6	10.1	10.0	10.4
5	12.0	10.7	10.9	12.1	11.2	11.1	12.0	11.2	11.2	11.7	11.3	10.1	10.0	11.9	11.0	11.1	10.2	10.0	10.7	10.6
6	11.5	10.3	11.0	11.6	11.7	11.1	10.9	11.1	11.5	9.6	9.7	9.8	9.9	12.4	11.9	9.9	10.1	9.7	10.2	10.4
7	12.0	11.0	11.2	11.6	12.1		11.1	10.9	11.5	11.3		10.2	10.0	12.2	10.9		9.6	9.7	10.7	10.7
8	11.7	10.2	11.3	12.2			10.6	11.1	9.7			10.0	9.7	12.6	10.2		10.0	9.8	9.9	
9	11.9	10.8	10.4				11.4	10.8				10.5	9.5				10.0	[illegible]		
10	11.6	10.5					10.1					9.7					9.3			
Speed	13	12	12	12	12	12	11.5	11.5	11.5	11.5	11.5	11.0	11.0	11.0	11.0	11.0	10.5	10.5	10.5	10.5
Rest	26	24	20	16	12	8	23.0	19.0	15.0	11.0	7.0	22.0	18.0	10.0	10.0	6.0	21.0	17.0	13.0	9.0
Start Int.	39	36	32	28	24	20	34.5	30.5	26.5	22.5	18.0	33.0	29.0	21.0	21.0	17.0	31.5	27.5	23.5	19.5
Reps	10	10	9	8	7	6	10	9	8	7	6	10	9	8	8	6	10	9	8	7

Time in Seconds

TABLE XXVIII

GROUP B - SPRINTS AND OVERDISTANCE

Subject: K. B.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	11.4	12.0	57.5	65.0	10.5	10.2	62.0	56.4	10.8	11.5	54.6	55.3	10.4	10.7	56.4	59.8	10.8	9.8	53.2	57.3
2	12.5	12.0	55.7	63.8	10.7	10.5	63.0	57.3	11.1	11.2	51.3	59.4	10.6	10.4	56.4	58.8	10.4	10.0	55.2	58.9
3	14.0	12.1			11.6	10.8			11.2	11.6			11.0	11.0			10.4	11.0		
4	12.5	13.2			11.6	11.8			11.2	12.0			11.5	10.9			10.8	9.9		
5	13.0	12.2			11.7	11.6			11.3	11.5			11.2	10.8			10.3	11.1		
6	13.0	13.5			11.2	10.4			10.9	11.7			11.1	10.6			10.8	10.7		
7	13.4	13.0			11.6	11.5			11.1	11.5			11.2				10.3	10.7		
8	13.0	13.5			11.5				10.9	10.8			11.4				11.0	10.5		
9	12.0	12.0							11.1								10.2	10.1		
10	13.0	11.5															10.5			
Speed	15.0	13.0	70	68	12.0	12.0	66	64	11.5	11.5	62	60	11.5	11.5	58	56	11.0	11.0	56	54
Rest	30.0	26.0	140	136	16.0	12.0	132	128	19.0	15.0	124	120	15.0	7.0	116	112	22.0	18.0	112	108
Start Int.	45.0	39.0	210	204	28.0	24.0	198	192	30.5	26.5	186	180	26.5	18.5	174	168	33.0	29.0	168	162
Reps	10	10	2	2	8	7	2	2	9	8	2	2	8	6	2	2	10	9	2	2

Time in Seconds

TABLE XXIX

GROUP B - SPRINTS AND OVERDISTANCE

Subject: D. D.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	14.0	52.8	51.5	10.4	9.4	51.9	59.0	9.6	10.3	51.8	51.0	8.9	9.4	52.0	59.2	9.6	10.0	55.0	53.4	9.1
2	11.5	52.1	51.9	11.5	10.0	59.0	58.4	10.0	10.1	58.8	51.2	9.0	9.9	55.0	58.7	10.5	10.6	58.8	65.4	9.0
3	15.0			13.0	11.1			9.5	10.1			9.2	10.1			9.7	10.7			10.1
4	15.0			11.7	10.9			10.2	9.7			8.7	9.7			10.5	11.3			9.8
5	14.5			11.6	10.7			10.0	10.4			8.8	11.0			10.6	11.1			10.1
6	15.0			11.9	11.2			10.7	10.0			10.2	9.9			11.0	11.9			9.9
7	15.5			12.9	9.8			10.0	10.2			10.0	10.7			11.4	11.7			10.4
8	14.0			10.5				10.9	10.3			10.2	10.0			12.4	10.5			10.0
9	14.0							10.3				10.1	10.1							
10	14.0											9.9								
Speed	15	70	68	12	12	66	64	11.5	11.5	62	60	10.5	10.5	58	56	10.5	10.5	56	56	10.5
Rest	30	140	136	16	12	132	128	19.0	15.0	124	120	21.0	17.0	116	112	13.0	13.0	112	112	13.0
Start Int.	45	210	204	28	24	198	192	30.5	26.5	186	180	31.5	27.5	174	168	23.5	23.5	168	168	23.5
Reps.	10	2	2	8	7	2	2	9	8	2	2	10	9	2	2	8	8	2	2	8

Time in Seconds

TABLE XXX

GROUP B - SPRINTS AND OVERDISTANCE

Subject: C. L.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	13.5	10.0	55.7	52.8	10.4	9.4	61.0	55.3	11.8	10.0	52.7	52.8	10.6	10.4	55.8	:60.2	10.0	9.1	55.7	59.4
2	13.3	10.5	54.6	54.3	11.5	10.0	60.7	58.0	11.3	11.7	60.1	52.2	10.6	10.9	55.8	59.2	10.2	10.8	55.9	58
3	14.0	12.5			13.0	11.1			12.0	11.4			10.9	11.3			10.4	10.4		
4	13.0	12.0			11.7	10.9			11.5	11.1			10.6	11.1			10.9	11.4		
5	14.0	13.5			11.6	10.7			11.1	11.3			11.7	10.8			10.3	10.4		
6	13.0	14.0			11.9	11.2			11.1	10.9			9.6	11.2			10.4	11.4		
7	15.0	14.5			12.9	10.4			11.0	11.4				10.9			10.9	10.4		
8	15.0	15.5			10.5				10.7	10.8				10.9			10.3	10.8		
9	14.5	13.0							10.9					10.9			10.1			
10	15	10.0												10.0						
Speed	15	13	70	68	12	12	66	64	11.5	11.5	62	60	11.5	11.0	58	56	11.0	11.0	56	54
Rest	30	26	140	136	16	12	132	128	19.0	15.0	124	120	7.0	22.0	116	112	18.0	14.0	112	108
Start Int.	45	39	210	204	28	24	198	192	30.5	26.5	186	180	18.5	23.0	174	168	29.0	25.0	168	162
Reps.	10	10	2	2	8	7	2	2	9	8	2	2	6	10	2	2	9	8	2	2

Time in Seconds

TABLE XXXI

GROUP B - SPRINTS AND OVERDISTANCE

Subject: L. N.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	11.5	12.0	56.5	70	10.5	11.4	61.0	68	10.6	10.9	52.2	64.6	10.8	11.5	55	60.0	10.6	10.9	60.7	65.2
2	12.5	12.0	59.0	78.9	10.7	12.2	66.6	68	11.9	11.5	53.4	67	12.0	11.9	56.9	65.3	11.5	11.4	60.0	66.8
3	11.4	13.1			11.6	12.1			11.4	11.6			11.5	11.7			11.3	11.5		
4	12.5	13.2			11.6	12.3			12.1	12.0			11.7	11.6			11.4	11.2		
5	14.0	12.2			11.7	13.4			12.2	12.5			11.8	12.4			11.4	11.6		
6	12.5	13.5			11.2	12.4			11.9	12.6			11.8	11.1			12.3	11.0		
7	13.0	13.0			12.6	13.3			11.7	11.8			12.0				11.3	11.6		
8	13.0	13.5			11.5												11.5	11.0		
9	13.4	12.0															11.3	10.6		
10	13.0	15.5															11.5			
Speed	15	13	70	68	12	12	68	66	12	12	66	64	12	12	64	62	11.5	11.5	60	60
Rest	30	26	140	136	16	12	136	132	12	12	132	128	12	7	128	124	23.0	19.0	120	120
Start Int.	45	39	210	204	28	24	204	198	24	24	198	192	24	19	192	186	34.5	30.5	180	180
Reps.	10	10	2	2	8	7	2	2	7	7	2	2	7	6	2	2	10	9	2	2

Time in Seconds

TABLE XXXII

GROUP B - SPRINTS AND CVERDISTANCE

Subject: S. O.

	Training Session																			
Reps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	13.4	12.0	58.0	62.0	10.5	10.3	59.0	57.0	10.8	11.5	55.6	55.7	10.8	10.3	61.4	57.3	11.2	11.2	65.0	61.2
2	13.0	12.0	55.7	63.8	10.7	11.0	69.0	59.0	11.1	11.2	52.4	63.6	13.1	11.4	60.3	59.1	10.8	11.5	58.9	61.8
3	12.0	12.1			11.6	11.2			11.2	11.6			11.9	11.2			11.9	12.3		
4	13.0	13.2			11.6	12.1			11.2	12.0			11.1	11.0			10.9	11.7		
5	11.0	12.2			11.7	11.8			11.3	11.5			10.7	11.0			11.3	11.5		
6	10.5	13.5			11.2	12.0			10.9	11.7			11.6	10.8			10.9	11.5		
7	11.5	13.0			11.6	12.2			11.1	11.5			11.7	11.0			11.3			
8	11.4	13.5			11.5				10.9	12.3			11.4	10.8						
9	12.0	12.0							11.1											
10	11.5	11.5																		
Speed	15	13	70	68	12	12	66	66	11.5	11.5	64	62	11.5	11.5	62	60	11.5	11.5	58	58
Rest	30	26	140	136	16	12	132	132	19.0	15.0	128	124	15.0	15.0	124	120	11.0	7.0	116	116
Start Int.	45	39	210	204	28	24	198	198	30.5	26.5	192	186	26.5	26.5	186	180	22.5	18.5	174	174
Reps.	10	10	2	2	8	7	2	2	9	8	2	2	8	8	2	2	7	6	2	2

Time in Seconds.

TABLE XXXIII

GROUP A - SPRINTS (DROPPED--ACCIDENT)

Subject: J. K.

	Training Session																			
Reps.	1	2	3'	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	14.0	10.0	10.2	10.0	10.4	10.7	10.2	11.8	10.0	9.8	11.1	8.9	10.2	9.4	9.0	10.0	9.7	10.1	9.5	10.4
2	11.5	10.5	10.3	10.3	11.5	13.0	12.1	11.3	11.7	11.2	10.9	9.0	11.0	9.7	9.1	10.8	10.2	10.7	10.0	10.5
3	15.0	12.5	10.7	10.3	13.0	11.4	11.0	12.0	11.4	10.9	9.8	9.2	11.4	10.4	10.7	10.9	11.0	11.1	11.1	10.9
4	15.0	12.0	10.0	10.7	11.7	11.2	11.5	11.5	11.1	12.3	9.6	8.7	11.8	10.0	10.1	11.2	10.8	11.1	10.1	10.9
5	14.5	13.5	10.7	10.9	11.6	11.2	10.8	11.1	11.3	10.9	10.1	8.8	11.4	10.0	10.9	11.9	11.5	11.5	11.1	11.4
6	15.0	14.0	10.3	11.0	11.9	11.3	11.0	11.1	10.9	11.2	10.6	10.2	11.5	9.9	9.3	11.4	12.5	11.7	10.8	10.8
7	15.5	14.5	11.0	11.2	12.9	10.9		11.0	11.4	11.3		10.0	11.2	10.0	10.6	12.2	11.5	11.1	10.9	10.4
8	14.0	15.5	10.2	11.3	10.5			10.7	10.8	9.4		10.2	11.4	9.7	9.8	10.5	9.6			10.8
9	14.0	13.0	10.8	10.4				10.9	9.2			10.1	11.1	9.5						11.0
10	14.0	10.0	10.5					9.6				10.4								9.8
Speed	15	13	12	12	12	12	12	11.5	11.5	11.5	11.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.0
Rest	30	26	24	20	16	12	8	23.0	19.0	15.0	7.0	21.0	17.0	13.0	17.0	9.0	9.0	9.0	9.0	20.0
Start Int.	45	39	36	32	28	24	20	34.5	30.5	26.5	18.5	31.5	27.5	23.5	15.5	19.5	19.5	19.5	19.5	30.0
Reps.	10	10	10	9	8	7	6	10	9	8	6	10	9	8	9	7	7	7	7	10

Time in Seconds