NAME OF AUTHOR/*NOM DE L'AUTEUR* FREDERICK PETER GUTOSKI

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NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* DR. MOHAN SINGH

DATED/*DATÉ* February 20/75 SIGNED/*SIGNÉ* Fred Gutoski

PERMANENT ADDRESS/*RÉSIDENCE FIXE* SCHOOL OF PHYSICAL EDUCATION
UNIVERSITY OF MANITOBA
WINNIPEG, MANITOBA

THE UNIVERSITY OF ALBERTA

EFFECTS OF FORCED TREADMILL SPRINT TRAINING ON SELECTED PHYSIOLOGICAL PARAMETERS

BY

© FREDERICK PETER GUTOSKI

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance a thesis entitled "EFFECTS OF FORCED TREADMILL SPRINT TRAINING ON SELECTED PHYSIOLOGICAL PARAMETERS," submitted by FREDERICK PETER GUTOSKI in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

....
Supervisor

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External Examiner

Date. September 17, 1974.

ABSTRACT

The purpose of this study was to investigate the effects of high speed treadmill training upon 100 meter sprint performance and eight physiological parameters. A flat track training group and a control group were utilized for comparison purposes.

Twenty-four subjects (mean age 22.9 years) were ranked according to 100 meter sprint time (mean 12.54 sec.) and blocked into three levels. The subjects from each level were then randomly assigned to one of three groups. The first group acted as control; the second group trained on a flat track five days per week for seven weeks; the third group trained on a high-speed treadmill five days per week during the same period.

Analysis of Covariance, multiple stepwise regression, simple correlation matrix and single sample t-tests were utilized to analyze the data.

No statistically significant difference was found in any of the parameters among groups after seven weeks of training. Each of the three groups experienced significant improvement ($\alpha = 0.05$) in 100 meter sprint performance after seven weeks of training. Statistically significant differences in number and pattern of muscle-joint stress sensations between groups was evident as a result of training.

Correlation coefficients revealed statistically significant relationships between 100 meter time, hip flexion, hip extension, sargent jump, standing long jump and concentric, eccentric and isometric leg strength. Reaction time measures did not correlate with any of the physiological parameters studied.

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CHAPTER I

STATEMENT OF THE PROBLEM

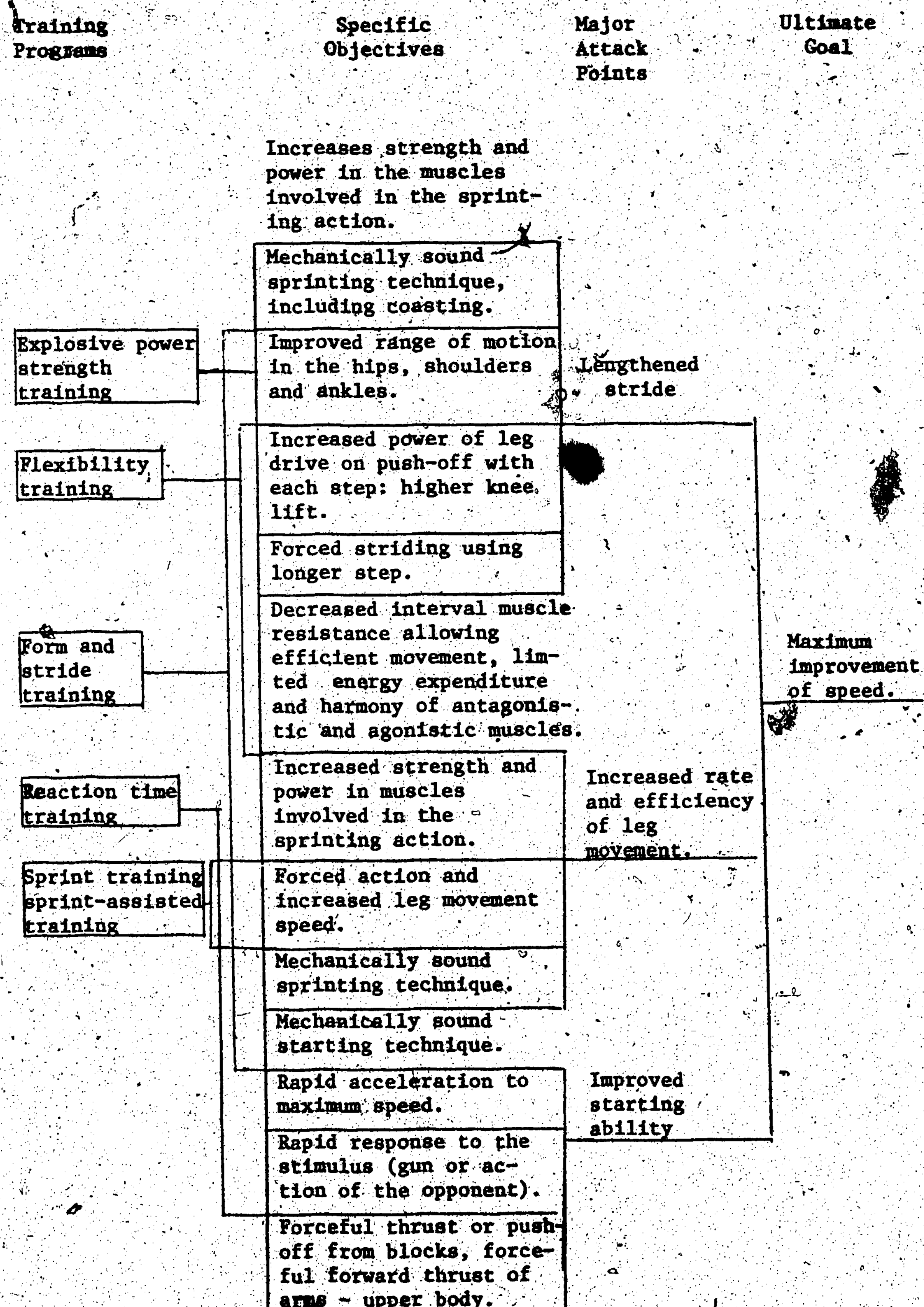
Introduction

Chronological plots of world records (30) in track and field provide evidence of irregular but consistent improvements in the performance capacity of men and women. These new records reflect a complex interaction between improvements in sports equipment, performance, technique, training, more competitions, and changes in social and nutritional influences. Research by Exercise Physiologists, Physical Educators, Psychologists, and Medical Doctors has provided new knowledge which now enables coaches to scientifically design training programs in terms of developing an athlete to the fullest potential. Many coaches have utilized this knowledge and the results have been phenomenal in most events. Sprinting performance, however, has not experienced this degree of improvement. The best results that man has been able to achieve in the 100 meter race have not been improved by more than 0.3 seconds during the 51 year period following Charley Paddock's 10.2 world record in 1921 (30). As a comparison, man has lifted 2137 more pounds, ran the mile 16.5 seconds faster, high jumped 9.125 inches higher, threw the shot put 12 more feet and slung the discus 60 more feet during this time span (24).

Why is it then that man or woman cannot run faster? A review of literature suggest no answer (15). Several researchers claim that sprint ability is inherent (16, 28, 48). Others (13, 19, 20, 26) state that the physiochemical properties of the leg muscles are the most important limiting factors of running speed. The neuromuscular mechanism has also been stated to be the limiting factor for sprinting speed by several researchers (31, 32, 38, 46, 49). Huttinger (29) found that a person's racial characteristic was a limiting factor in running speed (22, 39, 44). Those who study and coach sprint athletes agree that there may be certain limiting factors but that these can be overcome by developing the athletes' strength, reaction time, flexibility, power, endurance and running mechanics (6, 7, 9, 10, 16, 17, 21, 22, 23, 31, 39, 45, 48, 75). These researchers do not place a strict limit on running speed. They encourage athletes and coaches to develop and follow a diversity of training programs (7, 15, 16, 22, 39, 48), each with a specific goal. Figure I is a diagramatic representation of current training programs and their ultimate goals. Much research has been reported regarding the effects of each of these different training programs (6, 11, 12, 42).

When an athlete becomes successful and breaks a world record his training program is sought after. Soon thousands of young athletes are found adjusting their training programs to simulate the Champions' program. Books (47) have been published presenting the training programs of Champion athletes.

Generally, any strength, endurance, flexibility, power and skill training programs will produce a significant amount of improvement in those respective parameters. It is very difficult, to improve a sprinter's performance beyond his natural ability once he has participated in a conditioning program (30).



Maximum improvement of sprinting speed through specialized programs (15).

FIGURE I

Three theories provide the fundamental basis for current training practices: overload, specificity and reversibility (18). The principle of overload contends that for a physiological parameter to improve in functional ability it must be taxed to the limit of its present ability to respond. The theory of specificity maintains that training is specific to the cell and to the specific structural and functional elements within a cell that are overloaded. Transfer of training occurs only to the extent that the same muscle fibers are recruited and used in a similar manner. The theory of reversibility asserts that the effects of training are transient (43). These theories must be considered in planning a speed training stimulus. A speed training stimulus is difficult to differentiate from a strength training stimulus. Both red and white muscle fibers demonstrate a broad range of contractile speed (25) and rapid movements should result in the selective recruitment of the faster fibers. The maximum rate of contraction of an unweighted muscle is not related to its strength but is inversely related to the relative load placed on it (27). If the load lifted, expressed as a percentage of the maximum load the muscle can lift is small, the maximum rate of contraction is fast. If the load lifted is a substantial percentage of the maximum load that can be lifted the rate of contraction is slow. Physiologically this relationship provides a safety factor to prevent rapid muscle contractions at high loads from tearing tendons and from breaking bones (3). The margin of safety for sprinters is minimal and these athletes are prone to muscle pull injuries. Speed training requires the movement of light loads at maximum speed, theory of overload, such as in 50 and 100 meter sprint races. The precise interaction of the rate of contraction, the load on the muscles, the duration of the sprint, and the range of motion provides a complex motor unit recruitment system that has yet to be analyzed. According to Astrand and Rodahl (27), the recruitment of motor units differs depending on the velocity of the contraction. Therefore a sprinters' speed training program must be planned with the theory of specificity in mind. The optimum stimulus for speed training should be sprinting carried out at the highest speed compatible with correct technique; based on the principle of overload sprint training.

Coaches and exercise physiologists have thus far not succeeded in finding a suitable method of overload sprint training. They have explored various ways of making an athlete run as fast as physically possible and have not been satisfied with running on flat surfaces. Several coaches have experimented with down-hill running (16, 34, 36) holding on to an elastic rope fastened to a motorcycle (36), harness running (37, 40), running with the aid of a following wind (34), running while being towed by a car (15, 33), running without any footwear to decrease the load (8), and stair case running (15). Athletes have also tried running holding on to the side of a tram car (34) once per day each time the car went past during its daily route. "Running on Hot Bricks" that is full speed running concentrating on "light" action and rapid pick-up of feet has been practised (1). A small degree of success has been experienced in all of these overload sprint training methods. In many cases, however, the program had to be terminated because of injuries due to the runner's inability to maintain his balance at high speeds (36). As a result, most coaches maintain that sprinting ability is best developed by interval sprint training methods.

Dintiman and others (15) reported that overload sprint training is the most scientific approach to improving sprinting ability. Dintiman suggested that a high-speed treadmill should be used. He hypothesized that adjusting treadbelt speed to gradually force an individual's rate of leg movement to a speed beyond that of which he is capable in unaided running, will lead to improved speed on a flat surface. It has been shown that daily use of a motorized bicycle ergometer that forced a more rapid rate of leg movement than that possible without aid of a motor, carried over to increased revolutions without this assistance (15). Thus, the rate of leg movement in riding a bicycle was improved through forced techniques. Dintiman tested his hypothesis and concluded that high speed treadmill running is effective in improving 20-yard dash times. No research has yet been carried out to investigate the effect of high speed treadmill running on 100 meter sprinting and on other selected physiological parameters.

This research was designed to study the effects of overload sprint training on a high-speed treadmill. The safety of the subjects was insured by using an overhead gymnastic spotting safety harness and a bar which could be held by the runners to prevent falling forward. A pilot study by Bates and Gutoski (5) showed that this is a safe and efficient method of overload sprint training. This overload sprint training method was compared to a current universally accepted (1, 7, 16, 22, 34, 39) method of sprint training on a flat track, standardized for statistical comparison purposes. In the past, researchers have used training programs without any concern as to why speed may have improved (15). In order to gain a better insight into speed development eight physiological parameters were studied. These parameters have been implicated in sprint training programs by many authorities in the field of coaching and exercise physiology (3, 16, 1[illegible], 26, 28, 32, 38, 39).

The Problem

The purpose of this study was to train subjects employing a high speed treadmill sprint training method and thereby improve the 100 meter sprint time. This led the investigator to the following sub-problems:

1. To compare overload sprint training with the conventional method of sprint training on a track.
2. To determine the effects of treadmill sprint training compared to the conventional method of 100 meter sprint training on the following physiological parameters:

(a) reaction time

(b) concentric leg strength

(c) eccentric leg strength

(d) isometric leg strength

(e) leg power

(i) vertical jump

(ii) standing long jump

(f) hip flexibility

(i) extension

(ii) flexion

Hypotheses

The following null hypotheses were tested at the 0.05 level of probability.

1. There is no difference in 100 meter sprint time as a result of different training methods employed.
2. The 100 meter sprint time will not change as a result of forced sprint training.
3. No difference will occur in the eight physiological parameters between the three groups after training.
4. There is no difference in the eight physiological parameters as a result of treadmill sprint training.

Limitations Of The Study

1. The experimenter had no control over his subjects, except during the testing and training situations, and thus could not eliminate other activities which

may have affected the results of this research.

2. The experimenter could not control the subjects' motivation to perform maximally during the testing and training situations. The experimenter did however encourage the subjects to perform maximally.

Delimitations

1. The study was limited to male volunteers from the local track and field clubs from students at the University of Alberta.
2. The subjects in the experiment were limited to those who had maximum oxygen uptake of 45 ml./kg./min. or higher.
3. The experiment was limited to the 100 meter sprint thus inferences to other sprint distances are questionable.

Definition of Terms

Overload sprint training. Overload sprint training is sprint training whereby the individual attempts to run above his maximum running speed, thus adhering to the overload principle of training. In this study, subjects were forced to run faster by using a high speed treadmill.

100 meter sprint time. 100 meter sprint time is the shortest time it takes an individual to run 100 meters starting from a crouch start. The time is recorded from the instant the runner is

given the command "go" to the instant he crosses the 100 meter finish line.

Reaction time. Reaction time is the time that elapses between the appearance of a stimulus and a motor response.

Leg strength. Leg strength is a test of the capacity of an individual to exert muscular force with the muscles of the leg at the knee by having the subject provide maximum resistance concentrically, eccentrically and isometrically on a leg dynamometer. The strength curve was recorded on a Honeywell Medical Electronic System.

Concentric contraction. Concentric contraction is a dynamic contraction during which the length of the contracting muscle decreases. In this experiment, the strength of the concentric contraction is measured during the movement of the knee joint through the angle of 120 degrees.

Eccentric contraction. Eccentric contraction is a dynamic contraction during which the length of the contracting muscle increases. In this experiment, the strength is measured when the isometric contraction is performed at the knee angle of 120 degrees.

Conventional method of sprint training. Conventional method of sprint training is a universal and current method of interval training used by track and field coaches to improve sprinting (Figure 1).

Leg power. Leg power is the ability to release maximum muscular force at maximum speed. In this experiment the standing vertical and long jumps were used as measures of leg power.

Cardiovascular endurance. Cardiovascular endurance is the ability of the circulatory and respiratory system to adjust to and recover from the effects of exercise or work and was evaluated by the Mitchell-Sproule Chapman Method (35) of maximum oxygen uptake measurement.

Maximum oxygen consumption. Maximum oxygen consumption is the maximum volume of oxygen which the body can remove from the air per minute. It is used as a measure of the peak capacity of the cardio-respiratory systems to take up, transport, and release oxygen to the working tissues, and for these tissues to utilize the oxygen in energy production. Maximum oxygen uptake is considered by most exercise physiologists to be the best single indicator of physical fitness (2, 3, 4, 14, 41).

Hip flexibility. Flexibility is a measure of hip flexion and extension by using a Leighton flexometer and using Leighton's standardized technique.

Physical fitness. Physical fitness is the ability of a biological organism to maintain various equilibria as closely as possible to the resting state during strenuous exertion and restore promptly after exercise any equilibriums which have been disturbed (4). The definition specially acceptable in this study is the ability to perform prolonged moderate to heavy work, provided that large muscle groups are utilized (3).

Training. A regular regime of physical activity that is carried out over a period of time.

Flat Track Training. Flat track training is training on a level running track as opposed to training on a track that declines or inclines (Russian Methods recently developed).

Stress Sensations. Stress sensations are subjective sensations of pain or stiffness that were felt as a result of physiological stress due to training.

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CHAPTER II

REVIEW OF LITERATURE

Leg Strength And Sprinting

Researchers and writers in the area of Track and Field (2, 6, 24, 25, 28, 43, 51, 68, 81, 84, 85) have stressed the necessity of a high degree of leg strength for good sprinting ability. Research evidence, however, is somewhat conflicting.

A survey by Fiedlius (47) revealed that leading Polish sprinters on an average were well below the strength level of physical education students of the Warsaw University. He also discovered that the correlation of running speed and strength was statistically insignificant. His findings were similar to those of Clarke (14) who showed that there was no significant relationship between strength/mass and speed of movement. This lack of relationship shows that dynamic and static strength follow different neuromotor patterns. Another study by Clarke (13) with a training group using a selected series of strength exercises indicated that there was no correlation between individual differences in speed and strength/mass ratio, but individual changes in this ratio correlated significantly with individual changes in speed. Henry (34) also showed that the correlations between the strength/mass ratio and speeds of movement were almost nil, except in the middle phase of the action, where the relationship was .29 for men and .27 for women. A group of Soviet physiologists (47) headed by Jakavlev, working with several experimental groups, found that "optimum nervous processes" were obtainable from complex training programs when strength, speed and endurance training was carried out simultaneously without emphasizing any one of these parameters. Second best results were obtained by the group concentrating mainly on speed. The groups emphasizing endurance and strength training were last on the list. Strength training had only limited influence on speed but restricted the development of endurance. Similar results were also obtained by Kalidein and Lukin (47) when they investigated various training methods and their effect on the physiological development for "sports". Colgate and Pierson (119) along with Rasch (67) demonstrated that increases in general arm strength did not affect the speed of reaction or arm extension. Smith and Whitley (78) experimented with thirty-one college men participating in an eight-week strength training program which involved isotonic and multipositional isometric exercises. The object of the experiment was to determine whether a substantial increase in strength was associated with a proportional improvement in speed of movement. As a result of the strength training program there was a 22 percent increase in speed. The strength training resulted in significant and nearly identical strength increases at each of the six angles. This overall strength increase had an insignificant effect on net speed at timing station one, significant losses at stations two and three, with highly significant gains in speed at stations four and five. The authors stated:

A comparison of the results of the present study with the findings of previous studies, which involved the investigation of the effect of an increase in strength upon speed of movement, revealed that the most significant increase in strength is not necessarily associated with the most substantial increment in speed.

Meisel (55) found a loss of speed in running ten yeards, after a six-week weight training program. 104 male university students were divided into experimental and control groups and were equated on the basis of time required to run ten yards after a 15 yard running start. The experimental group participated in a six week training program consisting of exercises designed specifically for strength development of the legs while the control group did not participate in an organized exercise program. The exercises included heel raises, squats, leg flexion and gluteal pull. Strength was measured by a back and leg dynanometer. Results showed a significant increase in the leg strength of the group using the progressive resistance weight training program. The experimental group showed a loss of speed in the 10 yard sprint, a decrease significant at the 0.03 level of significance. The control group showed no significant differences in either strength or speed of running.

Several researchers have reported significant sprinting speed increase following strength training programs. Dintiman (22) studied 145 subjects randomly assigned to one of five training groups. The subjects were tested for flexibility, leg strength, and running speed before and after an eight week training period. Results showed that both weight training and flexibility training, as supplements to sprint training, increased running speed significantly more than sprint training alone. Chui (11) conducted one of the first studies pertaining to weight training and athletic power. Although most of the items in the experiment were concerned with power events, such as shot put, one item was concerned with sprinting speed. One group participated in an intensive weight training program twice a week for three months, while the other group acted as the control group. A retest at the end of the program showed that 17 of the 22 subjects had a mean improvement of .33 seconds in a 60 yard sprint, gains varying from .1 to .6 seconds. Four subjects showed no difference in time and one subject was .1 second slower. From this, Sills (74) concluded that these results indicate the probability of increasing sprinting speed through training with systematic weight training exercises. The level of significance of the differences between the groups was not stated. Slater-Hammel (75) found that the speed of movement is not the speed of the legs per se. His study determined that leg rates in sprinting range from 3.10 - 4.85 per second, in cycling from 5.6 to 7.1 per second. Therefore, the sprinter could move his legs faster without the load of the legs and body. Hence, Slater-Hammel concluded that leg rate is not limited by neuromuscular mechanism but by the weight (load) the muscles must move. Hence, strength is the limiting factor. Sperry (79) makes a similar interpretation of his finding that the contraction rate of the large muscles of the shoulder vary under differing conditions of load.

Glenski (27) studied sprinting performance of three groups of athletes who participated in fartlek, interval and sprint training programs. He found that all three groups improved equally in 60 yard sprint performance. All three methods of training improved leg strength equally as measured by a leg dynanometer.

Leg Strength and Knee Angle

Carpenter (10) studied the effects of different knee angles on leg lift. He concluded that the maximum in leg lift is obtained when the thighs and lower leg make an angle at the knees between 115 degrees and 124 degrees. Strength at angles less than 115 degrees or greater than 139 degrees was found to be inferior. Mathews (52), Willgoose (10) and Clarke (15) agree that the maximum lift should occur when the subject's legs are almost straight at the end of the lifting effort.

Leg Power and Sprinting

A great number of authors and researchers (2, 6, 8, 11, 12, 18, 24, 25, 28, 29, 51, 58, 84, 85, 86, 87) have implicated power with sprinting. At least two sources (69, 111) have questioned the use of the term "power" as a mechanical physiological parameter. In this study power is defined as the ability to release maximum force in the shortest possible time, as is exemplified by the Sargent Jump (70) and the standing long jump (1).

For nearly a half century the Sargent Jump has been the most commonly used test of leg power by Physical Educators.

D. S. Sargent (70) originally used the test to indicate neuromuscular efficiency but L. W. Sargent (70) regarded it as a test of power, he states:

> the work done by causing the body to rise above the ground as the excess of work done over that required merely to raise it from the squatting to the standing position and this excess work consists of building up velocity, an accomplishment possible only when the rate of doing work (power) is above a certain minimum.

McCloy (53) states that the Sargent Jump when combined with an appropriate formula containing factors of age and weight predicts the "power type" of athletic ability. He indicated that it was probably the best single measure of predicting explosive energy. Several others (9, 30, 61, 81) also regard it as the best index of power.

The standing broad jump has also been used as a test of power by several researchers (7, 41, 80). A study by Stuart et al evaluated power by using both the Sargent Jump and the standing long jump. Both these tests of power have been accepted as reliable measures of power (44).

Balsevitch and Siris (4) who studied the aptitude of children for sprinting stated:

> Our experience is that for establishing ideas as to the aptitude of children for sprinting the following evaluative exercises can be of help: 30-meter run with flying and crouch starts, standing long jump, distance jumps from the crouch position.

They found that children's ability to sprint was highly correlated with power.

Gray et. al. (29) designed a test of leg speed using the bicycle ergometer. The factors of leg speed and leg power were then compared and a correlation of .47 was established. The test used to measure leg power was the vertical jump. The correlation was significant at the .001 level. The correlations between speed and power obtained by Gray et al "were mathematically", though not statistically, lower than correlations between the tests of leg speed and power studied by Rarick (69) and Harris (31). Rarick obtained correlations of .64 and .61 between the time taken to cover the last 10 yards of a 30 yard sprint and the Sargent Jump. When he eliminated the arm movement in the Sargent Jump the correlation was .63. Harris found that leg speed as measured by the 40 yard dash correlated .59 with the Sargent Jump. The different tests used to measure the factors of speed and power together with sample and experimental errors probably accounted for the differences in these correlations.

Start et al (80) utilized 63 male subjects to study power, speed and strength in the lower limb. They studied 19 measures: seven of isometric strength, four of power, seven anthropometric estimates and one of speed. The tests of power used were: the sargent jump, the vertical power jump, squat jump and the standing long jump. Factor analysis of the data suggested that power was linked with speed rather than strength.

Flexibility and Sprinting

A practical explanation regarding the concept underlying the mechanical factors in relation to sprinting was offered by McCloy (54) in which he stated: "Flexible performers, whether athletes or dancers, have on the average a higher degree of competence." To illustrate this concept he visualized a hypothetical runner whose movements were impeded by elastic cables simulating tense hamstring muscles.

Very little research has been reported concerning the effects of increased flexibility upon sprinting speed. Nelson (60) attempted to determine the effects of increased hip and ankle flexibility upon running speed. He equated two groups of 20 subjects on the basis of hip hyperextension and flexion, ankle extension and flexion, and 50 yard sprint time. The experimental group took part in a flexibility training program, involving ballistic exercises, while the control group remained inactive. He concluded that an increase in hip and ankle flexibility did not improve running speed.

Dintiman (21), attempted to determine whether a flexibility training program, a weight training program, and the combination of both would improve sprinting speed, when used as supplementary training, to the conventional method of training sprinters. One hundred and forty-five subjects, randomly assigned to one of five training groups, were tested for flexibility, leg strength, and running speed before and after an 8-week training period. Results showed that both weight training and flexibility training, as supplements to sprint training, increased running speed significantly more than an unsupplemented sprint training program.

De Vries (20) has pointed out that improvement of flexibility should decrease the negative forces involved in running and thus improve running speed. However, an investigation by de Vries (19), in which speed and oxygen consumption on a 100-yard sprint were measured failed to confirm this hypothesis. Static stretching was used as a warm-up procedure to allow evaluation of a relatively pure flexibility factor as a contributor to muscular efficiency or "looseness". Four subjects each ran ten 100-yard sprints anaerobically. Five trials followed no warm-up and five followed a period of static stretching. Respiratory gas samples were analyzed for gross and net O_2, CO_2, ventilation rate, and true O_2. Differences in running time and all respiratory measures were small in magnitude and most achieved significance at the .05 level.

Reaction Time and Speed of Movement

Research findings on the relationship between reaction time and speed of movement does not appear to be consistent. Slater-Hammel (76) and Henry (32) and others showed that these phenomena are unrelated, whereas studies by Scripture (72), Westerlund and Tuttle (82) provides evidence of a positive significant relationship. The latter studies utilized primarily a forward arm movement whereas the former have used a variety of movements.

(i) Significant Positive Correlations

An early study by Scripture (72) compared reaction times of sprinters and distance runners. On the basis of his data it was concluded that the reaction time was one-third shorter for sprinters than for athletes who competed in the distance running events.

Westerlund's and Tuttle's (82) findings supported Scripture. They studied the reaction time of sprinters, middle distance runners and distance runners and reported the mean reaction time for each group as follows:

sprinters.	.131 secs.
middle distance runners.	.149 secs.
distance runners	.169 secs.

The correlation between reaction time and 75 yard sprint time for these three groups was found to be .863.

In 1954 Hipple (38) reported a "possibly significant" correlation from the measurement on 12 to 14 year old white male subjects. Wilson (83) also found positive correlations between RT and MT in arm movements (r = .31). Two years later Younger (88) found a low but statistically significant correlation between reaction time and movement time for female college students, athletes, and non-athletes. During the same year Pierson studied 400 male subjects, aged 8 to 83 years. The subjects were measured for reaction time and movement time by a fractioning process. The correlation between these variables was computed for the 400 subjects as well as for certain age groups, and an analysis of these computations permitted the conclusion that for males between the ages of 8 and 83 years there was a statistically significant correlation between reaction time and movement time. Olson (62) compared athletes, non athletes, and an intermediate group consisting of intramural and junior varsity players as well as participants in a recreation program. The athletes displayed the fastest reaction time.

In 1962 Pierson and Rasch (66) found a significant relationship of .47 between reaction time and speed of movement. This significant correlation was still found to exist after the subjects participated in a 4 week strength training program (r = .37).

Two years later Kerr (45, 46) studied the RT of 47 male college students. The subjects were tested for speed of reaction and movement at a knee extension of 60°. One week later, 39 of the subjects were retested. In both tests, reaction time was found to correlate with speed of movement (r = .53 and .62). The two correlation coefficients were not found to be significantly different from each other.

In 1972, analysis of studies preceeding the Munich Olympic games were presented at the International Symposium on Sports Sciences held in Munich (71). The top ten sports or events which develop the best reaction times were listed as:

table tennis	sprinting
fencing	gymnastics
boxing	weight lifting
squash	basketball
goal keeping	judo

(ii) Nonsignificant correlations.

In 1952 Henry (32) reported that there was no correlation between simple reaction time and the duration of discrete movement. He concluded that the two functions must, therefore, be considered as independent and unrelated. Slater-Hammel (76) likewise found no correlation between reaction time and movement time and in addition indicated that the method of movement termination has no pronounced effect upon the relationship. He did not agree with Henry about the significance of the fact that reaction time and movement time appear to be independent and uncorrelated. The lack of correlation means only that the possibility of a "slow reactor" having a fast movement time is as great as it is for a "fast reactor". The results of Slater-Hammel's study were interpreted as simply indicating that measurement of reaction time cannot readily be used to predict speed of movement. In the same year, studies conducted by Fairclough (26) using different movements, reported nonsignificant correlations, all "well within the limits of the sampling error of a true zero correlation". During the next year these findings were supported by Sills (74) and Howell (40), who found a negative correlation ($r = -.382$). Subsequent research by Pierson (65) and Cooper (17), Hodgkins (39), Henry and Whitby (35), Lotter (50), Henry (36, 37), Smith (77), Mendryk (56) and Phillips (64) supported these findings. All researchers found non-significant or negative correlations between reaction and movement times.

The studies presented thus far have not used sprint running as movement time. Henry (33) found that reaction time is of very little importance in sprinting performance. Of the 25 sprinters tested, 12 showed positive relationship between fast reactions and fast sprints, and 13 showed a negative relationship. Further analysis of the data supplied an explanation: the variance between two sprint reaction times is extremely small, being on the average only .0009 seconds; whereas, the variance between two 50 yard sprints is 15 times greater, i.e. .0135 seconds. He then came to the conclusion that other factors than reaction time must evidently be responsible for any important differences in a sprinter's speed in successive runs. He further stated that there was no correlation among individuals "reacting ability" and sprinting ability - a fast sprinter may be either a fast or a "slow reactor", or an "average reactor."

In a study by Lacy (48), a group of experienced sprinters was compared with an inexperienced group. In the beginning, the inexperienced group was off the blocks in less time than the experienced sprinters. As the inexperienced group gained in skill and speed the time on the blocks increased. The best sprinters tended to be slower in leaving the blocks, but caught up and passed the others at the 10 yard mark. Recently, it was reported by Osolin (63) that there was no correlation between reaction time, acceleration, maximum speed, and speed changes in the sprinters tested.

The complex relationship between reaction time and movement time remains questionable. The direction of this relationship would appear to be negative. However, in view of the fact that some studies have shown significant correlations between reaction time and movement time, this study again observed this relationship.

New Methods of Sprint Training

In his report to the Art and Science of Coaching Symposium held in Toronto in the fall of 1971 Dintiman (22) stated that coaches for the past 50 years have stressed a type of training more conducive to the development of endurance than speed. He reported that coaches have almost completely neglected the two most important means of improving speed: by increasing both stride length and the rate of leg alteration. He also stated that:

> While typical sprint training programs will expedite recovery between sprints, delay slowing and allow maximum speed to be held over a longer distance, the maximum speed that an individual can reach is unaffected. A sound program to develop to one's maximum potential requires a change to anaerobic training (75 percent) and focus upon programs that alter stride length and sequence speed.

The rate of leg movement is usually regarded by coaches as an unalterable, inherent quality. However, there is evidence to the contrary. Slater-Hammel (75), for example, found that higher rates of leg alternation were possible in cycling than sprinting.

de Vries (20) suggested that the physiological reasons supporting improved running speed through increased flexibility is tremendous. He stated that research in support of this is grossly lacking but it is logical to assume that someone who is more flexible may be able to take a longer step. He further suggested that improved range of motion in the hips, shoulders and ankles possibly is a means of increasing stride length.

Dintiman (22) suggests that three specialized programs have attempted to achieve improved sprinting speed by increasing both stride length and frequency:

1. Towing
2. Downhill running.
3. Treadmill running.

1. Towing Method of Sprint Training

The first person to experiment with the towing method was Paavo Nurmi of Finland (49) in 1925. Nurmi had attributed his longer flowing stride to his habit as a youth of hanging on to the sides of a slow moving train. Nurmi related how he was able to run for miles without fatigue and at the same time increase his stride length. Hensley (49), a former champion marathon runner from Australia duplicated Nurmi's experiment. He improved his 100 yard sprint time by one second after a year of holding on to the side of a tram car whenever he had the opportunity. Hensley retired from competition and became a coach. He was thoroughly convinced that being pulled by a train, a tram car or an automobile would produce positive results. He developed a "towing plan" with his athlete. This car-towing method made it possible for his athlete to run many eight-second 100 yard sprints in repetition without any undue strain or fatigue. His athlete reported (49):

> As we had expected, the first few weeks revealed nothing in particular. I found that it was no effort to run repeat 100 yards in 9 seconds with only 110 yards recovery jogging after each. It soon became apparent that my own stride was noticably increasing in my races. After three weeks I was running 200 yard sprints in my tow training. In one session I recorded a 22-second effort, four 19-second efforts, and a blistering 17.5 clocking for my last two. The only recovery period that was necessary was the 200 yards jog back to the starting point. After six weeks of the experiment, I had my first track race of the Olympic season over 10,000 meters. My time of 29:50 was a new Australian record.

Soviet coach, Fruktov (63), observed similar development in his experiments with sprinters running attached by an elastic rope to a motor cycle. His athlete, Ponomaryev, raced after a minimal warm-up behind a motorcycle three repetitions with five minute recoveries over 50 meters from a flying start. Following a six-minute rest he performed two repetitions of 50 meters from a flying start under normal conditions and improved his best time by 0.3 seconds. In Ponomaryev's own words the runs behind the motorcycle gave him, "a feeling for higher speed".

2. Downhill Running Method of Sprint Training

Sprinters using downhill tracks to develop sprinting speed have reported success. Double gold medal winner Borzov (5) won both short sprints at the 1972 Olympic Games. He trained on downhill slopes. Research conducted by Ozolin, Lonov, Obbarius and Petrovsky (63), found that using a track with 2-3 per cent decline gave the best positive results. At the Sports Center in Belgrade, Yugoslavia, national coach Milakov (57) studied the effects of training on sloping surfaces. He had three groups of students following specific training programs. Group "A" trained on a regular flat surface. Group "B" trained on a downhill-uphill surface and Group "C" trained on a downhill-uphill-flat surface. Group "C" showed the best results in improving their sprinting performance.

3. High Speed Treadmill Running

High-speed treadmill running consists of running beyond voluntary maximum speed (forced). Dintiman (112) reported significant improvements in 20 yard sprint times after an eight week treadmill training program.

Injuries and Sprinting

A distance runner's injuries usually appear gradually. Sprint injuries, like the event itself, happen suddenly and are often very serious. Most injuries develop during the start of a sprint race. Two conflicting demands are apparent in sprinting: staying explosive and loose at the same time. Sprinters have to stay relaxed at high speed in order to sustain speed and economize energy, and powerful yet flexible to avoid injury. The most common injuries to sprinters reportedly (5, 20, 24, 68) are shinsplints, and injuries to the hamstrings and quadriceps muscles. Brubaker and James reported that the most common injuries to runners are strains (33%), fractures (20%), sprains (14%) and tenosynovitis (12%).

The injuries were distributed by event as follows: sprints (24%), middle distance (15%), distance (41%), joggers (3%). Strains accounted for 18 of the 26 injuries to sprinters which was the highest incidence of injury by category and event.

Overground Versus Treadmill Running

The motor driven treadmill has long been used by investigators to provide an easily standardized, reproducible work performance task. Its' advantages lie in using a common human movement which can be varied in intensity while the subject performs in close proximity to sophisticated electronic recording instruments. Initial treadmills were designed for slow pace running and they played a very important role in the discovery of many aspects of the physiological responses of man to exercise. The advent of the treadmill brought about a multitude of studies related to cardiorespiratory training. Of special importance has been the influence of physiological research on the formulation of training regimens and evaluation of training levels of athletes. The treadmill became a basic piece of equipment in all exercise physiology laboratories.

New models of treadmills have been developed recently that can perform 25 - 30 miles per hour. Since the fastest human has been recorded at 26 miles per hour the high-speed treadmill can actually cause the runner to run faster than he could under his own will.

Very few studies have been undertaken with subjects running at maximum speed on a treadmill. A very basic question arose regarding whether the results from treadmill studies can be directly applied to running overground. Astrand, Balke and Margaria (59) indicated that such an application is valid on the basis of fundamental mechanics. These researchers agreed that except for air resistance it can be assumed there is no difference in running on the two types of surfaces.

Nelson, Dillman, Lagasse and Bickett (59) compared the biomechanics of overground and treadmill running using cinematographic methods. Sixteen runners were filmed while running at three speeds and on three slopes over both surfaces. Temporal factors and vertical and horizontal velocities of the center of gravity were investigated. Treadmill running was chacterized by longer periods of support, lower vertical velocity, and less variable vertical and horizontal velocities than for overground running. It was concluded that performance on the treadmill produces significant changes in the biomechanics of running.

Dintiman (22) supported Nelson et al and pointed out several aiding and hindering factors in treadmill sprinting, (Figure II). He stated that treadmill running was smoother and provided a feeling of complete mastery with little effort. He further stated that since it was an aided device the total effort appeared less although research indicated that oxygen uptake and energy expenditure were similar in treadmill and unaided running.

Recently, Dintiman (23) studied the effects of high-speed treadmill training upon sprinting speed. Eight male subjects were divided into two groups using matched pairs, on the basis of pre-test 20 yard sprint time, age, height and weight. The experimental group engaged in an eight-week training program, three times weekly, consisting of weight training and high-speed treadmill running. The control group participated in weight training and conventional sprint training program. Treadmill running consisted of sprinting at maximum speed, and at near maximum treadbelt speed (up to 26.5 m.p.h.) for the prescribed number of repetitions while supported in a suspended harness that permitted free arm movement. Pre and post-test means were compared within each group to determine whether statistically significant improvement occurred in the 20 yard sprint with a running start. The experimental group improved significantly from the pre to the post-test while the control group failed to do so. Within the limits of this study, it was concluded that high speed treadmill running is more effective in improving 20 yard sprint times than a conventional program of sprint training when these programs are supplemented by weight training.

A pilot study (3) preceding this dissertation utilized five subjects who were experienced University level sprinters. The subjects were able to run all-out on their first trial without any conscious effort to change their style of running. It was concluded that if there is any difference in technique or style of sprinting on a treadmill it is not evident.

FIGURE II

Aiding And Hindering Factors In
Treadmill Sprinting

+ FACTORS Aiding	- FACTORS Hindering
*Breaking effect each time the lead foot touches the treadbelt - belt speed is slowed at this point to obscure speedometer reading.	Limited push-off possible from weight bearing foot.
No wind resistance	Form alteration required that affects positive transfer to flat surface, unaided sprinting.
No unfavorable environmental conditions - temperature, inclimate weather	
Energy conservation - steady, unaltered pace, less knee lift, no acceleration.	
Less time on weight bearing foot	
Motorized belt forces a faster pace	
Form correction possible while subject is sprinting	
Stride length increased	
Challenging - pre-knowledge of belt speed.	

*This braking effect is greater in initial stages of treadmill running and tends to be eliminated as acclimatization occurs and form instruction is given. At high speeds beyond one's maximum speed (in early use of treadmill), the braking effect almost reduces treadbelt speed to a sprinter's maximum speed. With continued training, this point is easily overcome, Dintiman (22).

Irwin (42), using the same subjects as in the present study, investigated the changes in stride rate and stride length with the aid of high speed photography. No significant changes were found in stride length or rate among any of the groups.

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CHAPTER III

METHODS AND PROCEDURES

Subjects

A sample of 24 male subjects was obtained from among track and field athletes and from University of Alberta Physical Education students.

The subjects were volunteers between the ages of sixteen and thirty-one. Only subjects whose maximum oxygen uptake was 45 mls./kg./min. and over were included in this study.

Experimental Design

All subjects were pre-tested and ranked according to their time for the 100 meter sprint. To overcome the differences in initial 100 meter sprint time the subjects were divided into three blocks of eight subjects each. From these three blocks the subjects were randomly divided into a control group, a track group and a speed-treadmill group. All subjects reported for the research project healthy and free of any known injuries, soreness or stiffness. The pre-test started two days before the training period began and the post-test started one day after the seven week training period ended. The tests were administered over a period of two days in each case. The following tests were made during the pre and post period: maximum oxygen uptake, 100 meter sprint time, standing vertical jump, standing long jump, hip flexion, hip extension, reaction time, concentric leg strength, eccentric leg strength, and isometric leg strength. The subjects were tested in assigned random order during each testing period. During the seven week training period all track and treadmill training was closely supervised and injury status was recorded daily. The study was conducted during July and August 1972 at the University of Alberta Faculty of Physical Education research laboratories and track and field facility.

Anthropometrical Data

The following anthropometrical data was collected from each subject: age, height, weight, and major activity.

Pilot Study

A pilot study was carried out six weeks prior to this research. Five subjects were utilized as an experimental group. The purpose of the pilot study was threefold:

(a) to design a harness to be used by the subjects during high-speed treadmill sprinting for safety purposes.

(b) ~~to design~~ economical procedures to follow during all aspects of the major thesis study to follow.

(c) to develop safety procedures and operational skills on the treadmill.

Test Procedures

All subjects were dressed similarily: running shoes, socks, light top, and shorts. All subjects received identical instructions on the method to be used in testing prior to both the pre and post-tests.

The pre and post tests were administered in the following order:

(a) Maximum Oxygen Uptake

The Beckman E2 oxygen analyzer, and the Godart Capnograph carbon dioxide analyzer were carefully calibrated with test gases prior to use each day, and at regular intervals during the testing sessions. The correction factor for converting the gas volume to STPD was taken each time a test was administered.

A Collin's triple-J valve was connected to a lightweight headgear and fitted with a sterilized rubber mouthpiece for easy attachment to the subject. A flexicoil hose was attached to the "out" vent on the J-valve, and coupled to a Douglas Bag. The subject's nose was clamped with a clip. Expired air was collected during the last minute of the two and one-half minute workloads. This was analyzed immediately for oxygen and carbon dioxide content (Beckman E2 Oxygen analyzer and Godart Capnograph). A Parkinson Cowan Dry Spirometer, Type CD4 was utilized to measure the volume of expired air.

An Olivetti 101 desk computer was pre-programmed with the formula from Consolazio, Johnson and Pecora (3). The input data consisted of:

a) correction factor to STPD;

b) volume of gas expired (BTPS) liters per minute;

c) body weight in pounds;

d) Beckman E2 oxygen analyzer reading;

e) % concentration of carbon dioxide in expired air obtained from the Godart Capnograph.

The following output was received:

a) % oxygen in expired air;

b) volumes of expired air (liters per minute STPD);

c) % nitrogen in expired air;

d) volume of inspired air (liters per minute STPD);

e) oxygen consumption (liters per minute STPD);

f) oxygen consumption (ml. per kg. per minute).

The maximum oxygen test was administered according to the method of Mitchel-Sproule-Chapman (13). To measure body weight (and height for anthropometric data record) a Health-O-Meter weight-height scale was utilized.

(b) 100 meter sprint performance.

Formal warm-up procedures were given to all subjects prior to the 100 meter sprint test. Two experienced timers started their watches on a hand signal given by an experienced starter. As the subjects raced across the finish line the watches were stopped when the chest of the sprinter crossed the vertical line above a 100 meter marker on the track. Each subject raced with someone and both were instructed to race three yards beyond the 100 meter marker.

To reduce timing errors the following steps were taken:

1) both watches were synchronized prior to the initial and final sprint tests.
2) both timers were taught to standardize their movements, such as the focus of attention at the start and finish of the sprint, and eliminating the slack in the stem before starting or stopping the watches.
3) each timer was presented with the same stop watch on each testing occasion.

The average time of the two watches was used as the official 100 meter time for each trial. The two timers, the starter and the runner determined whether maximum effort was given. If maximal effort was not given the trial did not count. The times were recorded to the nearest one-tenth of a second.

Each subject ran two trials on each of the two days of the pre and post-test periods. The second trial followed the first trial after a 10-15 minute rest period.

All subjects were instructed to wear the same shoes, socks, shorts and a light top for all of the 100 meter sprints. The subjects started from the crouched position and verbal even-cadence conventional starting commands were given accompanied by a rapid lowering of a raised hand for timing purposes.

The average time of the four trials was used for statistical analysis.

(c) The Sargent Jump and the Standing Long Jump tests were administered following the standardized procedures outlined by [illegible] and Nelson (8).

(d) Hip flexion a[illegible]xtension was measured using the Leighton Flexometer Method (11, 12).

(e) Reaction time was measured by utilizing a sensitive load cell connected to the Honeywell electronic medical system consisting of a Model 1912 Visicorder for recording physiological phenomena, and a Model 8011 multichannel oscilloscope for data display. A sample recording of reaction time data is presented in Figure III. The 3000 pound capacity load cell, model U31 tension type from BLH Electronics was connected to each subject's ankle by a leather strap. Although Payne (126) found that in general both front and rear legs started to exert forces during the crouch start, the ankle of the leg that is placed in the rear position during the crouch start was used for standardization purposes. Figure IV displays the reaction time apparatus. Only the researcher and the subject were allowed in the room during reaction-time testing period.

Each subject was seated in a relaxed position facing a light stimulus, knees flexed at approximately 110 degrees and both feet flat on the floor. Each subject was allowed three practice trials after which 5 trials were recorded. A warning signal preceded the presentation of the visual stimulus. The time span between the warning signal and the stimulus was varied to prevent any anticipation by the subjects. For statistical analysis purposes the average of the five trials was used.

(f) Concentric, eccentric and isometric leg strength were measured by using an experimental leg dynamometer developed at the University of Alberta and described by Singh (17) in combination with a load cell connected to a Honeywell Medical Electronic System (1). Each subject exerted maximally through an angle of 120 degrees measured at the knee joint with a fixed angle apparatus. Each subject kept his entire back against a moveable sliding board attached to a vertical stand. This was enforced to prevent any flexion of the back and hip regions. The standardized procedures outlined by Singh (17) were followed. A sample recording of leg strength data is presented in Figure V.

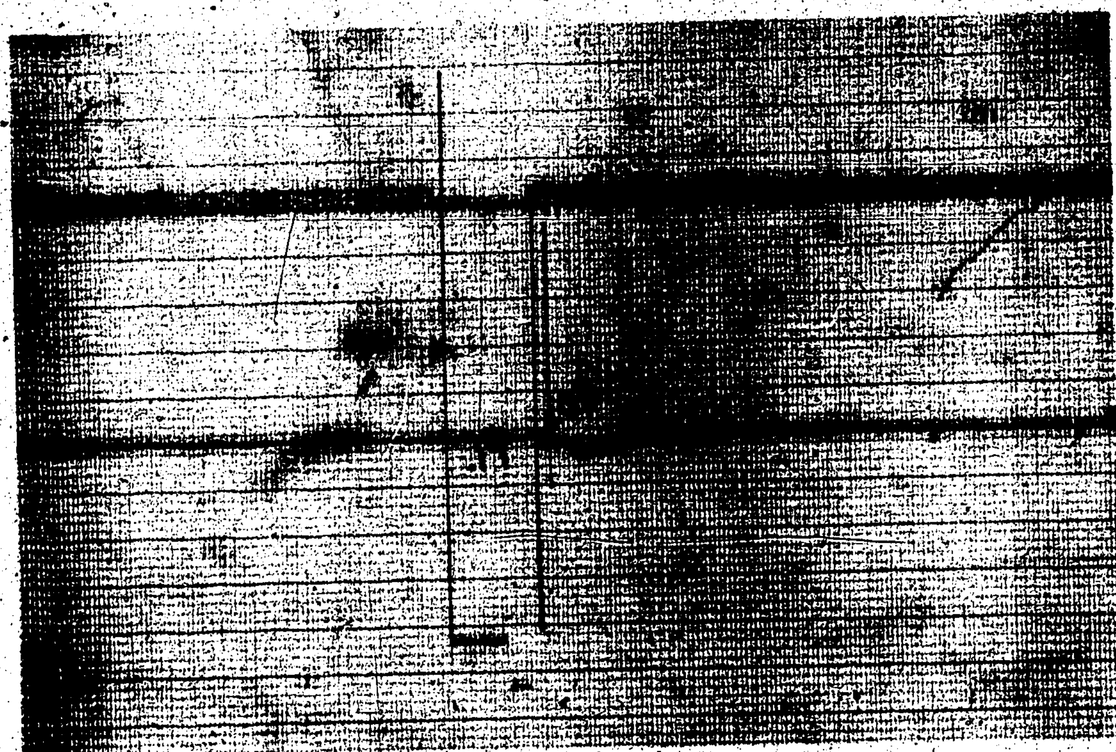

FIGURE III

SAMPLE RECORDING OF REACTION TIME DATA

FIGURE IV

REACTION TIME APPARATUS

FIGURE V

SAMPLE RECORDING OF LEG STRENGTH DATA

Experimental Groups

(1) Inactive control group

This group of eight subjects was required to participate only in the two testing periods: pre-training and after seven weeks of training. They were ~~instructed~~ to carry on with their normal activities but not to engage in any form of sprint training. A verbal summary of their experimental period daily activity was given to this investigator at the end of the research period. Stress sensations were recorded for comparison purposes.

(2) Track training group

In addition to the pre and post-tests this group of eight subjects was required to participate in a conventional interval sprint training program (2, 5, 6, 7, 10, 15, 18, 19). A warm-up consisted of one-half mile jog, 5 minutes of calesthenics and slow stretching and 2-3 sprint accelerations. Seven training sprints followed. The warm-down consisted of a 1/2 mile jog. The seven sprints were all-out efforts of 60, 60, 80, 100, 80, 60, 60 yards. The rest interval between the sprints consisted of a walk back to the starting line. The maximal rest interval was limited to three minutes. These workouts were performed five days a week for seven weeks. Each subject chose his two weekly rest days depending upon how he felt. All sensations of stress were recorded.

(3) High speed treadmill group

The high speed treadmill group performed a daily warm-up consisting of five minutes jogging at 4.5 miles per hour on the treadmill with two or three sprint accelerations to near maximum followed by calisthenics exercises. The subjects then performed seven sprints on a treadmill five days per week for seven weeks. The rest interval between each sprint consisted of three minutes' walking. Each sprint consisted of a rapid acceleration to 100 per cent of maximum running speed as determined by the pre-test 100 meter performance. As soon as the subject reached his maximum running speed the treadmill speed was increased one-half mile per hour every three days or until the subject began to lose his running control after which the treadmill was stopped. The sprint period was calculated to last approximately the same number of seconds it took the track training group to run their seven all-out sprints of varying distances, 7-14 seconds. The warm-down period consisted of 3 to 5 minutes of jogging.

A gymnastics belt was attached to each subject at waist level. Two ropes connected the belt to two sturdy cables on the ceiling above the treadmill. A rope was also attached from the gymnastics belt to a hand rail in front of the runner. This hand rail attachment prevented the subject from falling behind during a run while the gymnastic-to-ceiling engagement prevented the subject from falling down. This harness was designed so that arm and leg movements were free of any restrictions (Figures VI & VII). The investigator kept his hand on the treadmill controls in the event a subject was experiencing difficulty in which case the treadmill belt would be stopped within two and one half revolutions A five day workout acclimatization period was utilized to allow subjects to learn to run at high speeds.

The subjects trained five days a week for seven weeks. Each subject decided what days he would rest depending on how he felt. A one-day rest period was allowed before the tests were administered. All subjective stress sensations were recorded daily.

FIGURE VI

TREADMILL AND SAFETY HARNESS

FIGURE VII

STUDENT TRAINING ON TRAMPOLINE WITH
SAFETY HARNESS, FRONT AND REAR VIEW

Calibration of the Apparatus

The load cell and the Honeywell Electronic System were calibrated by comparing the indicated deflections on the graphs with known weights added to the load cell. Linearity of the load cell measurements was confirmed. This calibration procedure was carried out previous to both pre and post-test periods. During both testing periods a calibration check was made at regular intervals.

Statistical Treatment

The significance of the differences between pre and post-test group means of each variable in each test set was computed using the analysis of covariance technique (4). The analysis of covariance was done via the IBM 360 computer at the University of Alberta.

To determine what set of variables was most strongly related to 100 meter sprint time a stepwise multiple regression analyses on the pre minus post-test data set was also calculated utilizing the IBM 360 computer system at the University of Manitoba. The dependent variable was 100 meter sprint time and the independent variables were the eight physiological parameters under investigation. A correlation matrix was also determined for each of the pre, the post and the pre minus post-test data sets.

One-tailed T-tests were computed on each variable to determine if any statistically significant pre and post differences within groups existed.

Differences at the 0.05 level were considered to be significant in each analysis.

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CHAPTER IV

RESULTS AND DISCUSSION

Results

The pre and post-test means are shown for each variable for each group in Table I.

The data were treated with an analysis of covariance technique to determine if any significant differences between groups occurred at the post-test when corrections were made for any sampling differences at pre-test time. The results are shown in Table II.

To determine if statistically significant differences existed between pre and post scores within groups, one-tailed t-test computations were made ($df = 7$, $t_{\alpha} 0.05 = 1.895$), Appendix B. All groups were found to have significant differences between pre and post-test mean 100 meter times. Mean concentric leg strength was found to decrease significantly from pre to post-test time in the high-speed treadmill group.

Mean reaction time scores increased significantly from pre to post in all the control and track training groups. The significant intragroup values are denoted in Table I.

TABLE I

PRE AND POST-TEST MEANS AND DIFFERENCES

	CONTROL GROUP			TRACK TRAINING GROUP			HIGH SPEED TREADMILL TRAINING GROUP		
	Pre	Post	Post minus pre	Pre	Post	Post minus pre	Pre	Post	Post minus pre
SVJ	20.1875	20.4375	0.2460	19.6250	19.9687	0.3437	19.5749	19.7812	0.2062
SLJ	94.4375	95.1875	0.7500	89.8750	89.1875	-0.6875	88.1875	88.5625	0.3750
100m	12.9999	12.8724	-0.1275*	12.8474	12.6649	-0.1825*	12.6524	12.3349	-0.3175*
HF	93.7500	95.1250	1.3750	93.1250	90.8750	-2.2500	99.5000	96.0000	3.5000
HE	31.1250	33.7500	2.6250	34.5000	36.3750	1.8750	31.7500	33.8750	2.1250
CLS	1008.7500	962.5000	46.2500	770.0000	724.3750	-45.6250	903.7500	679.3750	-224.3850*
ELS	1157.5000	1197.5000	40.0000	1111.2500	1064.3750	-46.8750	1112.5000	1065.6250	-46.8750
ILS	937.3750	1063.1250	128.7500	955.0000	903.7500	-51.2500	950.0000	854.3750	-95.6250
RT	0.1241	0.1503	0.0262*	0.1044	0.1297	0.0252*	0.1297	0.1288	-.0008

*denotes values greater than the t-critical ($\alpha=0.05$), (df=7) for pre-test and post-test differences within groups.

TABLE II

ADJUSTED POST-TEST MEANS

VARIABLE	CONTROL GROUP	TRACK TRAINING GROUP	HIGH SPEED TREADMILL TRAINING GROUP	SIGNIFICANT CHANGES BETWEEN GROUPS
SVJ	20.093918	20.118591	19.974945	NO
SLJ	91.746704	90.102371	91.088379	NO
100 m	12.722555	12.652244	12.497666	NO
HF	96.965820	93.389297	91.644836	NO
HE	34.562607	35.130661	34.306702	NO
CLS	896.36694	796.03882	673.84375	NO
ELS	1177.4358	1074.8191	1075.2446	NO
ILS	1072.1416	897.37598	851.73193	NO
RT	.15038264	.12972486	.12889206	

Maximum Oxygen Uptake

There was no significant change in the maximum oxygen uptake between the pre and post scores within the three groups, (Table III). Further, there were no significant changes found in-between group comparisons, (Table III). The control group mean maximum oxygen uptake decreased by 2 ml./kg./min. The track and treadmill training groups demonstrated mean increases of 1.96 and 1.56 ml./kg./min. respectively.

Body Weight

There was no significant change in subjects' body weight following the seven week study period, (Tables III and IV). The control, track and treadmill groups experienced nonsignificant mean increases in body weight of 0.5, 0.4 and 0.06 pounds respectively.

Subjects' Injury Record

Prior to the pre-test all subjects reportedly were healthy individuals without any complaints of muscle or joint stiffness or soreness. During the seven week investigation, 45 complaints of muscle and joint stiffness and soreness were registered, (Table V). The control group recorded 3 complaints and the track group recorded 10 during the first four weeks. The treadmill training group recorded 32 muscle-joint complaints. The inter and intra-group differences were statistically significant at the 0.05 level.

TABLE III

MAXIMUM OXYGEN UPTAKE AND BODY WEIGHT CHANGES

SUBJECTS	POST MINUS PRE VALUES IN ml./kg./min O_2 UPTAKE	POST MINUS PRE VALUES IN POUNDS BDY. WT.
Control Group		
1	-2.32	3.5
2	-2.34	1.0
3	-1.55	-3.0
4	-1.48	.5
5	-2.84	-3.0
6	4.13	2.5
7	- .37	1.0
8	-6.22	2.0
Track Training Group		
1	1.14	-5.0
2	-2.12	5.0
3	.30	-2.0
4	6.44	-4.0
5	-1.43	2.0
6	- .04	2.5
7	11.66	1.5
8	- .23	-6.5
High Speed Treadmill Training Group		
1	-1.26	-2.5
2	-1.64	-3.0
3	1.03	3.0
4	3.93	.5
5	3.88	-1.0
6	1.04	.5
7	.61	-2.0
8	4.93	5.0

TABLE IV

SUBJECTS PERSONAL DATA

	AGE (years)	HEIGHT (inches)	PREWEIGHT (pounds)	POSTWEIGHT (pounds)	MAJOR ACTIV[illegible]
Control Group					
1	24	68	150	153.50	Gymnastics, jogging for personal fitness
2	22	73	167	167	Racket ball
3	19	69	165	162.25	Gymnastics, jogging for personal fitness
4	20	67.50	145	145.50	Sprinting and long jumping
5	29	66.50	155	152	Personal fitness, jogging & weight training
6	25	68	135	137.50	Distance running
7	21	67	148	149	Gymnastics
8	21	75	164	166	Distance running
Mean	22.62	69.25	153.62	154.09	
Range	19-29	66.5-75	135-167	137.5-167	
S.D.	3.04	2.87	10.51	9.71	
Track Group					
1	31	74	197	192	Decathlon
2	29	75.50	178	183	Cross country skiing and jogging
3	25	74	166	164	Distance running
4	20	73	141	137	Hurdles
5	20	72	133	135	Sprints
6	17	67	148	150.50	Middle distance and football
7	24	74	185	186.50	Hurdles and comtemporary dance
8	33	72	196	189.50	Sprints, middle distance, basketball
Mean	24.87	72.68	168	167.18	
Range	17-33	67-75.5	133-197	135-192	
S.D.	5.37	2.41	23.37	22.28	
Speed Treadmill					
1	26	73	166	168.75	Sprints, long jump
2	25	71.75	147	144	Middle distance runner
3	22	71.50	173	176	Decathlon
4	18	69	127.50	128	Sprints
5	24	70.50	150	149	Personal fitness, jogging & boxing
6	19	70	139.50	140	Speed skating & jogging
7	20	70	152	150	Long jump
8	17	68.50	152	157	Cyclist & jogging
Mean	21.37	70.53	150.87	151.59	
Range	17-26	68.5-73	127.5-173	128-176	
S.D.	3.66	1.40	13.28	14.46	

TABLE V

MUSCLE-JOINT SENSATIONS

	COMPLAINTS	NO. OF COMPLAINTS
Control Group		3
1	stiff from camping and hiking trip	
2	nil	
3	blisters	
4	nil	
5	nil	
6	heel bruise	
7	nil	
8	nil	
Track Training Group	(no complaints after 4 weeks training)	10
1	sore groin, stiff quadricep	
2	sore feet, stiff quadriceps	
3	stiff quadricep	
4	stiff quadricep	
5	shin splints	
6	slightly sprained ankle	
7	stiff quadriceps	
8	stiff quadriceps	
High Speed Treadmill Training Group	(complaints throughout 7-week period)	32
1	tight hamstrings, stiff hamstrings, tired	
2	back of knees tight, stiff calves, stiff quadriceps, tired, outside of rt. knee sore	
3	tight calves, tight hamstrings, left knee sore, left ankle sore	
4	tight calves, sore hamstrings, stiff hamstrings, tight hamstrings, rt. hamstring sore	
5	back of legs tight, tight hamstrings, rt. knee sore, sore left side, sore outside rt. knee	
6	back of legs tight, stiff hamstrings, tired	
7	tight calves, stiff calves, sore rt. ankle, rt. calf sore	
8	back of legs tight, rt. knee sore, tired, left calf stiff	

A multiple stepwise regression analysis, (Table IX), resulted in no statistically significant relationships evident between 100 meter sprint performance and other parameters.

Other Analysis

Simple correlation matrices were computed for the pre, the post and the pre and post-test differences, (Tables VI, VII and VIII).

The pre-training correlation coefficients revealed that Sargent vertical jump (SVJ) was significantly correlated with standing long Jump (SLJ), 100 meter performance (100 m.), hip flexion (HF), hip extension (HE) and isometric leg strength (ILS). The standing long jump significantly correlated with Sargent Jump, hip flexion and the three measures of leg strength. 100 meter performance was found to have statistically significant correlations with Sargent Jump, and hip flexion.

The measure of hip flexion possessed a statistically significant correlation with Sargent jump, standing long jump, 100 meter performance, hip extension and isometric leg strength.

Hip extension correlated significantly with Sargent Jump and hip flexion.

Concentric leg strength displayed a statistically significant correlation with standing long jump, eccentric leg strength (ELS) and isometric leg strength (ILS).

Eccentric leg strength significantly correlated with

Sargeant jump and the other two measures of leg strength.

Isometric leg strength analysis revealed statistically significant correlations with both measures of power (SLJ, SVJ), hip flexion, and concentric and eccentric leg strength. Table VI denotes values greater than the t-critical (α=0.05, df=23) for pre-training test results.

Reaction time did not demonstrate any statistically significant correlation coefficients.

Table VII portrays the correlation coefficients for the post-training test values.

Sargent jump displayed a significant correlation with standing long jump and 100 meter performance. The significant correlation that existed with hip extension and isometric leg strength was not demonstrated at post-test.

Standing long jump demonstrated a statistically significant correlation with Sargeant Jump, 100 meter performance (not in existance at pre-training test time), hip flexion and concentric leg strength. The significant correlation between standing long jump and eccentric and isometric leg strength that was demonstrated at pre-training test time was not present at post-training test time.

100 meter performance at post-training test time displayed a significant correlation with Sargeant jump, standing long jump and hip flexion.

Hip flexion demonstrated statistically significant correlation with both measures of power (SVJ and SLJ) and 100 meter performance. The correlation with hip extension and isometric leg strength was lost at post-training test time.

At post-test hip extension did not display significant correlations with any of the parameters under study.

Concentric and eccentric leg strength demonstrated statistically significant correlations with standing long jump.

The three measures of strength correlated significantly with each other at post-test. Isometric leg strength lost its correlation with the two measures of power (SVJ and SLJ) and hip flexion after training.

A correlation coefficient matrix using pre and post test differences, (Table VIII) demonstrated the following statistically significant correlations:

(a) Hip flexion and hip extension

(b) Eccentric leg strength and hip flexion

(c) Eccentric and isometric leg strengths.

TABLE VI

PRE-TRAINING CORRELATION COEFFICIENTS

PARAMETERS		SVJ 1	SLJ 2	100 m 3	HF 4	HE 5	CLS 6	ELS 7	ILS 8
SLJ	2	0.825*							
100 m	3	-0.630*	-0.386						
HF	4	0.565*	0.647*	-0.481*					
HE	5	0.427*	0.392	-0.238	0.570*				
CLS	6	0.321	0.467*	0.005	0.232	-0.015			
ELS	7	0.360	0.522*	-0.115	0.239	0.186	0.747*		
ILS	8	0.534*	0.648*	-0.306	0.423*	0.194	0.838*	0.830*	
RT	9	0.069	0.230	0.104	0.275	0.244	-0.027	-0.122	-0.001

*denotes values greater than the t critical (0.396, α =0.05, df=23) for pre-training test results

TABLE VII

POST-TRAINING CORRELATIONS COEFFICIENTS

PARAMETERS		SVJ 1	SLJ 2	100 m 3	HF 4	HE 5	CLS 6	ELS 7	ILS 8
SLJ	2	0.755*							
100 m	3	-0.550*	-0.411*						
HF	4	0.484*	0.533*	-0.529*					
HE	5	0.180	0.069	-0.159	0.248				
CLS	6	0.372	0.586*	-0.195	0.253	-0.115			
ELS	7	0.365	0.277	-0.090	-0.037	-0.070	0.670*		
ILS	8	0.367	0.326	-0.265	0.194	-0.008	0.658*	0.632*	
RT	9	-0.011	-0.161	-0.071	0.131	-0.139	0.227	0.248	0.279

*denotes values greater than the t critical (0.396, α=0.05, df=23) for post-training test results

TABLE VIII

CORRELATION MATRIX POST MINUS PRE-TEST VALUES

PARAMETERS	SVJ	SLJ	100 m	HF	HE	CLS	ELS	ILS	RT
SVJ	1.00000	0.07198	0.13711	0.23168	0.28387	0.07435	0.09170	0.16593	0.01145
SLJ	0.07198	1.00000	0.10130	-0.18070	0.14764	0.17829	-0.15893	0.16556	-0.10921
100 m	-0.13711	0.10130	1.00000	0.17884	0.12906	0.03618	-0.00195	0.06797	0.09775
HF	-0.23168	-0.18070	0.17884	1.00000	0.45217*	0.10315	0.50221*	0.28945	0.05925
HE	-0.28387	0.14764	0.12906	0.45217*	1.00000	-0.13437	0.18818	0.24239	0.00037
CLS	0.07435	0.17829	0.03618	0.10315	-0.13437	1.00000	0.30634	0.33872	-0.03780
ELS	0.09170	-0.15893	-0.00195	0.50221*	0.18818	0.30634	1.00000	0.68270*	0.03742
ILS	0.16593	0.16556	0.06797	0.28945	0.24239	0.33872	0.68270*	1.00000	0.28906
RT	-0.01145	-0.10921	0.09775	0.05925	0.00037	-0.03780	0.03742	0.28906	1.00000

*denotes values greater than the t-critical (0.396, α=0.05, df=23) for post minus pre test values

TABLE IX

MULTIPLE STEPWISE REGRESSION ANALYSIS

(Critical $t^{.05}_{24.3} = 1.725$)

VARIABLE NUMBER	REGRESSION COEFFICIENT	STD. ERROR OF REG. COEFF.	COMPUTED T-VALUE
4	0.00676	0.01002	0.674
2	0.00971	0.02340	0.415
1	-0.02594	0.07681	-0.338
9	0.78429	2.58031	0.304
7	-0.00012	0.00037	-0.325
8	0.00006	0.00043	0.142
6	0.00002	0.00031	0.080
5	-0.00011	0.01211	-0.009
INTERCEPT	-0.20603		

FOF 8 Variables Entered

Multiple Correlation Coefficient	0.280
(Adjusted for D. F.)	0.570
F-Value for Analysis of Variance	0.160
Standard Error of Estimate	0.308
(Adjusted for D. F.)	0.369

DISCUSSION

While attempting to recruit subjects for this study it was evident that good sprinters were apprehensive about volunteering to participate. Because high-speed treadmill training was a relatively new approach to sprint training many sprinters were in fear of jeopardizing their chances for improving their performance. Several stated that they would participate only if they were randomly selected to represent the control or track training group. As a result two of the best sprinters dropped out after the pre-training tests.

Pre-training Analysis

A summary of the results of the pre-training tests on all original subjects reinforces previous findings in the review of literature. When all measures are ranked and compared (Appendix A), it is evident that the best sprinter on the average, was the most physically fit, the tallest, the heaviest, the strongest, the most powerful and possessed more hip flexibility than the poorer sprinter. Reaction time, however, was on the average similar for all the subjects. Irwin (37), using the subjects in this study, analyzed stride rate and stride length at pre, mid and post-training periods, and was able to determine that on the average the best sprinters possessed the longest stride length. Stride rate, however, was similar for both groups.

It was interesting to note that both stride rate and reaction time were on the average similar for all subjects. These two measures would in theory appear to reinforce each other since both have been related to neuromuscular control by several researchers (8, 45, 73, 81).

Computation of correlation coefficients using pre-training test scores for all subjects revealed that reaction time was not correlated with any of the parameters studied. This finding was in disagreement with research by Scripture (69), Hipple (27), Wilson (82), Westerlund and Tuttle (81), Younger (85), Pierson and Rasch (59), Kerr (41, 42) and studies in Munich (67). However the results of the analysis in this study strongly agreed with Henry (29), Slater-Hammel (74) and others (12, 21, 28, 30, 31, 33, 34, 40, 44, 47, 52, 58, 61, 70, 72, 76). These researchers failed to find statistically significant correlation coefficients when simple reaction time was compared to other physiological parameters and sprint performance after training.

Johnson and Nelson (38) have attempted to explain why insignificant relationships exist. They stated:

> . . . . It has been fairly well established that some individuals react quickly but move slowly; and some react slowly but are able to run or move very rapidly once they get started.
>
> . . . when speed of movement and reaction time are to be studied separately, the specificity of each must be considered, as well as how each may operate in relation to the movements involved and the task. In other words it would not make much sense to measure reaction time by having the subject release a telegraph key device upon hearing a buzzer, and speed of movement by the 100 yard dash, and then attempt to make conclusions regarding the reaction and movement speed of a defensive lineman in football. The tasks are too unrelated.

This investigation measured simple reaction time by using the leg and muscle groups that were specifically involved in the sprint start (back leg; leg extension muscles). Final analysis revealed no significant correlation although Johnson's and Nelson's (38) advice was followed. Since adherence to specificity did not demonstrate a significant correlation it is reasonable to conclude that reaction time is not an important component in the make up of a good sprinter.

The relationship between 100 meter performance, strength, power and stride length, in the present study, are supported by other findings (15, 16). Strength, by definition, is a component of power. Only isometric strength demonstrated a significant correlation coefficient with the Sargent jump, (Table VI). However all three measurements of strength were found to be significantly correlated with standing long jump. 100 meter performance on the other hand, displayed a statistically signficiant correlation coefficient with standing vertical jump but not with any of the three measures of strength. This power-strength -- 100 meter performance relationship suggests that the Sargent jump is more important than the strength measures or the standing long jump as a predictor of 100 meter performance. This deduction is supported by two studies which found static strength (5, 20) and dynamic strength (5, 49) significantly related to leg power, thus indicating strength as an important variable in power measurement. Also several studies (9, 14) have indicated that speed was significantly related to power and that it was more important than strength in athletic performance. Additional support is evidenced when McCloy (50) found the Sargent jump was significantly related to the total point score of select track (including sprinting) and field events.

Dyson (19) states, ". . . stride length is the product of a driving forward of the entire body." Since the best sprinters possessed more strength and power they were able to "push-off" more forcefully against the ground and therefore displayed a longer stride pattern. A characteristically longer stride results in a greater range of movement in the hip joint and therefore the fastest sprinters also displayed more hip flexion. The fact that 100 meter sprint performance, leg power and hip flexion demonstrated statistically significant correlation coefficients supports this theory. This was evident in all analyses (Tables VI, VII, VIII and IX).

This analysis should have practical applications in training of sprinters. Many drills have been suggested by coaches (6, 62, 83) to improve stride length. In all cases these drills attempt to have the runner consciously lengthen his stride while sprinting. The analysis of the data in this study and others (6, 15, 18, 22, 62, 83) would suggest that more emphasis should be placed on leg power so that a greater "push off" could be produced resulting in a lengthened stride. This is only true if the stride rate remains constant. If runners have low levels of flexibility in the hip joint the stride length could possibly be restricted until this quality was improved.

Pre and Post-Test Differences Analysis

A minimum maximum oxygen uptake of 45 ml./kg./min. was the criterion for acceptance of subjects into this study. This was necessary so that any changes in performance would not be due to physical conditioning and so that a conditioning phase was not necessary at the beginning of the project. This minimum requirement was also necessary to ensure that the subjects were physically fit enough to withstand the physiological stress if they were randomly selected to represent either of the training groups. According to Balke's classification of fitness, which is based on max VO_2 (ml./kg./min.), the subjects were in "good" cardiovascular condition at the time of the initial test and could be considered being in a trained state (2).

The pre-test mean maximum oxygen uptake of the twenty four subjects was 54.92 ml./kg./min., (Appendix A). This value is similar to the maximum oxygen uptake of Olympic sprinters during the XVIIth Olympic Games in Rome in 1960. De Prampero et al (17) calculated their mean maximum oxygen uptake to be 55.50 ml./kg./min.

As expected there was no statistically significant change in the maximum oxygen uptake values between the pre and post periods. All subjects were instructed to continue with their normal everyday pattern of activity. The two training groups did additional training as outlined in Chapter III. The fact that the pre minus post MVO_2 only changed .44 ml./kg./min. meant that the subjects did carry on normally as instructed. Several investigators have studied the changes following cessation of training and found, in general, a rapid return to pre-training levels when activity is terminated (24, 53, 64, 65, 66, 79, 80). There was no detraining effect evident in this study including the control group.

The pre minus post mean difference in body weight for the twenty-four subjects was 0.5 pounds. This value strengthened the suggestion that the subjects did not change their normal diet and or exercise pattern during the seven weeks.

"Stress is the state manifested by the specific syndrome which consists of all the non-specifically induced changes within a biologic system" (70:52). Simply stated, stress is the rate of wear and tear in the body which would include being tired, jittery, weak muscle sensation, or ill. These are known as subjective sensations of stress. The stress changes include damage and adaptive reactions which include mechanisms of defense set up by the body to combat stress. This stress syndrome, as it is know, is defined as the "totality of changes" (70:55). Forty-five muscle-joint complaints were recorded during the course of this study (Table V). The control group reported three complaints which can only be explained as normal incidentals, not symptoms of training stress. The track and high-speed treadmill training groups registered 10 and 32 complaints respectively. These complaints may be considered as subjective sensations of stress (70:52). Complaints by the track training group were non-existent after four weeks of training whereas the treadmill group registered complaints throughout the seven week period, although fewer during the last two weeks.

This would suggest that physiological stress was present throughout the seven weeks in treadmill training. This would also suggest that adaptation to stress was still continuing at the end of this study whereas the track training group had complete adaptation after the fourth week. A logical conclusion would be that high speed treadmill training is a form of overload sprint training. The flat-track training could have reached a plateau and another form of 100 meter sprint training stress would be required as further stimulus. This was somewhat in evidence when 100 meter sprint performance improvement was less in track than in the treadmill group (Table I). No difference in sprint performance was demonstrated by the track group after the fourth week (37). Coaches who have realized that flat-track sprint training does eventually limit improvement have experimented with various methods of forced running. Athletes have attempted running downhill (16, 48, 56) running behind cars, motorcycles, trains (16, 46, 48, 56) and a variety of resistance running methods (16, 57).

The track training group registered six stress sensations in the quadriceps muscle group. The treadmill group registered only one such complaint. However, fifteen hamstring and back of the legs stress sensations were experienced by the treadmill group. This is clearly a definite significant difference in stress and suggests that a different technique was required to run on the treadmill. Similar views were expressed by Nelson et al (55) and by Dintiman (16). Furthermore, there was a general advancing pattern of stress sensation in the treadmill group as recorded by five of the eight subjects. A stress sensation was first experienced in the calf muscle, then the hamstring group and finally the knee joint. This pattern again suggests that a possible change in running technique was occurring during the seven weeks. In conversations with the subjects during the study they reportedly were not conscious of trying to run with different technique. Their immediate objective was "to keep up with the treadmill." Constant personal observations by the investigator revealed that the treadbelt was throwing the leg backward so that maximum knee flexion was occurring, in many instances heels touching buttocks. This resulted in a shortened radius and resultant increased velocity (7:331) of the leg coming through (recovery) to a final extension before being placed on the treadbelt to complete the stride cycle. If this happened, the knee was actually hyper extended before the foot touched the treadbelt. This hyper extension and resultant hamstring activity would explain the hamstring and knee joint sensations of stress.

This hyper extension does not occur while running on a flat track because the lower leg does not have the momentum that results from the rapid stride recovery on the treadmill.

The fact that the flat track group experienced stress sensations in the quadriceps implies that they were pushing against the ground as they ran. This is the action (extension of the leg) of the quadriceps group of muscles and is the required technique for running on a flat track unaided (19). The treadmill group obviously was unable to push against the treadbelt because they could not apply force fast enough. Their action was simply to lift their legs and set them down rapidly in succession. This leads the writer to conclude that this knowledge could be utilized to determine whether subjects were ready to experience an increase in treadbelt speed during training. If a subject was experiencing quadriceps stress sensation or a feeling of pushing this could be an indication of adaptation to the existing treadbelt speed. The speed should then immediately be increased and adoption to a new plateau advanced. This would be a monotered scientific approach to observing the overload principal of training. Only the treadmill group recorded sensations of being tired; four were recorded. This strengthens the suggestion that the treadmill training was physiologically much more stressful.

Dintiman (16) did not experience complaints of injury or discomfort during the high-speed workout by his subjects. He credits this record to his warm-up which consisted of the following drills executed by running in place:

1/2 speed (low knee lift) -- 2 repetitions of 30 seconds each
1/2 speed (high knee lift) -- 2 repetitions of 30 seconds each
3/4 speed (high knee lift) -- 2 repetitions of 15 seconds each
7/8 speed (high knee lift) -- 2 repetitions of 8-10 seconds each
Maximum speed (high lift) -- 2 repetitions of 5-8 seconds each.

Dintiman reported that: "no complaints of injury or discomfort during the high-speed workouts". Most of the complaints were voiced before the warm-up when subjects were questionned upon arrival at the laboratory. Other probable explanations for this difference in stress sensations between these two studies might be accounted for by the fact that Dintiman allowed more rest between sprints and between workouts.

Intra and inter-group pre and post-test differences were not statistically significant for both measures of power. Similar results were observed by others (23, 25, 63) who found insignificant differences between groups in power measures after training to improve sprint performance.

Multiple stepwise regression analyses demonstrated low positive statistically insignificant relationships between 100 meter sprint performance and power as measured in this study.

Analyses of correlation coefficients (Tables VI, VII) and Rank Order analysis, (Appendix A) associate power with flexibility, strength and 100 meter performance. This association was very evident in the pre-test analysis and in other investigations (16, 15). These correlations further demonstrate the complex interrelationships that have been evidenced by researchers in the past. Since the better sprinters are more powerful and have more strength and flexibility (Appendix A) it is obvious that it is desirable to improve the level of these physiological parameters in training sprinters.

Analysis of covariance revealed no statistically significant differences between groups in 100 meter sprint performance after training. Since no other research has been undertaken to compare flat track and high speed treadmill training upon physiological parameters this initial investigation can be used for guide and comparison purposes. The pre minus post within group differences were statistically significant at the 0.05 level of confidence, (Table I). High speed treadmill training did improve 100 meter sprint performance by 0.31 seconds. This improvement is more than the improvement in the 100 sprint performance world record during the last fifty years (39). This 0.31 second improvement was more than the 0.18 second improvement by the flat track group despite the fact that the treadmill group had a mean 100 meter performance time which was better than the control and track group (Table I).

The fact that the treadmill group improved their sprint performance significantly substantiates findings by Dintiman (15). Dintiman observed a mean improvement of 0.20 seconds for the high speed treadmill group yielding a t-value of 4.9 which was significant at the 0.05 level of confidence.

Analysis of covariance determined no statistically significant differences between groups occurring at post-test time in hip flexibility. The treadmill group displayed a trend of a low positive improvement in both hip flexion and extension (Table I), which in total was greater than the combined flexibility (flexion and extension) of the control and flat track groups. This difference was not statistically significant and agrees with observations which were made by Nelson (54) when he studied the effects of increased flexibility upon sprinting speed. Change in flexion did not necessarily parallel an equal change in extension. This has been positively demonstrated by Harris (26) who performed a factor analysis on flexibility studies and found that each possible joint action was uncorrelated to any other joint action and by Dickinson (13) who observed low correlations of joint movements; that the different movements possible at a joint are independent of each other. The mean values obtained from the three tests of strength executed in this study, generally agree with those reported in the literature.

There was no statistically significant difference between groups at post-test time in the three measures of leg strength, (Table I). The control group had low positive improvements in leg strength which could be accounted for by the fact that the pre-test occurred at the end of spring and the post-test was administered in late summer. During the summer people tend to be more active than in the winter and therefore leg strength should improve during the spring and summer months. The improvement could still be occurring at pre-test time. This could also partially explain the reason the control group displayed a trend of low improvement in the power measures, (Table I).

Both training groups displayed decrements in strength measures during the seven week program. This decrease in concentric strength between the pre and post-tests of the treadmill group was statistically significant at the 0.05 level of confidence. These observations were similar to others (10, 11, 32, 43, 51, 60, 73) who found low strength-movement-time improvement relationships. Since strength is a component of power by physiological definition these significant differences parallel those of the power tests already discussed.

It is possible that the strength-sprint relationship being observed in this study and others supports the current theory of neuromotor specificity (1, 3, 4, 36, 68, 71) with respect to all forms of motor coördinations. If this in fact is the observation, physiologists must search for new designs of measuring strength which is more related to the sprinting action itself. Perhaps some means of measuring the forces (strength in sprint action) against the ground during an actual sprint is needed to demonstrate strength-100 meter sprint performance.

Since strength is a component of power and since these two measures have been related to 100 meter performance, (Tables VI & VII), it is obvious that a high level of specific strength is necessary for optimal sprint performance.

Analysis of covariance revealed no statistically significant difference in reaction time between groups at post-test time. Single sample T-tests did determine a significant difference in pre minus post values within groups for the control and track groups. These differences denoted a slowing of reaction time, (Table I). The treadmill group experienced a low mean improvement in reaction time but this was not statistically significant. Seventeen of the twenty six studies reviewed in the literature indicated that reaction time is a complex integration of neuromuscular design and cannot be easily related to movement performance. The results of this study regarding reaction time do not aid in our understanding of this parameter. These results would therefore agree with Henry when he stated (33) that:

> ". . . the postulation of a common mechanism for reaction time — movement time, vaguely described as 'speed,' suggests a prediction in which the fundamental reaction time-movement time correlations should be high. In contrast, there are separate neurophysiological mechanisms for movement speed and for reaction speed; muscular force causes speed of limb movement, whereas reaction latency reflects the time required for pre-movement operation of a central nervous system programming-switching mechanism. These concepts lead to the prediction that the fundamental reaction time-movement time correlation should approach zero."

In summarizing what happened during the seven-week study it was found that 100 meter sprint performance improved significantly in all three groups. A significant amount of concentric leg strength was lost in the treadmill group. The track and treadmill group experienced more stress sensations in leg muscles than the control group, the treadmill group experiencing the most. The stress sensations differed significantly between the three groups. These stress sensations could possibly explain the concentric leg strength loss and both in turn could explain why no statistically significant inter-group differences were demonstrated in 100 meter performance.

An analysis of the post-training correlation coefficients, (Table VII), reveals that hip extension and isometric leg strength lost their relationship with 100 meter performance. Again, the importance of leg power and hip flexion for sprinters was evident.

The fact that large inter and intra variance occurred makes it difficult to find statistical significance. However the general pattern that was observed in the statistical analysis, the heterogeneous findings in the review of literature and the complex relationships that exist between the parameters under study still permitted this investigator to demonstrate a safe method of improving 100 meter sprint performance. Although the improvement was not significantly better than the improvements experienced by the control and flat track training groups, the improvement was more consistent, greater and significant practically in as much as sprint improvements can be stimulated by conventional methods of training. The trend of greatest improvement was toward the direction of the experimental treadmill group despite the fact that to begin with this group displayed the fastest mean 100 meter sprint time (Table I). The pattern that has emerged has intrigued this investigator to pursue further research regarding this sprint training method.

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CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to train subjects on a high speed treadmill and thereby improve their 100 meter sprint time. One subproblem was to compare high speed treadmill training with the conventional method of interval sprint training on a flat track. A second subproblem was to determine the effects of the two sprint training methods upon leg strength, hip flexibility, reaction time, and leg power.

A sample of twenty-four male subjects were utilized. Each subject was ranked at pre-test according to 100 meter sprint time (overage time of four trials), and randomly blocked into one of three groups; control, track training and high-speed treadmill training.

Each subject was tested before and after a seven-week training period. In addition to the 100 meter sprint tests the following standardized tests were administered: maximum oxygen uptake, Sargeant Jump, standing long jump, hip flexion, hip extension, concentric, eccentric and isometric leg strength and reaction time. Anthropometric data from each subject was also recorded in pre and post- test periods. A daily record of subjective muscle-joint complaints was kept.

During the seven-week training period the control group was instructed to continue with their everyday activities as normal.

During this period the track training group trained on a flat track. The high-speed treadmill group trained similiarly on a treadmill. Both training groups performed seven interval sprints six days per week.

An analysis of covariance on each of the dependent variables to see if any significant differences between groups occurred at post-test time resulted in no significance being evident. Correlation coefficients with values of pre-test, post-test and pre and post test differences demonstrated statistically significant correlations between 100 meter performance, Sargent Jump, standing long jump, hip flexion, hip extension and the three measures of strength. Reaction time did not display significant correlation coefficients. Leg strength, leg power and hip flexibility correlation coefficients verified the importance of these parameters when training for 100 meter sprint performance.

Multiple stepwise regression analysis to determine which physiological parameters paralleled 100 meter sprint time improvements (negative or positive) also indicated statistically insignificant coefficients.

Single sample t-tests were computed to determine if any post minus pre differences occurred within groups. Statistically significant differences were observed in 100 meter sprint improvement in all groups, concentric leg strength decrease in the treadmill group and the control and track training groups experienced significant reaction time decreases.

Overload sprint training did improve 100 meter sprint time by a mean difference of .317503 seconds. This improvement was greater than that of the control and track training groups who experienced mean gains of .127505 and .182501 seconds respectively. The mean difference between groups was not statistically significance Of all the parameters under observation the difference between groups in the 100 meter time was nearest to statistical significan (Table II). These findings agreed with many previous studies (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23) which found insignificant differences between power, flexibility, strength, reaction time and sprinting performance after training.

Previous to the study all subjects had participated in some form of physical training as evidenced by the maximum oxygen uptake pre-test mean of 54.92 ml/kg/min., (Appendix A). During the seven-week training period the control, track and treadmill groups experienced 3, 10 and 32 injuries respectively (Table V). No doubt this number of complaints meant that physiological stress was being experienced and this continued in the high-speed treadmill group throughout the seven-week training period.

Conclusions

From the results of this study, the following conclusions were drawn:

(1) Overload sprint training did improve 100 meter sprint time. The mean difference of improvement was

statistically significant at the 0.05 level.

(2) High-speed treadmill training did not result in a statistically significant difference of improvement in 100 meter sprint performance as compared to training on a flat track and a control group.

(3) No statistically significant difference occurred in the eight physiological parameters between the three groups after training.

(4) There is no statistically significant difference in the eight physiological parameters as a result of overload sprint training.

Recommendations

It is recommended that the effects of high-speed treadmill training be studied over a longer period of time to allow for complete physiological adaptation to occur. It is also recommended that this training program should alternate daily with flat track running.

Further research comparing track and high-speed treadmill training should be attempted using sprinters who have reached a performance plateau and have not been able to improve their sprinting ability following conventional training programs. It is also recommended that high speed treadmill training should be utilized as a sprint training method under close supervision.

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APPENDIX A

RAW DATA

SARGEANT VERTICAL JUMP

Subjects	Pre-Trials 1	Pre-Trials 2	Pre-Trials 3	Best	Reach	Jumped Height (inches)	Post Trials 1	Post Trials 2	Post Trials 3	Best	Jumped Height (inches)	Difference in inches
Control												
1	8'8"	8'3"	8'10"	8'10"	7'3"	19.0	8'8"	8'10"	8'8"	8'10"	19.0	0.0
2	9'4"	9'6"	9'7"	9'7"	7'10"	19.0	9'7"	9'8"	9'8"	9'8"	20.0	+1.0
3	9'7"	9'7"	9'6"	9'7"	7'7.5"	23.5	9'6"	9'5"	9'6.5"	9'6.5"	[illegible]3.0	-0.5
4	9'6"	9'7.5"	9'7"	9'7.5"	7'4"	27.5	9'6"	9'7"	9'6"	9'7"	27.0	-0.5
5	8'8"	8'8"	8'9"	8'9"	7'3.5"	17.5	8'8"	8'8"	8'9"	8'9"	17.5	0.0
6	8'9"	8'8.5"	8'9"	8'9"	7'6"	15.0	8'9"	8'9.5"	8'10"	8'10"	16.0	+1.0
7	9'0"	9'1"	9'3"	9'3"	7'4"	23.0	8'11"	9'2"	9'2"	9'2"	22.0	-1.0
8	9'0"	9'1"	9'3"	9'3"	7'10"	17.0	9'3"	9'5"	9'4"	9'5"	19.0	+2.0
Track												
1	9'7"	9'7"	9'6"	9'7"	8'0"	19.0	9'8"	9'8.5"	9'7.5"	9'8.5"	20.5	+1.5
2	9'4"	9'5"	9'6"	9'6"	8'2"	16.0	9'2"	9'4"	9'4.5"	9'4.5"	14.5	-1.5
3	9'3"	9'4"	9'5"	9'5"	7'10"	19.0	9'6"	9'6.5"	9'6"	9'6"	20.0	+1.0
4	9'5"	9'4"	9'5"	9'5"	7'11"	18.0	9'2.5"	9'5.5"	9'6.75"	9'6.75"	19.75	+1.75
5	9'3"	9'3"	9'45"	9'45"	7'7"	21.5	9'4"	9'4"	9'5"	9'5"	22.0	+0.5
6	8'9"	8'9"	8'10"	8'10"	7'3"	19.0	8'8"	8'8"	8'9"	8'9"	18.0	-1.0
7	10'0"	10'3"	10'35"	10'35"	8'3"	24.5	10'2"	10'3"	10'2"	10'3"	24.0	-0.5
8	9'7"	9'7.5"	9'8"	9'8"	8'	20.0	9'7"	9'7.5"	9'9"	9'9"	21.0	+1.0
Treadmill												
1	9'25"	9'35"	9'35"	9'35"	7'10"	17.5	9'3"	9'35"	9'3"	9'35"	17.5	0.0
2	8'10"	8'10"	9'	9'	7'9"	15.0	9'	9'.5"	9'.75"	9'.75"	15.75	+0.75
3	9'6"	9'7"	9'6"	9'7"	7'10"	23.0	9'7"	9'7"	9'6.5"	9'7"	23.0	0.0
4	8'9"	8'11.5"	9'	9'	7'5"	19.0	9'	9'.5"	8'11"	9'.5"	19.5	+0.5
5	8'9"	8'10.5"	8'11.5"	8'11.5"	7'6"	17.5	8'11"	8'11.5"	[illegible]'11.5"	8'11.5"	17.5	0.0
6	9'2"	9'3"	9'3"	9'3"	7'6.25"	20.75	9'3.5"	9'3.5"	9'3.5"	9'3.75"	21.5	+0.75
7	9'7"	9'8"	9'6"	9'8"	7'6"	26.0	9'4"	9'6"	9'7"	9'7"	25.0	-1.0
8	8'11"	8'9"	9'	9'	7'6.25"	17.75	9'	8'10.5"	9'.75"	9'.75"	18.5	+0.75

STANDING LONG JUMP

Subjects	Pre 1	Pre 2	Pre 3	Pre Best	Post 1	Post 2	Post 3	Post Best	Inches Difference
Control Group									
1	7'7"	7'10"	7'9"	7'10"	7'2"	7'8"	7'10"	7'10"	0.0
2	8'1"	8'	7'10"	8'1"	8'4"	8'1"	8'2"	8'2"	+3.0
3	7'10"	8'3"	8'5.5"	8'5.5"	8'1"	8'6"	8'7"	8'7"	+1.5
4	8'11.5"	8'11"	9'	9'	9'1"	8'11"	8'10"	9'1"	+1.0
5	6'	6'4"	7'	7'	6'	6'7"	6'10.5"	6'10.5"	-1.5
6	5'11"	6'6"	6'10"	6'10"	6'6"	6'7"	6'10"	6'10"	0.0
7	8'	8'2.5"	8'6"	8'6"	8'4"	8'5"	8'5"	8'5"	-1.0
8	7'	7'2"	7'3"	7'3"	7'6"	7'4"	7'5"	7'6"	+3.0
Track									
1	7'11"	8'6"	8'6"	8'6"	7'11"	8'5.5"	7'11"	8'5.5"	-0.5
2	7'6"	7'6.5"	7'3"	7'6.5"	6'6.5"	7'1"	6'11.5"	7'1"	-5.5
3	7'1.5"	7'7.5"	7'9"	7'9"	6'10"	7'8"	7'4"	7'8"	-1.0
4	6'7"	6'9.5"	7'.5"	7'.5"	6'5.5"	6'10.5"	6'7"	6'10.5"	-2.0
5	7'8.5"	7'8"	7'5"	7'8.5"	7'8.5"	7'9"	7'7"	7'9"	+0.5
6	6'3"	5'10.5"	5'9"	6'3"	6'	6'6"	6'6"	6'6"	+3.0
7	7'4.5"	7'2.5"	7'7"	7'7.5"	7'7"	7'6"	8'	8'	+5.0
8	7'6.5"	7'3"	6'9"	7'6.5"	7'1.5"	7'1"	7'	7'1.5"	-5.0
Treadmill									
1	6'8"	6'5"	6'4"	6'8"	6'4"	6'10"	6'6"	6'10"	+2.0
2	6'1.5"	6'3.5"	6'.5"	6'3.5"	5'11"	5'10"	5'11"	5'11"	-4.5
3	7'6"	8'1"	7'11"	8'1"	7'9"	8'4"	8'7"	8'7"	+6.0
4	6'5"	6'10"	7'1"	7'1"	6'11"	7'5"	7'6"	7'6"	+5.0
5	5'10"	5'8"	5'9"	5'10"	5'10.5"	5'11.5"	5'9"	5'11.5"	+1.5
6	7'2"	7'10"	8'4"	8'4"	7'8.5"	8'2.5"	8'4.5"	8'4.5"	+0.5
7	9'7.5"	9'4"	9'3"	9'4"	8'8"	8'9"	8'1"	8'10"	-6.0
8	6'10"	7'	7'2"	7'2"	7'.5"	6'11"	6'9"	7'.5"	-1.5

100 METER TIMES

	Pre-Test (Seconds) T_1	T_2	T_3	T_4	Ave.	Post-Test (Seconds) T_1	T_2	T_3	T_4	Ave.	Pre-Post Diff.
Control											
1	14.2	13.5	14.6	13.85	14.03	14.0	13.7	14.1	13.5	13.82	-00.21
2	12.9	12.9	13.1	13.0	12.97	12.6	13.0	12.5	12.6	12.67	-00.30
3	13.4	13.5	13.35	13.35	13.40	13.2	13.7	13.1	13.25	13.31	-00.09
4	11.4	11.2	11.1	11.5	11.26	11.0	11.1	10.9	11.1	11.09	-00.17
5	14.1	14.0	13.9	13.4	13.86	13.9	13.5	13.5	13.5	13.60	-00.25
6	12.8	12.7	12.75	13.25	12.87	12.6	13.2	12.9	13.2	12.97	+00.10
7	12.6	12.3	12.1	12.1	12.27	12.7	12.4	12.3	12.1	12.37	+00.10
8	13.5	13.5	13.3	13.1	13.35	12.8	13.0	13.4	13.4	13.15	-00.20
Track											
1	11.9	12.4	12.25	12.1	12.16	12.1	12.2	12.3	12.45	12.26	+00.10
2	14.5	14.6	14.4	14.0	14.37	13.7	14.5	14.5	14.3	14.25	-00.12
3	13.0	13.5	13.45	13.75	13.42	13.0	13.0	12.9	13.0	12.97	-00.75
4	13.1	13.0	12.8	13.0	12.97	12.1	12.3	12.5	12.9	12.45	-00.52
5	12.0	11.5	11.9	11.4	11.70	11.1	11.5	11.5	11.4	11.39	-00.31
6	13.9	14.2	15.2	13.5	14.20	14.7	14.5	14.2	13.95	14.33	+00.13
7	11.9	11.85	12.1	12.1	11.98	11.7	11.7	11.7	11.8	11.70	-00.28
8	12.8	11.9	11.7	11.5	11.97	12.0	12.0	11.9	12.0	11.97	00.00
Treadmill											
1	12.3	12.6	12.5	12.5	12.48	12.2	12.0	12.0	12.4	12.15	-00.33
2	12.4	12.5	12.5	12.8	12.50	12.35	12.4	12.1	12.2	12.26	-00.24
3	11.2	11.5	11.6	11.7	11.57	11.3	11.8	11.6	11.6	11.57	00.00
4	12.2	12.1	11.9	11.8	12.00	12.2	11.8	11.7	11.9	11.90	-00.10
5	13.4	13.7	13.8	12.8	13.67	12.75	12.8	12.9	12.8	12.81	-00.86
6	12.3	12.8	12.5	12.7	12.58	12.7	12.4	12.8	12.7	12.65	+00.07
7	12.9	12.4	12.4	12.3	12.50	12.2	12.1	12.3	12.1	12.18	-00.32
8	14.5	13.8	13.8	13.6	13.92	13.1	13.2	13.15	13.2	13.16	-00.76

HIP FLEXIBILITY (Degrees)

	Flexion			Extension		
Control Group	Pre °	Post °	Degrees Difference °	Pre °	Post °	Degrees Difference °
1	76	85	+9	28	37	+9
2	104	90	-14	20	32	+12
3	105	118	+13	35	36	+1
4	110	115	+5	31	42	+11
5	80	85	+5	40	36	-4
6	70	65	-5	26	25	-1
7	95	98	+3	42	38	-4
8	110	105	-5	27	24	-3
Track						
1	102	95	-7	32	25	-7
2	95	102	+7	32	41	+9
3	90	85	-5	30	28	-2
4	80	85	+5	30	32	+2
5	110	105	-5	57	53	-4
6	65	45	-20	35	35	0
7	114	120	+6	30	44	+14
8	89	90	+1	30	33	+3
Treadmill						
1	105	110	+5	25	34	+9
2	85	82	-3	35	31	-4
3	85	90	+5	22	30	+8
4	130	116	-14	40	37	-3
5	75	61	-14	31	21	-10
6	114	120	+6	37	48	+11
7	117	114	-3	35	40	+5
8	85	75	-10	29	30	+1

LEG STRENGTH

CONCENTRIC (lbs.)

	Pre			Post			Pre Post
Control	1	2	Best	1	2	Best	Diff.
1	1110	1020	1110	1145	995	1145	+35
2	1070	820	1080	860	1050	1050	-30
3	1040	1160	1160	1095	950	1095	-65
4	1220	1460	1460			930	-530
5	650	940	940	600	1170	1170	+230
6	1090	540	[illegible]	800	940	940	-150
7	480	580	580	420	560	560	-20
8	650	440	650	385	810	810	+160
Track							
1	1310	1200	1310	980	1140	1140	-170
2	420	560	560	420	520	520	-40
3	570	460	570	570	660	660	+90
4	360	460	460	220	290	290	-170
5	560	800	800	320	440	440	-360
6	690	640	690	260	480	480	-210
7	370	640	640	980	990	990	+350
8	1130	1100	1130	1230	1275	1275	+145
Treadmill							
1	780	1120	1120	600	710	710	-410
2	460	510	510	260	445	445	-65
3	640	680	680	800	690	800	+120
4	280	560	560	450	330	450	-110
5	370	380	380	320	420	420	+40
6	1130	1380	1380	570	880	880	-500
7	1240	1400	1400	850	980	980	-420
8	870	1200	1200	610	750	750	-450

[illegible]ENGTH

ECCE[illegible](lbs.)

	Pre			Post			Pre Minus Post
Control	1	2	Best	1	2	Best	Diff.
1	1480	1180	1480	1430	1410	1430	-50
2	1060	980	1060	1230	1250	1250	+190
3	1180	1340	1340	1445	1305	1445	+105
4	1150	1360	1360			1020	-340
5	1050	1060	1060	1210	1215	1215	+155
6	1410	1440	1440	1360	1510	1510	+70
7	700	700	700	720	800	800	+40
8	720	820	820	785	910	910	+40
<u>Track</u>							
1	1530	1520	1530	1350	1280	1350	-200
2	480	440	480	685	970	970	+490
3	760	830	830	985	1040	1040	+210
4	420	480	480	320	400	400	-80
5	1010	1060	1060	1140	1295	1295	+235
6	1540	1380	1540	520	540	540	-1000
7	1160	1410	1410	1360	1460	1460	+50
8	1560	1550	1560	1465	1460	1460	-100
<u>Treadmill</u>							
1	740	730	740	440	600	600	-140
2	610	620	620	495	695	695	+75
3	1130	860	1130	1440	1570	1570	+440
4	680	950	950	730	650	730	-220
5	1060	1040	1060	670	640	670	-390
6	1200	1440	1440	1370	1460	1460	+20
7	1300	1420	1420	1360	1270	1360	-60
8	1530	1540	1540	1440	1380	1440	-100

LEG STRENGTH

ISOMETRIC (lbs.)

	Pre			Post			Pre Post
Control	1	2	Best	1	2	Best	Diff.
1	570	520	570	1110	1005	1110	+540
2	995	985	995	1280	1240	1280	+285
3	1250	1400	1440	1335	1225	1335	-65
4	1070	740	1070			1000	-70
5	1320	1390	1390	1210	1210	1210	-180
6	630	710	710	830	850	850	+140
7	620	640	640	720	740	740	+100
8	630	700	700	840	980	980	+280
<u>Track</u>							
1	1540	1540	1540	1340	1370	1370	-170
2	400	500	500	545	445	545	+45
3	500	540	540	600	730	730	+190
4	420	520	520	330	350	350	-170
5	730	850	850	1100	1160	1160	+310
6	780	1050	1050	380	410	410	-640
7	1090	1030	1090	1200	1200	1200	+110
8	1550	1310	1550	1465	1465	1465	-85
<u>Treadmill</u>							
1	1140	1120	1140	740	800	800	-340
2	440	620	620	445	445	445	-175
3	900	1060	1060	1230	1410	1410	+350
4	660	680	680	600	630	630	-50
5	690	600	690	480	460	480	-210
6	1170	1190	1190	1120	1140	1140	-50
7	1160	1150	1160	1140	1110	1110	-50
8	1050	1060	1060	810	820	820	-240

MAXIMUM O_2 UPTAKE

				Body Weight lbs.		
Control Group	Pre ml/kg.	Post ml/kg	Difference ml/kg/min	Pre Wt. (lbs.)	Post Wt. (lbs.)	Pre-Post Differences
1	49.05	46.73	-2.32	150	150	+3.5
2	51.87	49.53	-2.34	165	166	+1.0
3	50.97	49.42	-1.55	165	162	-3.0
4	56.85	55.37	-1.48	145	145.5	+0.5
5	48.54	45.70	-2.84	155	152	-3.0
6	59.26	63.39	+4.13	135	137.5	+2.5
7	52.17	51.8	-0.37	148	149	-3.7
8	63.36	57.14	-6.22	164	166	-6.22
Track						
1	56.21	57.35	+1.14	197	192	-5.0
2	61.32	59.20	-2.12	178	183	+5.0
3	57.50	57.8	+0.30	166	164	-1.0
4	45.78	52.22	+6.44	141	137	-4.0
5	60.20	58.77	-1.43	133	135	+2.0
6	58.19	58.15	-0.04	148	150.5	+2.5
7	49.03	60.69	+11.66	185	186.5	+1.5
8	51.21	50.98	-0.23	196	189.5	-6.5
Treadmill						
1	55.38	54.12	-1.26	168.5	166	-2.5
2	58.28	56.64	-1.64	147	144	-3.0
3	55.78	56.81	+1.03	173	176	+3.0
4	49.11	53.04	+3.93	127.5	128	+0.5
5	49.60	53.48	+3.88	150	149	-1.0
6	66.36	67.40	+1.04	139.5	140	+1.04
7	55.11	55.72	+0.61	152	150	-2.0
8	55.93	60.86	+4.93	152	157	+5.0

Pre test MV O_2 Mean = 54.92 ml/kg/min.
Post test MV O_2 Mean = 55.36 " " "

Post-test Reaction Time (seconds)

Control	Post Internal					Ave.	Post External					Ave.	Sum of Ave.	Difference in sum of ave
1	.33	.34	.32	.39	.27	.330	.05	.04	.03	.03	.02	.033	.363	+.147
2	.21	.30	.24	.34	.32	.283	.05	.02	.02	.01	.01	.017	.300	+.070
3	.33	.26	.22	.23	.23	.240	.02	.02	.02	.02	.03	.020	.260	+.030
4	.26	.39	.32	.27	.26	.283	.01	.02	.03	.03	.02	.023	.306	+.072
5	.35	.29	.25	.26	.28	.273	.01	.02	.01	.04	.05	.023	.296	+.002
6	.21	.18	.21	.20	.27	.206	.01	.03	.02	.02	.01	.013	.219	-.051
7	.22	.30	.24	.34	.32	.286	.03	.04	.02	.03	.02	.026	.312	-.018
8	.34	.37	.27	.38	.29	.333	.02	.05	.02	.02	.00	.020	.353	+.070
Track														
1	.24	.21	.22	.24	.18	.223	.02	.01	.01	.00	.01	.010	.243	+.060
2	.23	.27	.19	.24	.19	.220	.05	.06	.06	.04	.06	.056	.276	+.096
3	.22	.22	.40	.20	.21	.216	.02	.02	.03	.06	.01	.023	.239	+.052
4	.21	.36	.31	.26	.28	.283	.01	.03	.03	.02	.04	.026	.309	+.122
5	.22	.25	.28	.27	.26	.260	.03	.04	.04	.01	.06	.043	.303	+.070
6	.21	.23	.24	.19	.19	.210	.03	.03	.02	.03	.03	.030	.240	+.057
7	.23	.23	.28	.22	.22	.223	.05	.02	.02	.04	.03	.030	.253	-.037
8	.17	.22	.17	.21	.20	.193	.02	.00	.03	.03	.03	.026	.219	-.028
Treadmill														
1	.26	.26	.22	.27	.27	.263	.01	.00	.02	.00	.01	.006	.269	-.017
2	.24	.21	.22	.26	.22	.226	.01	.01	.04	.01	.02	.013	.239	+.028
3	.26	.25	.21	.23	.22	.233	.00	.00	.02	.01	.02	.010	.243	-.010
4	.24	.30	.30	.27	.25	.273	.00	.03	.07	.04	.03	.033	.306	+.067
5	.19	.20	.16	.18	.13	.177	.06	.03	.02	.04	.04	.033	.210	-.053
6	.23	.24	.26	.23	.26	.243	.01	.01	.00	.00	.02	.013	.256	-.037
7	.23	.20	.21	.20	.21	.206	.02	.03	.05	.06	.03	.036	.242	+.025
8	.27	.38	.40	.23	.21	.260	.04	.03	.05	.02	.06	.040	.300	-.020

Pre-test Reaction Time

	PreInternal					Ave.	PreExternal					Ave.	Sum of Ave.
Control													
1	.17	.12	.17	.19	.12	.153	.08	.07	.06	.05	.06	.063	.216
2	.25	.22	.22	.25	.19	.210	.03	.02	.02	.02	.02	.020	.230
3	.19	.14	.15	.11	.21	.160	.05	.08	.07	.08	.06	.070	.230
4	.17	.19	.17	.21	.18	.187	.06	.04	.04	.05	.05	.047	.234
5	.27	.27	.22	.21	.25	.247	.05	.05	.03	.05	.04	.047	[illegible]
6	.22	.22	.21	.32	.25	.230	.04	.04	.04	.04	.03	.040	.270
7	.18	.21	.21	.22	.20	.207	.04	.02	.03	.02	.03	.023	.230
8	.18	.23	.18	.22	.27	.210	.08	.07	.08	.06	.07	.073	.283
Track													
1	.13	.13	.15	.15	.14	.140	.04	.04	.05	.04	.05	.043	.183
2	.14	.13	.16	.12	.14	.137	.04	.04	.05	.05	.05	.043	.180
3	.20	.15	.15	.19	.15	.165	.02	.01	.03	.01	.02	.022	.187
4	.16	.17	.14	.15	.20	.160	.02	.03	.02	.03	.03	.027	.187
5	.19	.22	.16	.15	.25	.190	.03	.03	.04	.04	.03	.033	.222
6	.10	.10	.19	.13	.22	.140	.04	.05	.04	.05	.04	.043	.183
7	.25	.37	.25	.23	.25	.250	.06	.01	.03	.06	.03	.040	.290
8	.21	.22	.21	.22	.21	.220	.03	.03	.02	.02	.03	.027	.247
Treadmill													
1	.28	.28	.27	.27	.24	.273	.01	.01	.02	.01	.02	.013	.286
2	.20	.16	.22	.20	.22	.201	.01	.02	.01	.01	.01	.010	.211
3	.21	.18	.22	.19	.21	.203	.04	.05	.05	.05	.05	.050	.253
4	.22	.22	.26	.20	.13	.213	.02	.06	.02	.02	.04	.026	.239
5	.27	.25	.24	.27	.24	.253	.00	.00	.01	.02	.03	.010	.263
6	.26	.43	.23	.25	.28	.263	.05	.03	.03	.03	.03	.030	.293
7	.19	.18	.16	.18	.17	.177	.02	.03	.05	.06	.04	.040	.217
8	.25	.36	.26	.21	.32	.277	.06	.02	.03	.04	.06	.043	.320

Comparison of Fast and Slow Sprinters (Pre Scores Ranked)

Subjects	100 M. Times Pre	100 M. Times Post	Pre Max O_2	Height Rank Shortest 1st	Pre Age Rank Oldest 1st	Pre Body Weight Rank Lightest 1st	Pre Hip Flex Rank Best 1st
FAST							
1	11.1	10.9	9	3	18	7	7
2	11.4	11.1	4	19	18	2	7
3	11.5	11.3	12	17	13	24	23
4	11.5	11.9	17	19	1	28	22
5	11.6	11.1		9	26	3	2
6	11.8	11.7	20	9	26	1	1
7	11.85	11.7	22	24	9	27	4
8	11.9	12.1	10	24	2	29	15
9	12.1	12.1	15	2	16	10	19
10	12.3	12.1	14	12	18	14	3
11	12.3	12.4	1	12	23	12	4
12	12.3			24	9	23	13
13	12.3	12.0	13	21	5	20	11
14	12.4	12.1	7	18	6	8	23
			144	213 tallest	190 oldest	208 heaviest	154
slower							
1	12.7	12.6	5	4	6	4	30
2	12.8	12.75	19	15	9	12	29
3	12.8	12.1	24	21	18	6	26
4	12.9	12.5	16	21	13	22	13
5	13.0	12.9	8	24	6	20	21
6	13.0			12	18	12	17
7	13.1	12.8	2	21	16	18	7
8	13.2			4	23	9	16
9	13.4	13.1	18	9	23	19	11
10	13.4	13.5	23	1	4	16	26
11	13.5	13.5	21	4	9	12	28
12	13.5	13.95	6	2	28	10	31
13	13.6	13.1	11	8	28	14	23
14	14.0	13.7	3	28	3	26	18
			156	174	204 youngest	200 lightest	296 least flexion

Pre Hip Extension Rank	Pre SVJ Rank best 1st	Pre Rx. time pre rank (1st in slowest)	Pre Con leg Str. Rank	Pre Ecc. Str. Rank	Pre Iso. Leg Str. Rank
17	1	15	1	11	12
1	8	11	15	17	19
29	5	19	19	15	15
19	11	18	8	1	1
4	12	6	28	26	24
4	12	16	24	21	22
19	3	26	4	10	11
15	12	2	4	5	2
3	5	12	22	26	23
10	2	10	2	9	8
9	10	27	3	7	7
2	7		26	16	14
28	22	25	9	25	9
10	28	8	27	29	25
170	138	195	209	218	192
27	28	21	12	7	20
17	22	20	30	17	26
19	19	4	29	30	29
31	12	12	13	17	17
19	12	4	23	23	28
4	8		17	22	18
26	25	24	20	24	21
8	25		31		26
10	4	12	7	28	21
4	22	29	14	13	4
25	12	9	10	17	27
10	12	2	18	6	13
24	21	27	6	2	16
15	27	1	24	30	30
239	249	165	254	236	296
least extension	least	fastest	weakest	weakest	weakest

Subjects	Pre SLJ	Pre Stride Length	Pre Stride Rate
Fast			
1	2		
2	15	5	7
3	10		
4	17	12	4
5	12		
6	22	7	13
7	16	3	16
8	4	1	20
9	4	15	15
10	1	9	12
11	6	2	19
12	3		
13	27	11	14
14	30	10	8
	169	75	118
Slow			
1	25	4	15
2	31	14	11
3	23	6	18
4	10	20	3
5	14	13	9
6	19		
7	20		
8	26		
9	5	19	2
10	24	21	11
11	12	18	6
12	29		
13	21	17	10
14	17	16	17
	276	148	92
	least	shortest	faster rate

Comparing Fast and Slow Runners (Pre test Ran Order)

(Shortest, Oldest, lightest, fastest, most flexible, strongest, longest, and best performance is ranked first)

Comparison of Fast and Slow Sprinters - Post Scores Ranked

(Best or Fastest is Ranked First) (Training Groups Only)

Training Group Subjects	SLJ	SVJ	RT	CLS	ELS	ILS	HF	HE	SR	SL
FAST										
1	15	4	14	14	8	5	6	1	2	4
2	2	3	7	6	1	2	9	12		
3	9	6	2	1	2	1	9	9	1	8
4	8	10	15	12	9	11	3	6	11	2
5	5	2	8	3	2	4	1	3	10	1
6	3	7	7	2	7	3	8	15	14	3
7	1	1	6	4	6	7	4	5	3	9
8	4	5	9	5	2	6	1	2	7	6
	47	38	68	47	37	39	41	53	48	33
SLOWER										
1	12	13	10	8	14	9	5	8	8	7
2	16	15	3	13	12	13	13	11	4	10
3	15	13	1	15	13	14	15	16	9	11
4	13	9	16	16	16	16	11	10	6	14
5	7	8	3	9	7	10	11	14	12	5
6	14	12	5	11	15	15	16	7		
7	11	11	13	7	5	8	14	12	5	13
8	10	16	12	10	10	12	7	4	13	12
	98 weaker	97 weaker	63 faster	89 weaker	92 weaker	97 weaker	92 less flexion	82 less extension	49 same	72 shortest stride length

Comparing Fast and Slow Sprinters

Post Minus Pre Values - Training Group Subjects

Training Group Subjects	100 m	SVJ	SLJ	HF	HE	CLS	ELS	ILS	RT
FAST									
1	-.31	.50	.50	-5	-4	-360	235	310	.040
2	0	0	6	5	8	120	440	350	-.005
3	0	1.0	-5	1	3	145	-100	-85	-.014
4	-.10	.5	5	-14	-3	-110	-220	-50	.034
5	-.28	-.5	5	6	14	350	50	110	-.019
6	.11	1.5	-.5	-7	-7	-170	-200	-170	.013
7	-.32	-1	-6	-3	5	-420	-60	-50	.013
8	.07	.75	.5	-6	11	-500	20	-50	-.018
	.90	2.75	17.5	-12	27	-945	165	365	.057
SLOWER									
1	-.33	0	2	5	9	-410	-140	-340	-.009
2	-.24	.75	-4.5	-3	-4	- 65	75	-175	.014
3	-.86	0	1.5	-14	-10	40	-390	-210	-.026
4	-.52	1.75	-2	5	2	-170	- 80	-170	.061
5	-.75	1.0	-1	-5	-2	90	210	190	.026
6	.13	-1.0	3	-20	0	-210	-1000	-640	.029
7	.76	.75	-1.5	-10	1	-450	-100	-240	-.010
8	-.14	-1.5	-5.5	7	9	- 40	490	45	.048
	-3.3	1.75	-8	-35	5	-1215	-925	-1540	.133

POST -- PRE DIFFERENCES

SUBJECT	SVJ inches	SLJ inches	100 m seconds	HF degrees	HE degrees	CLS pounds	ELS pounds	ILS pounds	RT seconds
Control									
1	0	0	-.21	9	9	35	-50	540	.073
2	1	3	-.30	-14	12	-30	190	285	.035
3	-.5	1.5	-.09	13	1	-65	105	-65	.015
4	-.5	1	-.17	5	11	530	-340	170	.036
5	0	-1.5	-.25	5	-4	230	155	-180	.001
6	1	0	.10	-5	-1	-150	70	140	-.026
7	-1	-1	.10	3	-4	-20	40	100	.041
8	2	3	-.20	-5	-3	160	90	280	.035
Ave. Dif.	.25	.75	-.127 improvement	1.37	2.62	86.25	32.50	128.75	.02625
Track									
1	1.5	- .5	.11	-7	-7	-170	-200	-170	.031
2	-1.5	-5.5	-.14	7	9	-40	490	45	.048
3	1.0	-1.0	-.75	-5	-2	90	210	190	.026
4	1.75	-2.0	-.52	5	2	-170	-80	-170	.061
5	.50	.50	-.31	-5	-4	-360	235	310	.040
6	-1.0	3.0	.13	-20	0	-210	-1000	-640	.029
7	-.50	5.0	-.28	6	14	350	50	110	-.019
8	1.0	-5.0	.00	1	3	145	-100	-85	-.014
Ave. Dif.	.34375	.6875	-.1575 improvement	2.25	1.875	-45.625	-49.375	-51.25	.02525
Treadmill									
1	0	2	-.33	5	9	-410	-140	-340	-.009
2	.75	-4.5	-.24	-3	-4	-65	75	-175	.014
3	0	6	.00	5	8	120	440	350	-.005
4	.5	5	-.10	-14	-3	-110	-220	-50	.034
5	0	1.5	-.86	-14	-10	40	390	-210	-.026
6	.75	.5	.07	6	11	-500	20	-50	-.018
7	-1	-6.0	-.32	-3	5	-420	-60	-50	.013
8	.75	-1.5	-.76	-10	1	-450	-100	-240	-.010
	.21875	.375	-.3175 improvement	3.50	2.125	-224.375	-46.875	-95.625	-.000875

Post-Training Test Data Summary.

Variable	MEAN	STD. DEV.	MINIMUM	MAXIMUM
SVJ	19.7958	3.31816	15.0000	27.5000
SLJ	90.8333	10.5457	70.0000	112.0000
100M	12.8333	0.893166	11.2600	14.3900
HF	95.4583	16.8471	65.0000	130.0000
HE	32.4583	7.53531	20.0000	57.0000
CLS	894.167	337.871	380.0000	1460.0000
ELS	1127.08	357.243	480.0000	1560.0000
ILS	946.458	328.861	500.0000	1550.0000
RT	0.119458	0.206038E-01	0.900000E-01	0.160000

Pre-Training Test Data Summary

Variable	MEAN	STD. DEV.	MINIMUM	MAXIMUM
SVJ	20.0626	3.02907	14.5000	27.0000
SLJ	90.9792	10.6806	71.0000	109.0000
100M	12.6241	0.855754	11.0900	14.3300
HF	94.0000	19.8253	45.0000	120.0000
HE	34.6667	7.67643	21.0000	53.0000
CLS	788.7500	287.898	290.0000	1275.0000
ELS	1109.17	362.094	400.0000	1570.0000
ILS	940.417	343.189	350.0000	1465.0000
RT	0.136333	0.206668E-01	0.105000	0.181000

APPENDIX B

ANALYSIS OF COVARIANCE SUMMARY AND T-TEST STATISTICAL COMPUTATION FOR EXPERIMENTAL PARAMETERS (PRE AND POST)

ANALYSIS OF COVARIANCE SUMMARY

Adjusted Analysis of Variance - Sargeant Jump

Source	DF	MS	ADJ F	P
GRP	2	0.44807434E-01	0.56782637E-01	0.945
WTH	20	0.78910446E 00		

R SQ= 0.92456090E 00

Adjusted Analysis of Variance - Standing Long Jump

Source	DF	MS	ADJ F	P
GRP	2	0.53304443E 01	0.46158594E 00	0.637
WTH	20	0.11548107E 02		

R SQ= 0.90415514E 00

Adjusted Analysis of Variance - 100 Meter Sprint

Source	DF	MS	ADJ F	P
GRP	2	0.10243511E 00	0.16954298E	0.209
WTH	20	0.60418367E-01		

R SQ= 0.92278510E 00

Adjusted Analysis of Variance - Hip Flexion

Source	DF	MS	ADJ F	P
GRP	2	0.58039063E 02	0.73968238E	0.490
WTH	20	0.78464844E 02		

R SQ= 0.82406491E 00

Adjusted Analysis of Variance - Hip Extension

Source	DF	MS	ADJ F	P
GRP	2	0.13797607E 01	0.32301068E-01	0.968
WTH	20	0.42715637E 02		

R SQ= 0.35291588E 00

Adjusted Analysis of Variance - Concentric Leg Strength

Source	DF	MS	ADJ F	P
GRP	2	0.98057563E 05	0.26585093E 01	0.095
WTH	20	0.36884410E 05		

R SQ= 0.51973045E 00

Adjusted Analysis of Variance - Eccentric Leg Strength

Source	DF	MS	ADJ F	P
GRP	2	0.27862500E 05	0.33781630E	0.717
WTH	20	0.82478250E 05		

R SQ= 0.43545473E 00

Adjusted Analysis of Variance - Isometric Leg Strength

Source	DF	MS	ADJ F	P
GRP	2	0.10821050E 06	0.19078379E 01	0.174
WTH	20	0.56718898E 05		

R SQ= 0.54957259E 00

Adjusted Analysis of Variance - Reaction Time

Source	DF	MS	ADJ F	P
GRP	2	0.11603795E-02	0.31141062E 01	0.066
WTH	20	0.37262030E-03		

R SQ= 0.26081370E-05

T-Test Computation Formula

1 tailed df = 7

$$T = \frac{\overline{X}_1 - \overline{X}_2}{S/\ n}$$

where $\overline{X}_1$ and $\overline{X}_2$ are pre and post mean values

Critical T = 1.895

Sargent Jump Single Sample T-Test Calculation

Groups

Control $\frac{.2500}{.3536} = .707$

Track $\frac{.3428}{.4250} = .808$

Treadmill $\frac{.2038}{.2084} = .977$

Standing Long Jump Single Sample T-Test Calculations

Groups

Control $\frac{.7500}{.5976} = 1.2550$

Track $\frac{.6875}{1.2745} = .539$

Treadmill $\frac{.3750}{1.4933} = .251$

100 Meter Sprint Single Sample T-Test Calculations

(pre minus post values)

Groups	
Control	$\frac{.1275}{.0534} = 2.3876*$
Track	$\frac{.1788}{.0866} = 2.064*$
Treadmill	$\frac{.3138}{.1178} = 2.6638*$

*significant at 0.05 level

Hip Flexion Single Sample T-Test Calculations

Groups

Control $\frac{1.38}{3.10} = .445$

Track [illegible] $\frac{[illegible]25}{[illegible]9} = .705$

Treadm[illegible] $\frac{3.50}{2.98} = 1.17$

Hip Extension Single Sample T-Test Calculations

Groups

Control	$\frac{2.63}{2.44} = 1.07$
Track	$\frac{1.88}{2.43} = .773$
Treadmill	$\frac{2.13}{2.61} = .816$

Concentric Leg Strength Single Sample T-Test Calculations

Groups

Control	$\frac{46.25}{81.45}$	= .567
Track	$\frac{45.63}{81.07}$	= .562
Treadmill	$\frac{224.38}{87.28}$	= 2.570*

*significant at 0.05 level

Eccentric Leg Strength Single Sample T-Test Calculations

<u>Groups</u>

Groups	Calculation
Control	$\frac{40.00}{59.68} = .670$
Track	$\frac{46.88}{156.59} = .299$
Treadmill	$\frac{46.88}{86.16} = .544$

Isometric Leg Strength Single Sample T-Test Calculations

Groups	
Control	$\frac{128.75}{83.42} = 1.543$
Track	$\frac{51.25}{103.50} = .495$
Treadmill	$\frac{95.63}{73.77} = 1.296$

Reaction Time Single Sample T-Test Calculations

Groups	
Control	$\frac{.2600}{.1044} = 2.490^*$
Track	$\frac{.2525}{.0974} = 2.592$
Treadmill	$\frac{.0088}{.0677} = .129$

*significant at 0.05 level

APPENDIX C

STUDY DROPOUTS

The following is a list of twelve subjects who dropped out of the study.

Subject	100 meter time (average of 4 pre-test trials)	Reason for dropping out.
1.	11.04	When randomly selected to treadmill group the subject chose to drop out of the study.
2.	12.40	The subject was forced to drop out due to an ankle injury received during 100 meter pre-test trials.
3.	12.90	The subject failed to complete the pre-test battery during the two day time limit.
4.	12.00	These subjects did not meet the minimal level of oxygen uptake requirement.
5.	14.20	
6.	13.10	These subjects did not submit to following training instructions.
7.	12.20	
8.	13.40	
9.	12.60	The subject dropped out due to academic pressures.
10.	16.20	The subject lost interest in the study.
11.	13.70	The subject dropped out due to quadriceps muscle injury not related to this study.
12.	12.70	The subject reported "stiff and sore" at post-test and thus had to be dropped. This stiffness and soreness was due to a camping and hiking holiday which was not normal for his daily activity.