THE EFFECT OF OVERSPEED TRAINING ON SPRINTING SPEED

by

ROBERT J. MAJDELL

A thesis
presented to the University of Manitoba
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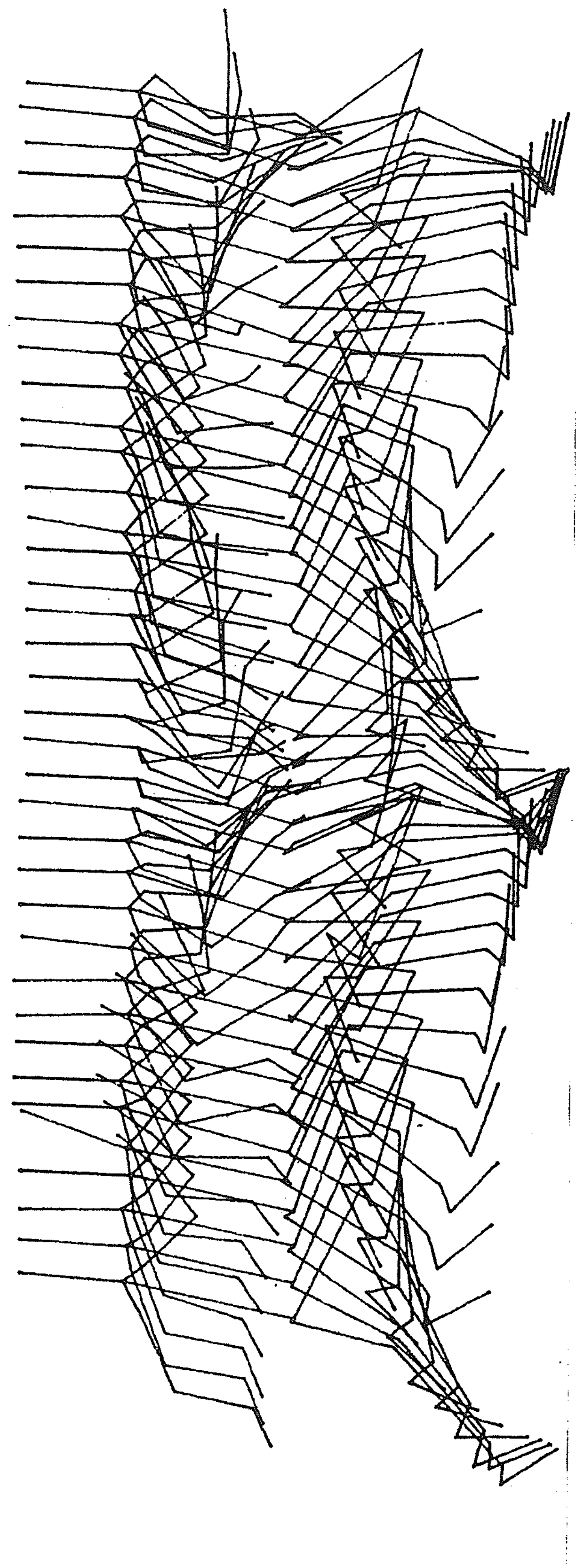

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ABSTRACT

The purpose of this study was to determine the effects of combining overspeed and overload running on the sprinting speed of college male athletes. Eighteen subjects, comprising three separate groups of six subjects per group, were each subjected to their own separate training regime. Three different types of training were employed in the training protocol: a control group which trained free of any external loading; group two, in which the athletes underwent assisted overspeed training; and group three which did the same overspeed tow training while supporting a ten pound weight vest. Each subject performed a test before and after the six week training program. The test included a timed maximum effort forty meter sprint. A high speed (100 frames/second) movie film was used to measure certain kinematic parameters involved in sprinting. The parameters included horizontal velocity, vertical velocity, stride length, stride rate, stride time, support time, non-support time, horizontal foot displacement, the position of the upper and lower leg at takeoff, the position of the upper and lower leg at maximum hip extension, the position of the upper and lower leg at maximum hip flexion, the position of the upper and lower leg at touchdown, the position of the lower leg at maximum knee flexion, the peak angular velocity

of the upper-leg during recovery and the angular velocity of the lower-leg at touchdown.

An analysis of covariance (ANCOVA) was employed to determine whether there were significant differences among the pre/post test scores as a result of the different training modalities. From the twenty kinematic sprinting variables measured in this study, only five exhibited significant differences at the prescribed $p<0.05$ level. The direct performance indicators that were significantly improved with training were: stride length (decreased), stride rate (increased) and support time (decreased). Of the lower body kinematic variables that were measured, the position of the upper leg at maximum hip flexion portrayed a significant ($p<0.01$) difference (increased) after the treatment sessions.

The variables that revealed significant differences as a result of the different training intensities were treated with a least square means test. The least square means (LSM) calculations was used to determine which group significantly differed from the others. Only horizontal velocity displayed a significant LSM value at the $p<0.05$ level between OSW and C.

Some evidence exists to infer changes occurred as a result of the different training techniques. The overload, overspeed trained group witnessed the most change, with respect to having a positive effect on the sprinting variables involved in increasing sprinting speed.

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1. My advisor, Dr. Marion Alexander who gave me the guidance and the courage.
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Chapter I
INTRODUCTION

1.1 OVERVIEW

There has always been an interest in running faster. However, in all sports only full out sprint times have stagnated during the years. 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 five decades following Charley Paddock's 10.2 world record in 1921 (Jokl & Jokl, 1968). Running speed is an important asset, especially in track and field, but it is also evident in almost all sports. Success is often awarded to the athlete who posesses the greatest increase in speed, therefore, any technique which could enhance sprinting speed would be embraced and welcomed by figures in the sporting world.

Some researchers have abandoned the task of determining how to make man run faster (Doherty, 1966; Wilt, 1959; Hill, 1966). They claim that sprinters are born, not made, and that sprinting speed is an inherent ability. "From all physical education components speed is the hardest to develop" (Torim 1980). If so, then high level athletics is doomed to the process of natural selection or attrition.

The credibility of the physical education profession would be tarnished if we could not alter the behavior of athletes. Jarver (1984) noted that: "Sprinting speed is a unique athletic ability which appears to be largely inherited but which can also be improved to some extent by certain training methods."

With recent technological advances and availability of such tools as cinematography and computers, biomechanics has become one method of analyzing sprinting (Dillman, 1975; Mann & Sorenson, 1979). The question of how to attain faster velocities in human locomotion is very difficult to answer, and is one of the reasons why sprinting has undergone such extensive study.

Coaches have employed different methods of sprint training to enhance sprinting speed (McFarlane, 1985; Jarver, 1984; Tabatschnik, 1983; Johnson, 1982). Presumeably, by conditioning the isolated factors involved in sprinting, sprinting speed may be increased. The training strategies employed, independently, or supplementary to each other, include: overspeed running, strength running, power training, strength training, endurance (muscle and cardiac) training, plyometric training, flexibility training, technique training, and others (McFarlane, 1985; Jarver, 1984; Tabatschnik, 1983; Johnson, 1982). Limited success has been attributed to these now conventional modes of training. However, no published articles to date have been found that have demonstrated the effect of simultaneously incorporating two or more of these training methods.

1.2 STATEMENT OF THE PROBLEM

The purpose of this study is to determine the effects of overspeed, and a combination of overspeed and overload running on the sprinting speed of college male athletes. Selected kinematic variables involved in sprinting technique will also be examined.

1.3 HYPOTHESIS

The null hypothesis for this study is that there will be no significant differences between the different training methods utilized to develop sprinting speed.

1.4 DELIMITATIONS

1. Only football athletes will be utilized for the study.
2. Only selected kinematic parameters of running speed will be investigated for this biomechanical study.

1.5 DEFINITION OF TERMS

1. ASSISTED or HIGH SPEED or OVERSPEED RUNNING is running at a faster horizontal velocity than one is normally capable of running.
2. STRENGTH or WEIGHTED or OVERLOAD RUNNING is running against an additional load or resistance.
3. STRIDE or STEP is the distance from the point of initial contact of one foot to the point of initial contact of the opposite foot (Williams, 1985).
4. STRIDE TIME is the time between the instant contact of one foot and the next instant contact with the other foot (Williams, 1985)
5. STRIDE RATE is the inverse of stride time or the number of steps per second.
6. SUPPORT or CONTACT PHASE is when the foot strikes the ground with the leg in the leading position and is continuous until it leaves the ground (Slocum & James, 1969).
7. RECOVERY or NON-SUPPORT PHASE is when the extremity (leg) does not bear weight but returns from the rear to lead position preparatory to contact with the ground (Slocum & James, 1969).
8. TOW TRAINING is a method of overspeed training performed while being towed. Towing techniques include car towing, motorcycle towing, rope towing by another athlete, and a "Sprint Master". The Sprint Master consists of a 5 h.p. Briggs and Stratton gasoline en-

gine, a centrifugal clutch, pulley and brake system, and governor-type manual speed adjustment and is designed for operation by the coach, manager, trainer, or researcher.

Chapter II

REVIEW OF LITERATURE

2.1 OVERVIEW

There is extensive published literature in the area of sprint training. Some of the research examines the biomechanical parameters involved in high speed running. Highly skilled sprinters have been analyzed to produce models utilized for teaching tools (Mann, 1985; Mehrikodge & Tabatschnik, 1983; Kusnezov, Petrovkiy & Schustin, 1982). Various means of developing sprinting speed have been investigated. Limited success has been achieved in improving running speed using conventional methods. New methods of improving sprinting speed need to be developed.

2.2 KINEMATIC FACTORS IN SPRINTING

2.2.1 Horizontal Velocity

The greatest factor dictating success in sprinting is the maximal horizontal velocity that an athlete is able to achieve (Mann & Herman, 1985). Typical sprint studies to date reported maximum horizontal velocity reached by any of the subjects tested have been between 8.85 and 9.49 m/s (Armstrong, Costill, & Gihlsen, 1984; Luhtanen & Komi, 1978; Mann & Sprague, 1983). Only in a recent study (Mann & Herman, 1985) involving elite sprinters from the 1984 Olympic Games have velocities of 10.78 m/s remotely approached the theoretical value of 12.9 m/s found in Mann and Herman (1985).

2.2.2 Vertical Speed

During the non-support phase the sprinters body is projected upward vertically to allow for leg recovery and in preparation for the next ground contact. Although the performer must project the body vertically upward, excessive vertical motion is unwanted. The better sprinters tend to produce just enough vertical speed to allow time to complete leg recovery and prepare for the next ground contact. To date only Mann (1985) has reported on vertical velocity of elite sprinters. During the 100-meter event at the 1984 Olympic Games, Mann (1985) found that the vertical speeds attained by the "good" sprinters were 0.52 m/s, the "average" sprinters reached 0.61 m/s, and the "poor" sprinters produced vertical velocity speeds of 0.69 m/s. It appears that good sprinters exert most of their effort toward maintaining horizontal speed.

2.2.3 Stride Length and Stride Rate

Coaches and investigators all agree that the two key components related to horizontal velocity are stride length and stride rate. Horizontal velocity equals the product of stride length times stride rate (Dillman, 1975). The rate at which the sprinter strides multiplied by the distance each stride covers determines the performance of the sprint, measured by the horizontal velocity (Mann, 1985).

In the opinion of Broom (1962), increases in speed result from increases in stride length, because although stride rate is somewhate trainable, stride length being dependent on the mobility of the hip joint, is more trainable. Armstrong, Costill and Gehlsen (1984), compared collegiate sprinters and marathoners running at a maximal sprint. They found that the sprinters demonstrated a superior stride length, but did not differ significantly in stride rate.

Other researchers who have done extensive work in the area have found that increases in speed are dependent upon stride rate (Hogberg, 1952; Hopkins & Holt, 1974; Ballreich, 1976; Murase et al, 1976).

Luhtanen and Komi (1978), looked at the mechanical factors influencing speed and found that stride length levelled off at high velocities, whereas stride rate continued to increase. Most recently Mann and Herman (1985), found a significant difference in stride rate (elite higher) while none was apparent in stride length. Williams (1985) indicated that at high velocity runners increase their speed by increasing stride rate to a relatively greater extent than stride length.

Kunz and Kauffman (1981), using a small group of world class sprinters (n=3), found a combination of greater stride length and higher stride frequency when compared to group of decathletes (n=16), performing a maximal sprint effort. Limited comparisons between "good" and "poor" runners indicate that, at a given velocity, the better runner has a longer stride and a lower stride rate (Dillman, 1975). Mann (1985), reported that speed is dependent upon maximizing stride length and rate through the production of a large productive ground force, as well as economizing the ratio of the two components. Kauffman (1980), stated that stride length and stride frequency have to be in optimal relationship (one cannot hinder the other) for maximal speed gains.

Large stride lengths are only beneficial if acceptable stride rate is maintained. Conversely, a high stride rate is only good if a large enough stride length is maintained. Increasing only one of these variables while the other one remains constant will also increase speed. Increasing one of these variables at the expense of the other one will not improve the athletes horizontal velocity.

2.2.3.1 Stride Length

Dillman (1975) mentioned a strong correlation between leg length and stride length. However, Hogberg (1952) stated that it is the leg drive and not the leg length that has the greatest importance in stride distance during sprint running. Broom (1962) suggested that increased muscle strength, causing increased power from the leg drive will increase stride length. Mann (1985) derived measurements for good, average and poor stride lengths from Olympic class sprinters. "Good" sprinters produced stride distances of 2.31 meters, "average" sprinters reached distances of 2.21 meters, and the "poor" Olympic sprinter's stride length measured at 2.04 meters.

2.2.3.2 Stride Rate

Stride rate is the number of strides per second. It is calculated by measuring stride time. Stride time can be divided into two components; the support phase and the non-support phase (Mann & Sprague, 1983). Dillman (1975), stated that the determining factor in increasing stride rate is in decreasing the time of support.

When Kunz and Kauffman (1981) compared world class sprinters against a group of decathletes, they found a significantly shorter ground support time for the sprinters while performing a maximal sprint effort. Kauffman (1980) also found that better sprinters decreased contact time. Atwater (1973) found that as sprinting speed increased, there was a decrease in the time of the support phase. From a film analysis of eight male sprinters, Atwater (1982), supported her initial findings, and concluded that better sprinters exhibited shorter support times. Mann and Herman (1985) agreed with those findings after their own film analyses of elite sprinters during actual racing conditions.

They discovered a significant difference in support times (lower), but no significant difference was found in non-support time.

From film analysis, Erdman (1985), claimed the best way to accomplish decreased support phase and optimal relationship between stride rate and length is to land on the balls of the feet. This will not only encourage proper mechanics but reduce the "braking" forces as well. Mann (1985), stated that improvement in stride rate is the means by which the better sprinters improve their performance. This result is improved by increasing leg strength so the necessary ground forces can be produced more quickly, as well as improving the mechanics of sprinting so that less energy is wasted while on the ground.

Mann (1985) calculated average stride rate for good, average, and poor male elite 100 meter sprinters from a film analysis sixty meters into a 100 meter race. The stride rate for the "good" sprinters was 4.8 steps per second. The "average sprinters" had a stride rate of 4.5 steps per second. The frequency rate for the "poor" sprinters was 4.15 steps per second.

2.2.4 Horizontal Foot Displacement

A factor that affects both stride distance and frequency is the horizontal foot distance to the body center of mass.

The further the foot contact away from the body, the greater the retarding or braking effect on horizontal velocity. Kauffman (1980), Ambrose (1978) and Dillman (1975) all recommended that in order to decrease this braking factor, the sprinter's center of mass should be directly over the foot at touchdown.

However, a film analysis of Olympic class sprinters revealed evidence contrary to those findings. Mann (1985) reported that the foot of these highly skilled sprinters is placed slightly in front of their center of mass during ground contact. Mann noted that placing the foot directly below the body's mass center will have a positive effect on stride rate, however at the expense of stride length. Not enough time is spent on the ground to exert the necessary forces to produce sufficient stride length (Radford, 1978). Conversely, too much horizontal displacement is counter productive in maintaining sufficient leg frequency.

The better elite sprinters favor decreases in ground time over an increase in leg range of motion. Mann (1985) suggested in order to establish optimal horizontal distance, superior leg strength of the hamstring and gluteal muscles is necessary to pull the body over the touchdown foot at touchdown point. "More than any other factor, the strength of these muscles dictate the success of a sprinter" (Mann, 1985).

Mann (1985) estimated that "good" elite male sprinters place their foot fifteen centimeters from the body's center of gravity during a 100 meter race. "Average" sprinters have horizontal foot contact twenty-three centimeters from the body. The foot displacement from the athlete's center of mass for "poor" Olympic class sprinters is twenty seven centimeters. These estimates were derived from a film analyse of the 100-meter event at the 1984 Olympic Games in Los Angeles.

2.2.5 Horizontal Foot Velocity

Equally as important as foot displacement is the horizontal foot speed at touchdown (Mann, 1985). Fenn (1930) and Hay (1978) stated that in order to avoid horizontal braking at touchdown, the foot should be moving backward relative to the body's center of gravity with a horizontal velocity at least equal to that at which the body's center is moving forward. Dillman (1971), however, found that even when the foot was placed beneath the mass center its backward velocity was still not great enough to prevent unwanted braking. Mann's (1985) film analysis of the 200 meter sprint at the 1984 Olympics suggested that the best sprinters displayed the slowest forward horizontal foot speeds at touchdown. In other words, the "good" sprinter is moving his foot towards his body faster than his less skilled counterparts. "Good" horizontal foot speed at touchdown for male elite 100 meter sprinters is 1.7 m/s (Mann, 1985). "Average" horizontal foot speed at touchdown for male elite 100 meter sprinters is 2.6 m/s (Mann, 1985). "Poor" horizontal foot speed at touchdown for male elite 100 meter sprinters is 3.5 m/s (Mann, 1985).

2.2.6 Lower Body Segments

2.2.6.1 Range of Motion

Complications could arise when analyzing the complexity of the lower body segments in motion during sprint running. To reduce the confusion, Erdman (1985) divided the running stride into the following phases:

1. The rear swinging phase or the position after take-off, that allows relaxation and makes preparations for the knee lift.
2. The front swinging phase, that influences the stride length and the preparation for the landing.
3. The front support phase, during which the breaking effect should be kept as restricted as possible.
4. The rear support phase or the position at takeoff, that decides the force and the direction of the drive and with it the forward motion.

Bunn (1978), Dillman (1975), and Hay (1978) stated that at takeoff and after takeoff the hip should be extended through as great a range of motion as possible, and that failure to complete extension is one of the most common faults in sprinting. In contrast Kunz and Kauffman (1981) found world class sprinters had less upper leg extension at takeoff and after takeoff than did a group of decathletes when performing a maximal sprint. Mann (1985) was in agreement with those findings after his film analyses of elite male sprinters. He stated that: "It must be emphasized however, that a very good angle at one position is only beneficial if the other results are acceptable."

Dillman's (1975) critique on sprinting literature suggested that "poor" runners do not obtain full extension of the lower leg during the takeoff of a sprint run, while "good" runners perform full extension of the ground leg at takeoff, therefore maximizing muscle forces which facilitate increased stride length. Recently Mann (1985), on the other hand, discovered that the "better" elite sprinters tend to minimize lower leg extension at takeoff. Mann further suggested that full leg extension needed to assist stride length is executed because of insufficient muscle strength.

Research into the kinematic pattern of leg movement during recovery revealed that as the thigh is moved forward rapidly, the lower leg is flexed acutely behind the thigh (Fenn, 1930; Slocum & James, 1969). This action facilitates forward recovery by reducing the moment of inertia of the leg about the hip joint. The elevation of the thigh increased with increased speed and "better" runners tended to have greater hip flexion (Sinning & Forsyth, 1970). Dillman (1975) suggested greater knee flexion is observed in "better" runners during the swing cycle during sprint running.

In contrast, Armstrong, Costill, and Gehlson (1984) found no significant difference in the lower leg recovery angle between collegiate sprinters and marathoners. However, Mann (1985) revealed that the superior performer minimizes the lower leg angle during the recovery phase to make the task of recovering the leg both faster and easier. "Poor results here, commonly point to a lack of leg strength (indicated by excessive extension at takeoff), or an inability to properly recover the leg (indicated by insufficient flexion during recovery)."(Mann, 1985, p.54). Dillman (1975) reviewed the literature on the kinematics of sprinting, and reported a consensus that at ground contact skilled runners have both greater hip and knee flexion of the support leg.

2.2.6.2 Rotational Speed

Most of the research conducted on lower body kinematics has been focussed on the range of motion. Critical to the range of motion of the lower limbs is the speed at which they perform that range. Mann and Herman (1985) found upper leg angular velocity scores, prior to and during ground contact, were highly correlated to sprint performance. Upper leg rotational speeds during recovery however were not a factor.

Mann and Herman (1985) found no significant difference in lower leg velocity during the recovery phase until just before foot contact, in comparing skilled versus unskilled sprinters.

2.2.7 Upper Body Segments

Upper body kinematics has not been a focal point for many investigators in regard to maximum running. Bunn (1978) and Hay (1978) both described the role of the arms in sprinting as that of a balancing action for the hips. Bunn further claimed that the vigorous backswing of the arm causes the legs to stride further and help to maintain velocity when the legs fatigue. From a kinetic analysis of sprinting, Mann and Sprague (1983), showed a minimal amount of muscular contribution by the arms. However no relationship could be established between arm motion and sprint performance. Mann and Herman (1985) indicated that the role of the arms in sprinting is more to maintain balance, than to aid in the sprint cadence or combat fatigue.

2.3 OTHER FACTORS RELATED TO SPEED DEVELOPMENT

Research in sprinting has been examined in an attempt to discover how the locomotion abilities of humans can be increased. Cavagna (1977) felt that the determining role in increasing speed was the athlete's ability or inability to use the muscle's elastic force. For speeds up to seven meters per second, the work done in running was due to the concentric contraction of the muscles (Cavagna, Kormarek & Mazzalen, 1971). At running velocities greater than seven meters per second, the work done to perform each step was contributed more from the energy absorbed from the eccentric contraction of the muscles involved (Cavagna et el, 1971).

At high speeds of opposite (concentric to eccentric) contractions, this "elastic energy" provides the force necessary to maintain velocity when time on the ground decreases (Cavagna, 1977). Cavagna (1977) explained that an increase in the concentric force a muscle can exert corresponds to an increase in the eccentric force it can produce. Mann (1985) suggested that sprinting demands great force, and insufficient hamstring and gluteal muscle strength is the cause of the majority of injuries sustained in maximum effort runs. Therefore the athlete who can produce a rapid rate of force development, has a definite advantage in sprinting (Radford, 1978).

Ballreich (1976) felt that sprinting for top level performers can probably be improved to a greater degree by developing the technical rather than the conditioning component. Tansely (1980) suspected that the increase in speed from assisted running of 100 meters was due to an increase in the quick energy or anaerobic alactic capacity longer than five seconds. Murase et al. (1976) attributed increases in running speed to running form as well as anaerobic power.

Slater-Hamel (1941) looked at the neuromuscular mechanism as being a limiting factor for the rate of leg movement. The results of their experiment ruled out any possibility of action potentials being the limiting factor. They concluded that the rate of leg movement in sprinting is a relation between muscle and load. Radford (1978) and Fenn (1931) both have been found to agree with this load/velocity relationship. As the load increases, the rate of moving this load decreases. The inverse holds true, for at constant muscle strength, in order to increase velocity the load has to decrease.

Irwin (1974) suggested that the increase in speed from high speed treadmill training may have been the result of the neuromotor pathway being "honed" or tuned by the treadmill.

The results of Radford's and Upton's (1976) tapping test reflected differences in coordination only between sprinters and a control population. Radford and Upton concluded that the major difference between sprinters and other athletes lies in the training of the nervous system rather than in the improvement of the peripheral neuromuscular mechanism. In another article, Radford (1978) claimed that the increases in running speeds obtained from assisted running is a result of "disciplined disinhibition". Johnson (1982) explained this phenomenon by stating, "the runner is apt to lose some of his fear of falling and get closer to having a 'sprinters syndrome' because he has partially overcome that fear of falling and can more easily 'let it all hang out'...Reduce the fear of falling and we can psychologically run faster and longer." In other words the athlete who can retard those inhibitors that prevent him from going beyond his capabilities (through sprint training) will have an advantage in speed development.

2.4 TRAINING METHODS TO INCREASE SPEED

Woicik (1982) divided sprint running into four phases: the starting phase, the acceleration phase, the speed maintenance phase and speed endurance phase.

McFarlane (1985),Tansely (1980), Boson (1979) and Murase et al (1976) each determined that it takes approximately thirty meters to reach top speed. Dowell et al. (1975), using cinematography during a 100 yard dash, discovered the acceleration phase lasted up to twenty-five yards. The next phase of running is devoted to the maintenance of this speed.

Uppal (1982) evaluated the effects of a two, three and five session per week sprint training workout schedule on speed development. He discovered that the three and five session per week schedule demonstrated significantly better increases in speed development than the two session per week workout schedule. It was also found that there was no significant difference between the three and five sessions per week schedule.

Tabatschnik (1983), suggested that based on translated extracts from Leykoja Atletka, Moscow (1982), planned steady work can increase both stride length and rate. For pure speed training, the total number of repetitions at maximum running speed should not exceed 300 to 400 meters. Recovery time between each repetition should range between two and three minutes, and between each series rest should last between eight and ten minutes.

Kotz and Koryak (1979) evaluated the strength and speed-strength qualities of the peripheral neuro-muscular system of two groups of track athletes, sprinters (n=10) and long distance runners (n=10). Tendometry, which makes it possible to record isometric strength of an individual muscle by the change in tension of it's tendon, was used to study the individual muscles of the athletes. They found that the differences in speed and strength capabilities of sprinters and long distance runners are determined by specifically different properties of the muscle system. The specific differences in the central control of this system arise as a result of specific training.

McFarlane (1985) discussed different strength programs to aid in speed development. He stated runs using weight vests are not new to speed development, and "seem" to have a positive effect on speed development. No other literature on this area has yet to be reported.

Various researchers and track coaches have investigated or experimented with and found relative success in increasing speed utilizing different forms of assisted running

(Irwin, 1974; Ozolin, 1976; Singh et al, 1978; Stocking, 1976; Tansely, 1980)

In Stocking's (1976) master's thesis, the author trained two groups of athletes. One group performed eight times fifty yard sprints on a flat surface three times a week for four weeks. The other group performed eight times fifty yard sprints running downhill three times a week for four weeks. The facilitated group displayed significant increases in sprinting speed, while the other group did not.

Using just high speed treadmill training, Irwin (1974) showed non-significant increases in the 100 meter sprint stride length and stride rate. Irwin suggested that high speed treadmill training interspersed with overground training would produce significant differences in running speed.

Sandwick (cited in Dintiman, 1975) felt that tow training is an unquestionable aid in the development of running speed. After five weeks of steady use he found sprinters to reduce their average 100 yard times from 10.5 to 9.9 seconds.

According to Dintiman (1975) the objective in overspeed training is to increase stride rate without decreasing stride length. However, assisted training has been shown to increase both stride length and frequency (Dintiman, 1984; Irwin, 1974).

Tansely (1980) felt that tow training by itself is not a complete training system, however when used as a supplement with regular overground training increases in range of motion, stride length and speed have occurred.

Mero and Komi (1985) experimented with thirteen male and nine female sprinters to determine the effects of supramaximal velocity on biomechanical variables in sprinting. It was concluded that in overspeed effort it is possible to run at a higher stride rate than in maximal running. Data suggested that supramaximal sprinting can be beneficial in preparing for competition and as an additional stimulus for the neuromuscular system during training. "This may result in adaption of the neuromuscular system to high performance level." (Mero & Komi, 1985, p.240).

The only side effects, reported in the literature, from this method of overloading the system to obtain a sprint training effect, were complaints about sore hamstring muscles (Dintiman, 1975; Irwin, 1974; Šingh et al, 1978).

Chapter III

METHODOLOGY

3.1 INTRODUCTION

This study attempted to determine the effects of overspeed training, and overload training combined on speed development. The term used to describe this unique mode of training is "Weighted Overspeed Sprint Training".

Two timers using hand-held stopwatches were used to measure the sprinting speed of each athlete. Cinematography was used to analyze various biomechanical parameters involved in sprinting. Following the initial filming the athletes involved were divided into three separate groups. Each group of subjects was then subjected to one of three respective high speed training modes. At the completion of this six week training period the individual athletes were again filmed for the same biomechanical sprinting kinematic variables initially measured. These pre and post training sprinting variables were treated by statistical analyses to determine whether any significant changes have occurred.

3.2 SUBJECTS

The twenty-one subjects used for the investigation were recruited from the University of Manitoba Bisons Football Team. These highly skilled athletes represent a large homogeneous group. The intense and strenuous nature of the sport of football allows these athletes to be familiar with the stress necessary to withstand the experimental training.

The athletes were arranged in three groups equally skilled in running. Group distribution was based on initial sprinting speed, size, and preference of the athletes. Each group performed their own respective training regime. Group one was designated the control group (C), group two was subjected to high speed tow training (OS), group three underwent high speed tow training while supporting a weighted vest (OSW).

3.3 TRAINING PROTOCOL

3.3.1 Preparation

Every athlete in the three groups was involved in a three session per week, six week sprint training program. Prior to the training program the athletes spent three sessions learning the training format. This was followed by three more sessions to familiarize each subject with their respective training mode. The training period allowed the athletes to rehearse and prepare themselves for the training program designed for the investigation.

3.3.2 Warm-up

The stressful sprint training involved required an extensive warm-up. This two part warm-up was performed to prepare the athletes for the extensive speed training involved as well as to decrease the chance of injury. Part one of the warm-up was acquired from McFarlane (1985).

3.3.2.1 Part One

1. ankle exercises - spelling the alphabet with each foot to warm-up, stretch, loosen and prepare the ankle joint to run
2. ten minute jog - to raise the body temperature and get the blood flowing in the running muscles of the body.
3. ballistic stretching - using repeated movements through a range of motion at a joint(s) by applying momentum (swinging, bouncing, flexing actions).
4. 3x50 meter stride runs - running at 70% of maximum speed to help "warm-up" the body in preparation to sprinting.
5. static flexibility exercises - develops hip, knee, and ankle joint flexibility necessary for sprinting.
   a) each athlete chose his favorite groin stretch
   b) each athlete chose his favorite gluteal stretch
   c) each athlete chose his favorite quadricep stretch

d) each athlete chose his favorite hamstring stretch

e) each athlete chose his favorite calf stretch

6. 3x50 meter stride runs
7. 2x5 m. A walks - high knee lifts while walking
8. 2x5 m. A skips - high knee lifts while skipping
9. 2x5 m. A runs - high knee lifts while running
10. 2x5 m. B walks - high knee lift and extension while walking
11. 2x5 m. B skips - high knee lift and extension while skipping
12. 2x5 m. heeling or bum kicks - heel bounces off track and to buttocks
13. 2x20 m. lunge walks - walking with as long as steps as possible
14. 2x20 m. lunge skips - skipping with as long as steps as possible
15. 2x20 m. bounds - running with as long as steps as possible
16. 3x50 meter stride runs

3.3.2.2 Part Two

1. 2x60 meter gradual acceleration from joggingg to near maximum sprinting
2. 2x20 meter falling to almost off balance starts
3. 2x60 meter change of pace runs from fast (near maximum) to slow (70% of maximum) to fast again

After the warm-up the athletes broke up into their respective groups ready for their particular training modes.

3.3.3 The Workout

During the six week period, the workouts became progressively more intense. For the first two weeks every athlete performed one set of three repetitions of their specific training regime. During weeks three and four the workload increased to two sets of three repetitions of their respective high speed or overspeed runs. The last two weeks the workload intensities increased to three sets of three repetitions for each particular group. There was a ten minute rest period between each set.

The method of training for Group One (C) involved full out or maximal forty meter runs with a ten meter running start. A two to three minute rest period was maintained between each run.

The athletes from Group Two (OS) were subjected to assisted high speed runs of similar distances and rest periods as C.

The athletes in Group Three (OSW) underwent the identical supramaximal runs and rest periods as OS, with the addition of wearing a ten pould weighted vest jacket.

3.3.4 The Towing Device

Towing athletes behind automobiles, motor scooters and motorcycles is not a new approach to the improvement of speed. In 1956, towing was used to train Olympic medal winner Al Lawrence, who held on to a rigid bar attached to a car, four times weekly for distances of 100-600 yards (Dintiman 1984). The assisted high speed runs were facilitated by a towing device called the "Sprint Master", developed and manufactured by George Dintiman. The Sprint Master consists of a 5 h.p. Briggs and Stratton gasoline engine, a centrifugal clutch, pulley and brake system, and governor-type manual speed adjustment. This refined and most practical method of tow training replaces the traditional methods of facilitated running. The "Sprint Master" allows the athlete full and proper use of the arms while being towed at speeds of five-tenths to one second faster than one can normally run over a distance of forty meters, with a ten meter running start. For more details, see Appendix A.

3.4 TIMING

Two, timed forty meter runs, started from the athletes initial movement, were performed before and after the treatment period to determine increases in speed. The average time between two timers' scores represented each forty meter sprint time. The best time between the two forty meter sprint trials of each athlete was recorded to demonstrate the athletes speed.

A convenient tool to obtain a measure of relationship between two sets of scores involving a small number of subjects (n<25) is the rank-difference or rho method of correlation. This method used the rank that each subject attained on a test; then the relationship was established in terms of the degree of difference between the rankings. This ranked-difference method of correlation was used to find the correlation coefficient to evaluate the reliability of the timing method used to determine the athlete's sprinting speed. Comparative analyses between the pre and post speed times were tested for significant differences to determine the effectiveness of the different training regimes.

3.5 CINEMATOGRAPHY

Prior to and at the completion of the treatment stage of the experiment each athlete was filmed for biomechanical analyses. The filming was conducted while each athlete performed an all out or maximal forty meter run, with a ten meter running start. (This was is to ensure the athlete reached top speed at the filming site). Information drawn from the film was used for biomechanical analyses on the effects of the training program on certain kinematic parameters involved in high speed human horizontal locomotion.

Filming was done at ground level from a side or saggital view at a point thirty meters into the sprint. The saggital view allowed for the exact sprinting variables the investigation was concerned with. White tape was placed on all of the segmental endpoints of each athlete to permit greater precision in digitizing. A Photosonics 16 mm camera equipped with a Angineaux 12-120 mm lens at a film speed of 100 frames per second was used for the data collection.

The camera was positioned to focus a field of view which produced at least two full out sprint strides for each athlete filmed individually.

During the timed forty meter runs the athletes were also videotaped at a film speed of thirty frames per second. The video film was later used to determine stride rate over the entire forty meter distance. This was calculated by dividing the number of strides it took to perform the forty meter sprint over the time of the sprint. This figure portrayed the number of strides per second or the stride frequenecy of the entire sprint.

3.6 FILM DATA ANALYSIS

The segmental endpoints for the individual athletes of the pre and post filming were recorded using a Hewlett Packard 9816 digitizer interfaced with a Hewitt-Packard 9816 micro-computer. This data was then stored on floppy discs, and processed using appropriate programs. Calculations for the kinematic variables studied in this investigation for each group of runners were as follows:

1. Horizontal velocity or the average horizontal velocity of the athlete's center of mass during the entire stride was measured by dividing the change in the horizontal distance the athlete exhibited during an entire stride over the change in time of that distance. A clock in the camera's field of vision was used in order to determine the precise camera speed. This precise film speed was used to calculate the exact time between each frame.
2. Vertical velocity or the average vertical velocity of the athlete's center of mass during the entire stride was obtained by dividing the change in the vertical distance the athlete produced during an entire stride over the change in the time of that distance.
3. The distance marker in the camera's field of vision helped produce the athletes' stride length or the distance between the first point of contact from one touchdown to the first point of contact of the next touchdown of the alternate foot.
4. Stride rate or the number of strides per second the athlete performed was calculated by taking the inverse of the number of frames for two consecutive touchdown points divided by the film rate.
5. Support-time or the time the athlete spends on the ground during the entire stride was calculated by counting the number of frames from touchdown to take-off and multiplying this figure by the time between frames.

6. Non-support time or the time the athlete spends in the air during the entire stride was obtained by counting the number of frames from takeoff to touchdown and multiplying this result by the time between each frame.
7. Horizontal foot displacement or the horizontal distance between the subjects center of mass and the point of initial contact with the ground.
8. The position of the upper and lower leg at takeoff (position 1).
9. The position of the upper and lower leg at full hip extension (position 2).
10. The position of the upper and lower leg at full hip flexion (position 3).
11. The position of the upper and lower leg at touchdown (position 4).
12. The position of the lower leg at full knee flexion (position 5).
13. The peak angular velocity of the upper leg between position 2 and position 3.
14. The angular velocity of the lower leg at touchdown.

3.7 EQUIPMENT AND FACILITIES

The entire project was conducted at the University of Manitoba Max Bell High Speed Development Center. The mondo track at the Max Bell National Training Center is reputed to be one of the fastest indoor tracks in Canada.

George Dintiman's towing device, the "Sprint Master" was purchased from a grant funded by the University of Manitoba's Faculty of Graduate Studies.

The biomechanics laboratory at the University of Manitoba has all of the other equipment necessary for the completion of this project. Included are a Photosonics 16mm high speed movie camera and movie lights, a Hewlett-Packard Microcomputer, digitizing system, printer, and plotter An Amdahl 570 mainframe computer is available on the campus which contains all the major statistical analyses packages and graphics packages for the data analyses and display.

3.8 STATISTICAL ANALYSIS

A statistical, rather than a experimental, method may be used to control or adjust for the effects of one or more uncontrolled variables, and permit a valid evaluation of the outcome of the experiment. The analysis of covariance (ANCOVA) is such a method. The analysis of covariance was used to remove the bias introduced by the differences in the initial level of subject performances, permitting unbiased comparisons between the training effects. The simple ANCOVA enables a comparison of the group post scores, adjusted for the differences of the group pre test scores. A level of significance of $p < 0.05$ was used for this comparison.

The least square means method for making multiple comparisons among mean scores was utilized to identify which group differs from the others. The effects the different training modalities had on speed development may then be described.

Chapter IV

RESULTS AND DISCUSSION

4.1 SUBJECTS

There were twenty-one male athletes from the University of Manitoba Football Team who began the treatment sessions. Three groups of seven subjects per group were formed based on initial sprinting speed, size, and preference. Group one (C) was used as the control group, running a series of maximum effort forty meter sprints unassisted three times per week for six weeks. Group two (OS) ran the same forty meter sprints as the control group, while being towed or assisted by a towing device. Group three (OSW) performed the same overspeed training as group two while wearing a ten pound weight vest. At the completion of the experiment, eighteen athletes remained. One athlete, from the control group, quit the football team, and decided the training sessions were no longer useful to him. An athlete from OS strained his hamstring muscle while performing a forty yard sprint test during a football practice; he had to discontinue the training sessions three weeks into the experiment.

The third athlete who had to withdraw from the experiment was from OSW. He withdrew at week five of the six week training program. A third degree ankle sprain occurred while performing an agility test for the football coach, which forced his resignation from the study. Fortunately, these three athletes represented each of the three training groups. Therefore, for the final analysis, eighteen subjects making up three groups of six subjects each was utilized.

TABLE 1

Description of Subjects/Groups

VARIABLES	GROUP MEAN±S.D. VALUES 1	2	3
AGE	21±3.52	23±2.73	19±1.36
HEIGHT (in.)	72±2.62	71±3.58	71±0.98
WEIGHT (lbs.)	205±28.30	200±43.06	195±19.86
FOOTBALL YEARS	6±3.26	8±4.52	7±2.41
40 m. speed	5.46±0.34	5.31±0.29	5.26±0.14

See Table 1. for description of subjects.

Although some muscle soreness or minor discomforts usually associated with high level training of this type was felt by the athletes, no injuries occurred at the training sessions. The subjects who were members of university football team represented a very cooperative and disciplined group of individuals. Each athlete took each training session very seriously. As a result the attendance rate for the six week, three session per week treatment regime ranged from eighty to 100 per cent. (See attendance sheet in Appendix B).

4.2 TIMED FORTY METER SPEED

During the pre-test a correlation value of 0.93 and 0.91 was found between the two timers, for each of two timed trials. During the post-test correlation values of 0.96 and 0.95 was calculated between the two timers, for each of two timed trials. As a result of this high correlation, the values obtained representing the athlete's sprinting speed were considered reliable enough to use in the experiment.

4.3 DATA ANALYSIS

4.3.1 SPRINTING SPEED

The pre/post test scores are reported in Figure 1 and Table 2. These values represented a significant difference between the pre and post scores within the groups at the $p<0.0001$ level, indicating that sprinting speed can be improved (See Table 3). However, when a least square means test was performed to determine if the mean speed of the groups differed from each other, non-significance was found. Although non-significance was found, the least square means test portrayed that differences found between the pre and post scores of C with OS and OSW were less likely due to error then the pre and post differences found between OS and OSW. Since the best results that sprinters have been able to achieve in the 100 meter race has not improved by more than 0.3 seconds during the past five decades (Jokl & Jokl, 1968), these values are important.

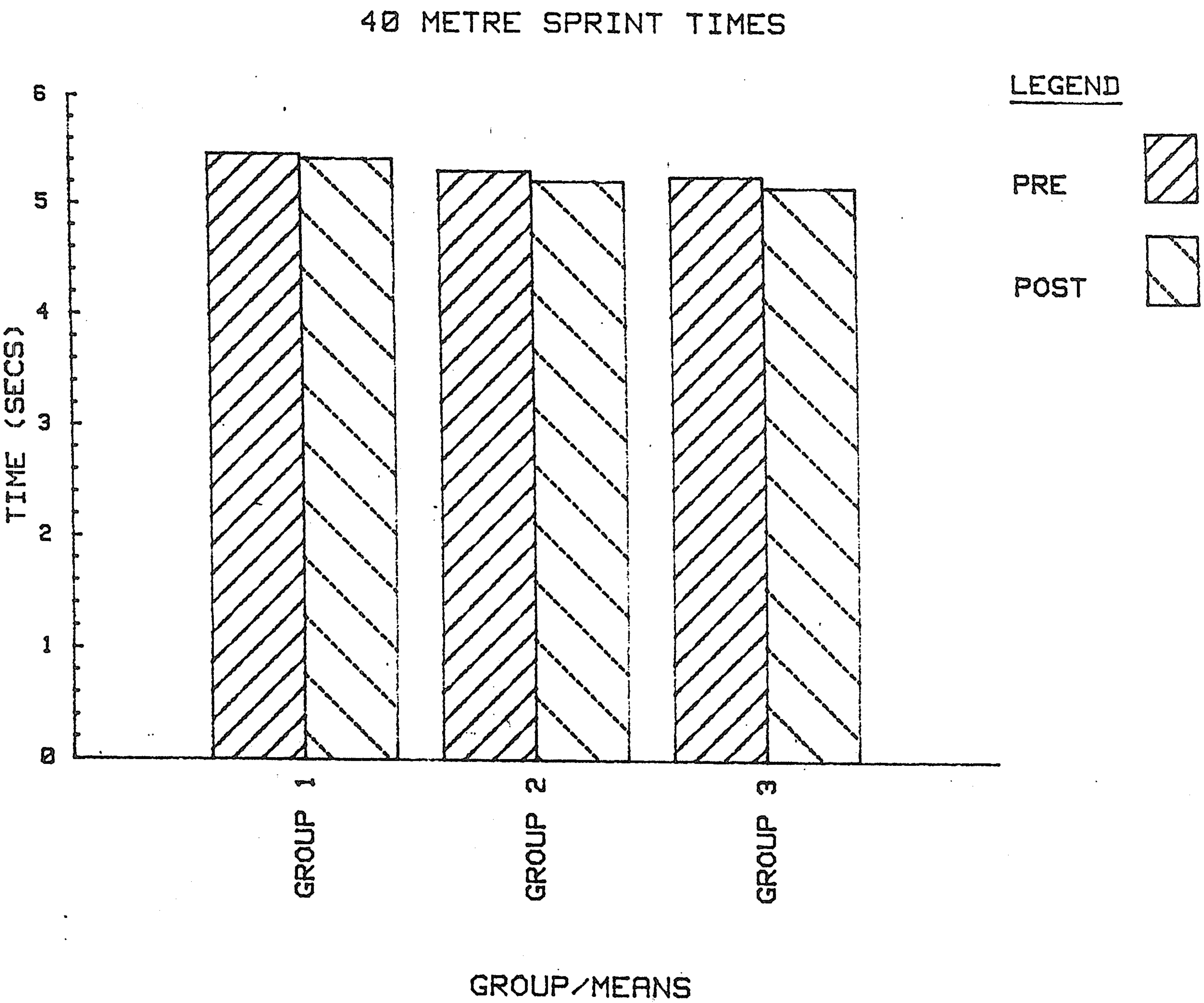

Figure 1: Change in sprinting speed

TABLE 2

Results for Direct Performance Indicators

VARIABLES	GROUP MEAN±S.D. VALUES (PRE/POST) 1	2	3
Time (s)	5.46±0.34	5.31±0.29	5.26±0.14
	5.42±0.39	5.22±0.29	5.16±0.17
HV (m/s)	8.23±0.70	8.40±0.56	8.27±0.35
	7.43±0.64	7.80±0.49	8.11±0.35
VV (m/s)	0.44±0.10	0.44±0.04	0.37±0.09
	0.28±0.07	0.38±0.06	0.41±0.14
SL (m)	1.71±0.14	1.79±0.17	1.78±0.07
	1.64±0.12	1.65±0.08	1.69±0.08
SR (vid)	4.43±0.14	4.49±0.23	4.44±0.14
	4.42±0.12	4.50±0.27	4.46±0.14
SR (film)	4.17±0.01	4.17±0.01	4.17±0.01
	4.17±0.01	4.35±0.03	4.35±0.01
ST (s)	0.14±0.02	0.13±0.02	0.13±0.01
	0.12±0.01	0.11±0.01	0.11±0.01
NST (s)	0.10±0.01	0.11±0.01	0.11±0.01
	0.12±0.01	0.12±0.02	0.12±0.01
HFD (m)	0.19±0.09	0.15±0.08	0.20±0.10
	0.16±0.06	0.13±0.03	0.17±0.05

TABLE 3

Differences Between Groups for Kinematic Variables

VARIABLES	ANCOVA (p)	LEAST SQUARE MEANS 1/2	1/3	2/3
Time	0.001	.3159	.3434	.9721
Horizontal Velocity	0.04	.2765	.0302	.2256
Vertical Velocity	ns			
Stride Length	0.009	.7454	.4052	.5910
Stride Rate	0.004	.6985	.7420	.9498
Support Time	0.007	.1268	.1735	.8300
Non-Support Time	ns			
Hor. Ft. Dis.	ns			

4.3.2 HORIZONTAL VELOCITY

The mean group scores for horizontal velocity (HV) were measured from the films by dividing the change in horizontal distance over the change in time of that distance, before and after the six week training program. These scores are reported in Table 2 and Figure 2. Although these values portrayed differences, the ANCOVA revealed a non-significance. However, instead of the predicted increase in the mean horizontal velocity, the scores indicated that there was a non-significant decrease between the before and after training scores. The least square means test further revealed that OSW decreased significantly less ($p<0.03$) than C. This finding may indicate that the overspeed/overload training group had a positive effect on horizontal velocity (See Table 3).

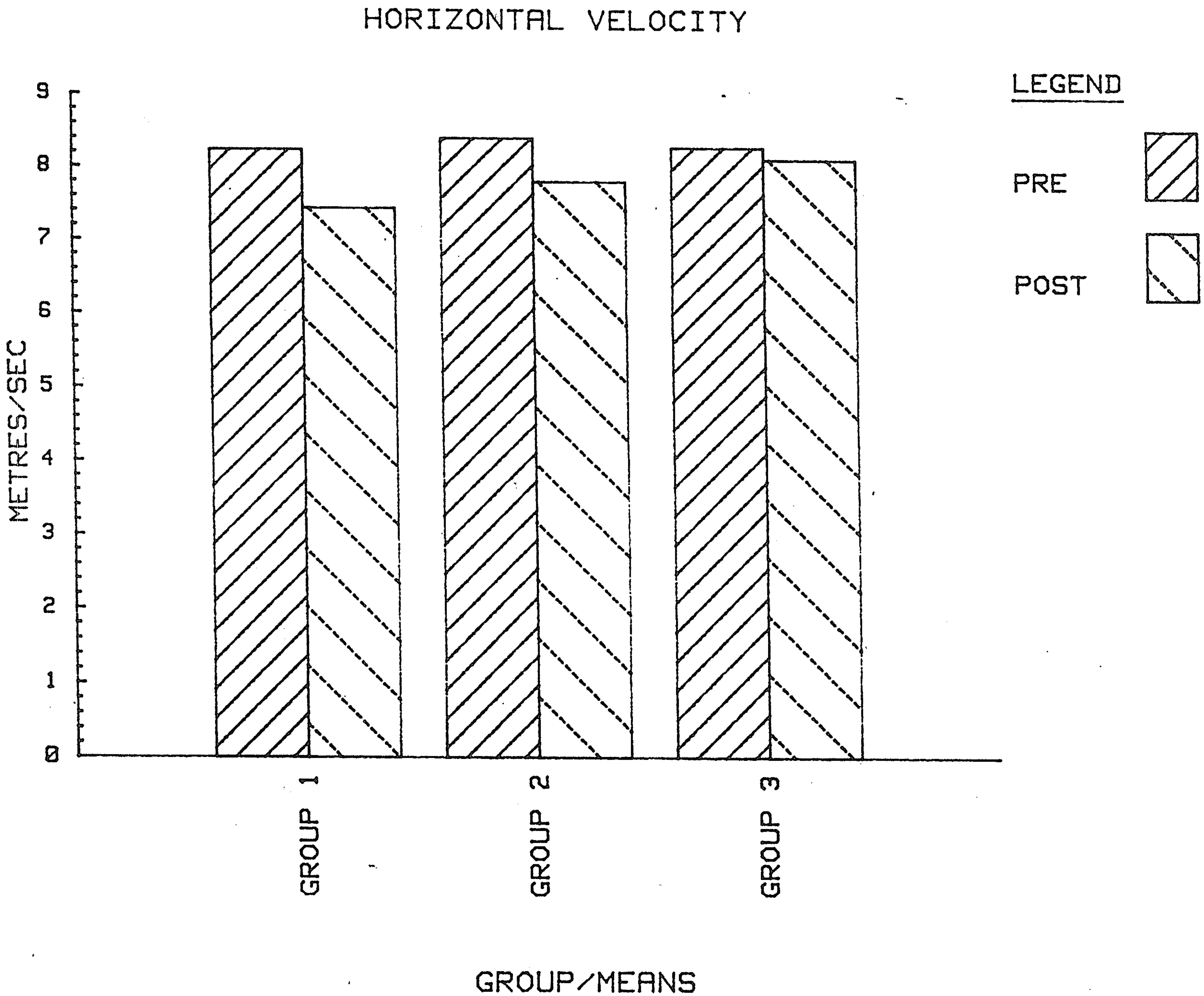

Figure 2: Change in horizontal velocity

Mann and Herman (1985) indicated that the greatest factor dictating success in sprinting is the maximal horizontal velocity that an athlete is able to achieve. The sprinting times showed a significant increase, yet the horizontal velocity displayed a close to significant decrease between the before and after treatment sessions. Isolation of sprinting variables cannot reveal the entire picture. Each variable is related and somewhat dependent on the others Horizontal velocity equals the product of stride length times stride rate (Dillman 1975).

In an ideal situation, horizontal velocity will increase if one of stride length or rate increased while the other remained constant. Usually however, if one of these direct performance indicators (stride length/rate) increase the other one will decrease. Mann (1985) discovered that "good" elite sprinters decreased their range of motion at the expense of decreasing the time spent on the ground. A decreased time on the ground leads to an increased stride rate, which could have a positive effect on sprinting speed (Mann & Sprague, 1983; Dillman, 1975; Kunz & Kauffman,1981; Atwater, 1973; Atwater,1982; Mann & Herman, 1985). A decrease in ground contact could also decrease stride length, because less time is available to produce the necessary ground forces . Therefore the athlete who can produce a rapid rate of force development, has a definite advantage in sprinting (Radford, 1978).

In this study stride rate improved, at the expense of stride length. However, because stride length for group three decreased significantly less than did stride length for group one, overspeed/overload sprint training could have a positive effect on the rate of force development, due to the increased development of power from the weight vest.

The horizontal velocities attained by the football players of this study do not approach the values of 8.85-10.78 m/s exhibited by elite sprinters reported in Armstrong et al (1984); Luhtanen and Komi (1978); Mann and Sprague (1983); and Mann and Herman (1985). The speed values of one to three meters per second less produced here demonstrate that the present football athletes may not have been as highly skilled in sprinting as other elite sprinters.

On the other hand, horizontal velocity was only measured during one stride at one point thirty meters down the track. While sprinting speed was measured over the entire forty meters of the sprint. The start and acceleration phase of the sprint could have been influenced by the training program. Power, essential during the start and acceleration phases of sprinting might have been increased as a result of the training undertaken by the athletes. A faster start and acceleration will produce a faster sprinting speed.

4.3.3 VERTICAL VELOCITY

The mean scores for each group for vertical velocity (VV) before and after the six week training program are reported in Table 2. The ANCOVA test for significant differerences amoung pre and post group scores produced a non-significant value ($p<0.06$). Similar to the horizontal velocity, the least square means calculations revealed a significant difference between OSW and C. The differences between C/OS and OS/OSW were found to be non-significant. Perhaps these differences are a reflection of the training methods employed, such that overspeed training and especially weighted overspeed training have a greater effect on decreasing vertical velocity than just non-assisted sprint training (See Table 3).

Mann (1985) reported that the mean vertical velocity attained by good sprinters was 0.52 m/s, the average sprinter reached 0.61 m/s, and the poor sprinters produced vertical velocity speeds of 0.69 m/s. These values, and the values obtained by the athletes of this experiment are direct estimates of the vertical displacement of the athlete's center of gravity during a sprinting stride. The trend from the study of Mann (1985) indicated that better sprinters exhibit lower vertical velocity scores. Relative to the sprinting level that the athletes of this study achieved, their change or decrease in vertical velocity could be interpreted as a positive change.

4.3.4 STRIDE LENGTH & STRIDE RATE

The mean group scores for stride length (SL) before and after the six week training program are reported in Table 2 and Figure 3. These different values represent a significant ($p<0.009$) decrease between the pre and post scores. However, a least square means test showed no significant differences were demonstrated between the three different intensity trained groups (see Table 3). The values for stride length obtained in this study were lower than values found in all other studies, verifying that the sprinters in this study were less skilled than those examined by other researchers.

The mean group scores for stride rate (SR {film}) before and after the six week training program are reported in Table 2 and Figure 4. A significant difference ($p<0.004$) was found by analysis of before and after stride frequency within groups values using ANCOVA. However, a least square means test revealed non-significant differences between groups (See Table 3).

It was concluded that the subjects of this study increased their sprinting speed by increasing their stride rate and decreasing their stride length regardless of their respective training group. Controversy reigns in analyzing the ideal economical or optimal relationship between these two direct performance indicators (stride length and rate). In the opinion of Broom (1962), increases in speed result

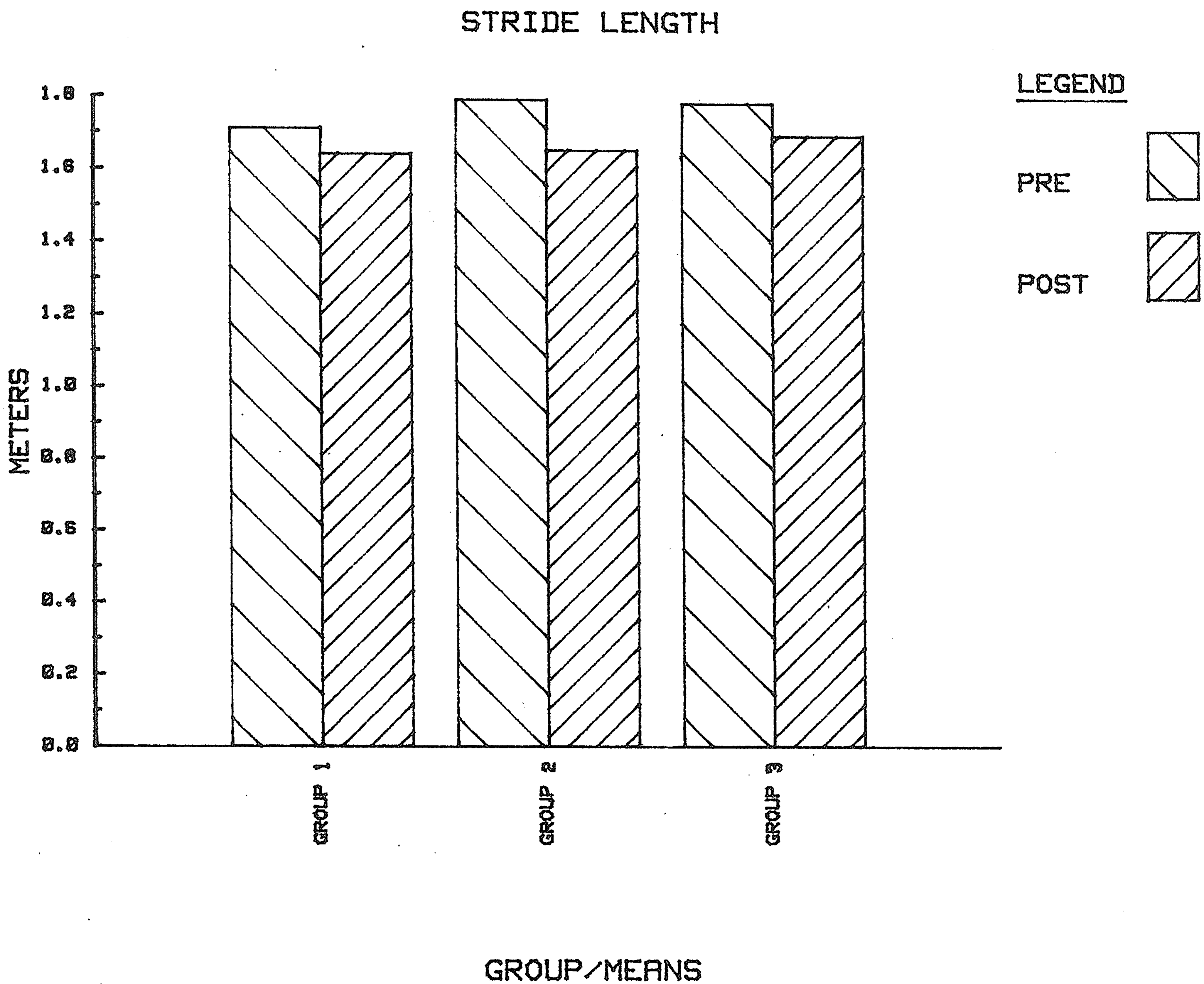

Figure 3: Change in stride length

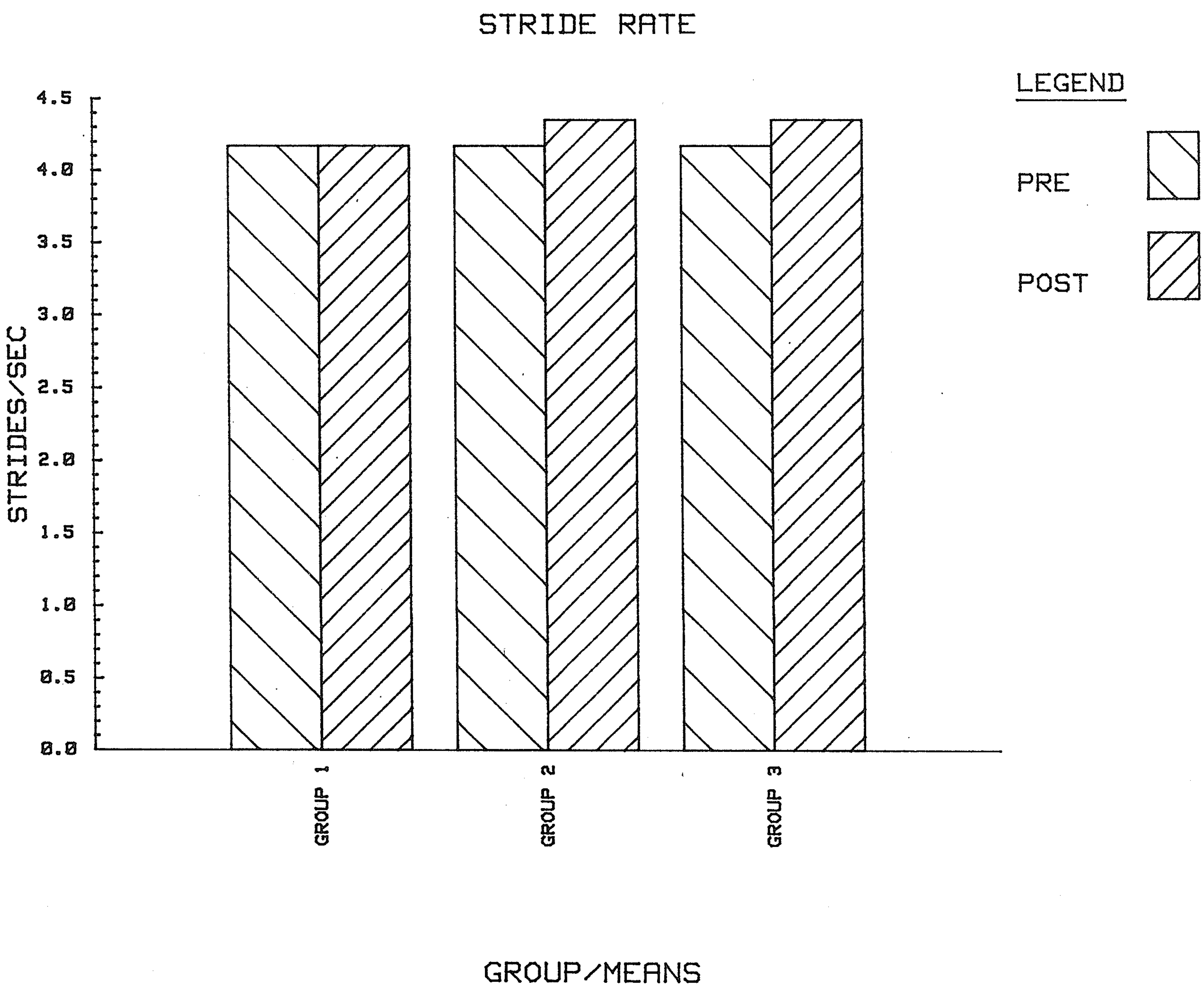

Figure 4: Change in stride rate

from increases in stride length, because although stride rate is somewhat trainable, stride length is more trainable. Armstrong, Costill and Gehlsen (1984) compared collegiate sprinters and marathoners running a maximal sprint. They found that the sprinters demonstrated a superior stride length, but did not differ significantly in stride rate. Other researchers who have done extensive work in the area, found that increases in speed are dependent upon stride rate (Hogberg, 1952; Hopkins & Holt, 1974; Ballreich, 1976; Murase et al, 1976).

Luhtanen and Komi (1978), examined the mechanical factors influencing speed and found that stride length levelled off at high velocities, whereas stride rate continued to increase. Most recently Mann and Herman (1985), found a significant difference in stride rate (elite higher) and support time (elite lower), while none was apparent in stride length or non-support time. Williams (1985) indicated that at a high velocity runners increase their speed by increasing stride rate to a relatively greater extent than stride length. Dillman (1975) stated that at a given velocity the better runner has a longer stride and a lower stride rate.

The values obtained in this study for stride rate were similar to those found in Mann's (1985) film analysis of the Olympic sprinters. This indicated that the major difference between elite sprinters and the University of Manitoba football players is in stride length (elite sprinters have greater stride length). Stride rate (SR {vid}) over the entire forty meter sprint was also recorded (See Table). The mean group pre and post scores for C were 4.43/4.42 (±0.14/0.12). The mean group pre and post scores for OS were 4.49/4.50 (±0.23/0.27). The mean group pre and post scores for OSW were 4.44/4.46 (±0.14/0.14) The ANCOVA test revealed these values as also being significantly different between the pre and post scores of the different groups. A least square means test however revealed non-significance between the groups.

4.3.5 SUPPORT TIME / NON-SUPPORT TIME

The mean group scores for support time (ST) before and after the six week training program are reported in Table 2 and Figure 5. There was a significant difference between the pre and post scores of the support phase ($p<0.007$). However, no significant difference was discovered between the different groups (See Table 3).

The mean group scores for non-support time (NST) before and after the six week training program were, for group one (C) 0.10/0.12 (±0.01/0.01) seconds, for group two (OS) 0.11/0.12 (±0.01/0.02) seconds and for group three (OSW) 0.11/0.12 (±0.01/0.01) seconds. These values portrayed a non-significant difference between the before and after training scores (See Table 3).

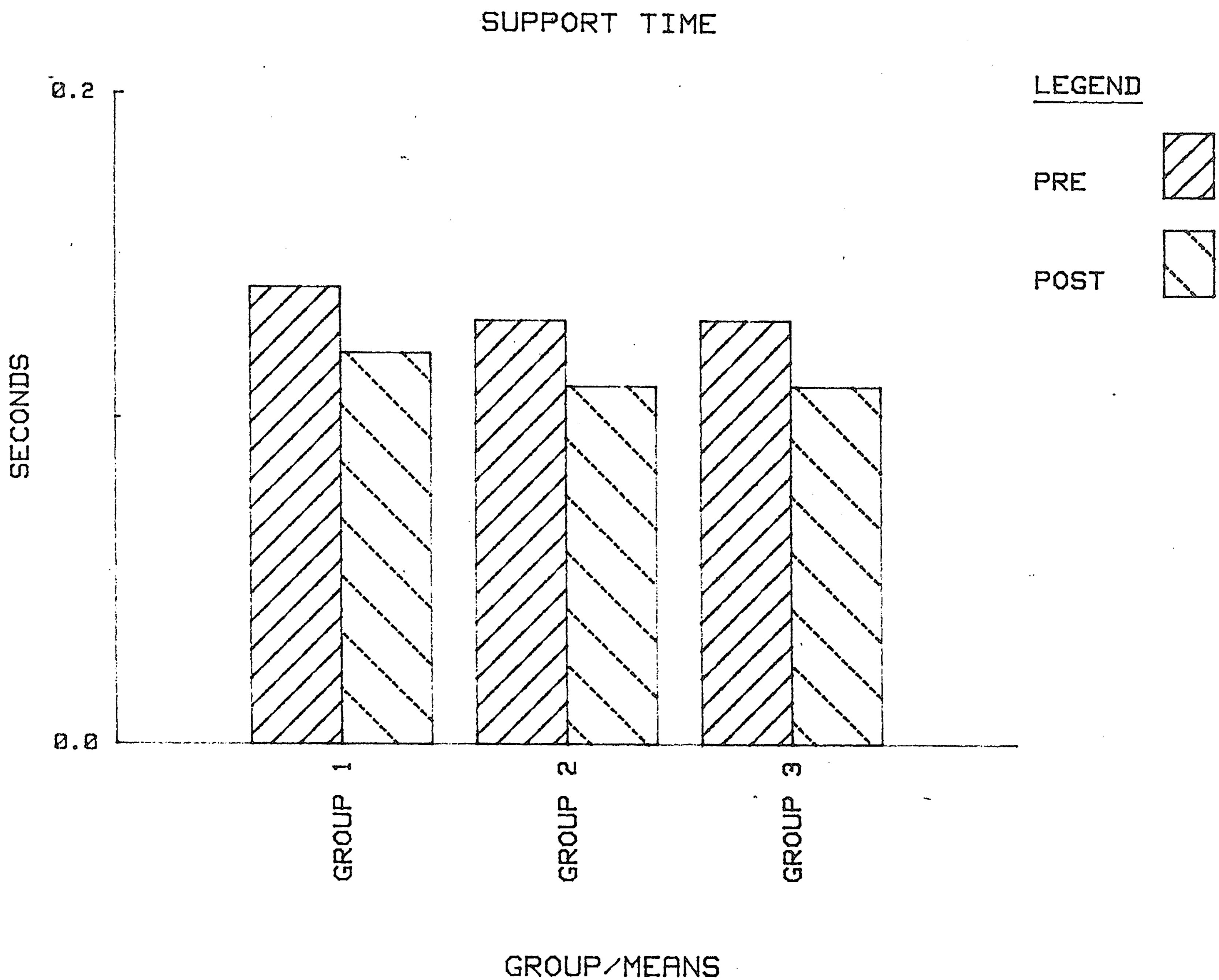

Figure 5: Change in support time

Radford (1984) stated that the relative airborne time accounts for fifty to sixty per cent of each stride cycle. The values for non-support time of this study improved to that desired level after the training sessions for each group. The per cent of air time to stride time for the pre and post tests for each group were: 41.67/50.00 for the control group, 45.84/52.17 for OS and 45.84/52.17 for OSW.

These findings are in agreement with the published research. When Kunz and Kauffman (1981) compared world class sprinters against a group of decathletes, they found a significantly shorter ground support time for the sprinters while performing a maximal sprint effort. Kauffman (1980) also found that better sprinters decreased contact time. Atwater (1973) found that as sprinting speed increased, there was a decrease in the time of the support phase. From a film analysis of eight male sprinters, Atwater (1982), supported her initial findings, and concluded that better sprinters have shorter support times. Mann and Herman (1985) agreed with those findings after their film analysis of elite sprinters during actual racing conditions. They discovered a significant difference in support times (lower), but no significant difference was found in non-support time.

4.3.6 HORIZONTAL FOOT DISPLACEMENT

A factor that affects both stride distance and frequency is the horizontal foot distance (HFD) to the body of mass. The further the foot contact away from the body, the greater the retarding or braking effect on horizontal. The mean group scores for horizontal foot displacement before and after the six week training program were, for group one (C) 0.19/0.16 (±0.09/0.06) meters, for group two (OS) 0.15/0.13 (±0.08/0.03) meters and for group three (OSW) 0.20/0.17 (±0.10/0.05) meters. A non-significant difference was found between the pre and post measurement for the horizontal distance between the subject's center of gravity and his touchdown point (See Table 3).

Kauffman (1980), Ambrose (1978) and Dillman (1975) recommended that the sprinter's center of mass should be directly over the foot at touchdown. Contrary to this, Mann (1985) reported that elite sprinters placed their foot slightly in front of the center of mass during contact. This study is in agreement with the findings of Mann (1985). The values obtained in this study are also similar to the values (0.15 m.) produced by the "good" elite sprinter of Mann's (1985) study. However, it is unlikely that the athletes involved in this study possess the same muscular leg power that Olympic caliber sprinters do (indicated by their shorter stride length).

4.3.7 LOWER BODY KINEMATICS

4.3.7.1 Upper Leg

Measurements from the upper leg (thigh) were performed at four positions; takeoff, maximum hip extension, maximum hip flexion and touchdown (See Figure 6). Bunn (1972), Dillman (1975), and Hay (1978) stated that at takeoff and after takeoff the hip should be extended through as great a range of motion as possible and that failure to complete extension is one of the most common faults in sprinting. This view may be outdated, as more recent studies have not agreed. In contrast Kunz and Kauffman (1981) and Mann (1985) found world class sprinters had less upper leg extension at take-off and after takeoff than did a group of decathletes when performing a maximal sprint.

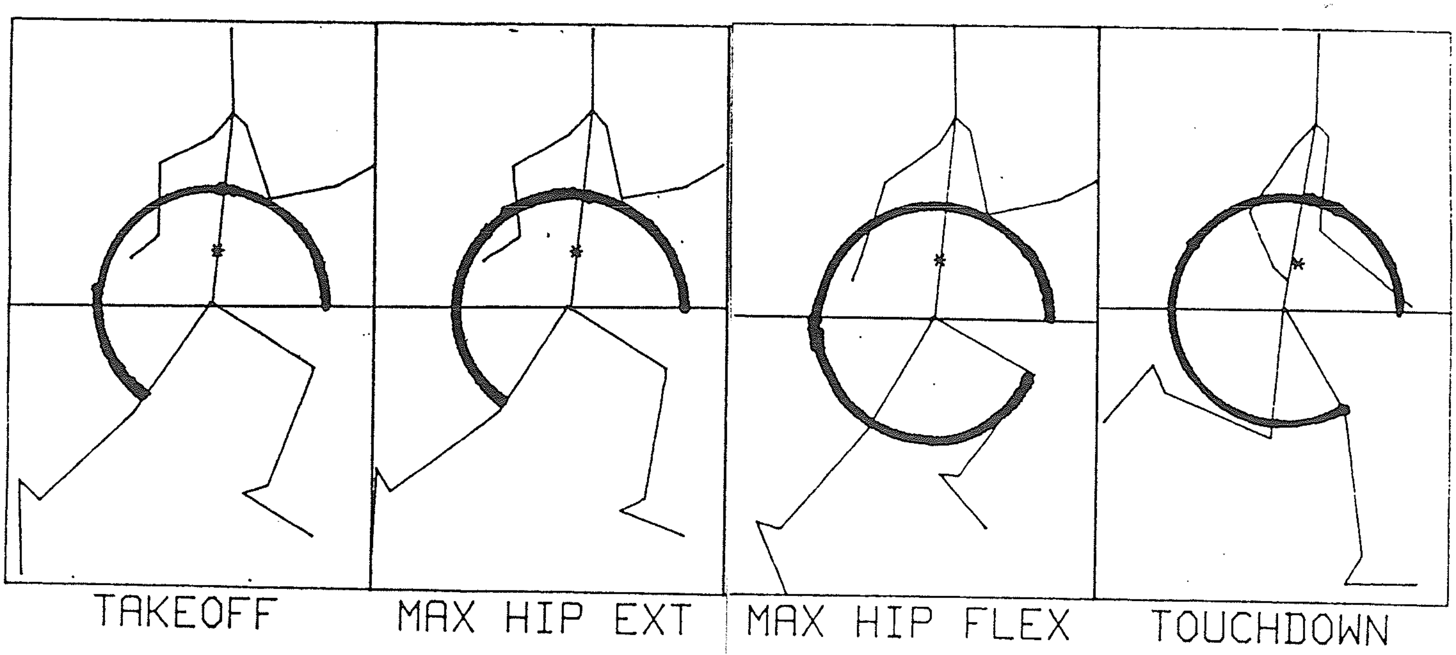

Figure 6: Upper-leg measurements

Although non-significant differences were obtained between subjects in the different training modalities, thigh inclination decreased at takeoff and after takeoff following the six weeks of sprint training. Mann and Herman (1985) performed a kinematic analysis of Olympic sprint performances of men's 200 meter event. To determine thigh inclination, each athletes trunk inclination was used as a reference point. Relative comparisons using the results reported by Mann and Herman (1985) and the results obtained in this study were conducted. It was found that the Olympic class athletes performed less thigh inclination or thigh extension at takeoff (approximately 170 degrees) and after takeoff (approximately 165 degrees) compared to approximately 153 degrees at takeoff and 147 degrees after takeoff for the less skilled football sprinters of this study. Although the athletes in this experiment were getting "better", their skill level was not high enough to classify them as skilled (See Table 4).

A significant difference was found between the before and after test scores for the position of the thigh at maximum hip flexion. However no difference was found between the three different group scores (See Figure 7 and Table 5). The range of motion values attained for thigh inclination by the athletes of this study approached the values found by the elite athletes of Mann's (1985) study (approximately 240 degrees). "It must be emphasized however, that a very good

TABLE 4

Upper-Leg Kinematic Results

VAR (r)	GROUP MEAN±S.D. VALUES (PRE/POST) 1	2	3
Pos 1	4.27±0.12	4.24±0.15	4.27±0.18
	4.09±0.03	4.14±0.02	4.12±0.07
Pos 2	4.21±0.18	4.14±0.08	4.08±0.06
	4.05±0.02	4.11±0.04	3.55±1.17
Pos 3	5.82±0.15	5.78±0.05	5.76±0.09
	5.75±0.14	5.77±0.07	5.77±0.14
Pos 4	5.25±0.06	5.22±0.13	5.31±0.17
	5.21±0.04	5.19±0.08	5.23±0.10

angle at one position is only beneficial if the other results are acceptable. (Mann, 1985, p.54)

Research into the kinematic pattern of leg movement during recovery has revealed (Fenn, 1930; Slocum & James, 1969) that as the thigh is moved forward rapidly, the lower leg is flexed acutely behind the thigh (See Figure 8). This action facilitates forward recovery by reducing the moment of inertia of the leg about the hip joint. The elevation of the thigh increased with increased speed and "better" runners tended to have greater hip flexion (Sinning & Forsyth, 1970).

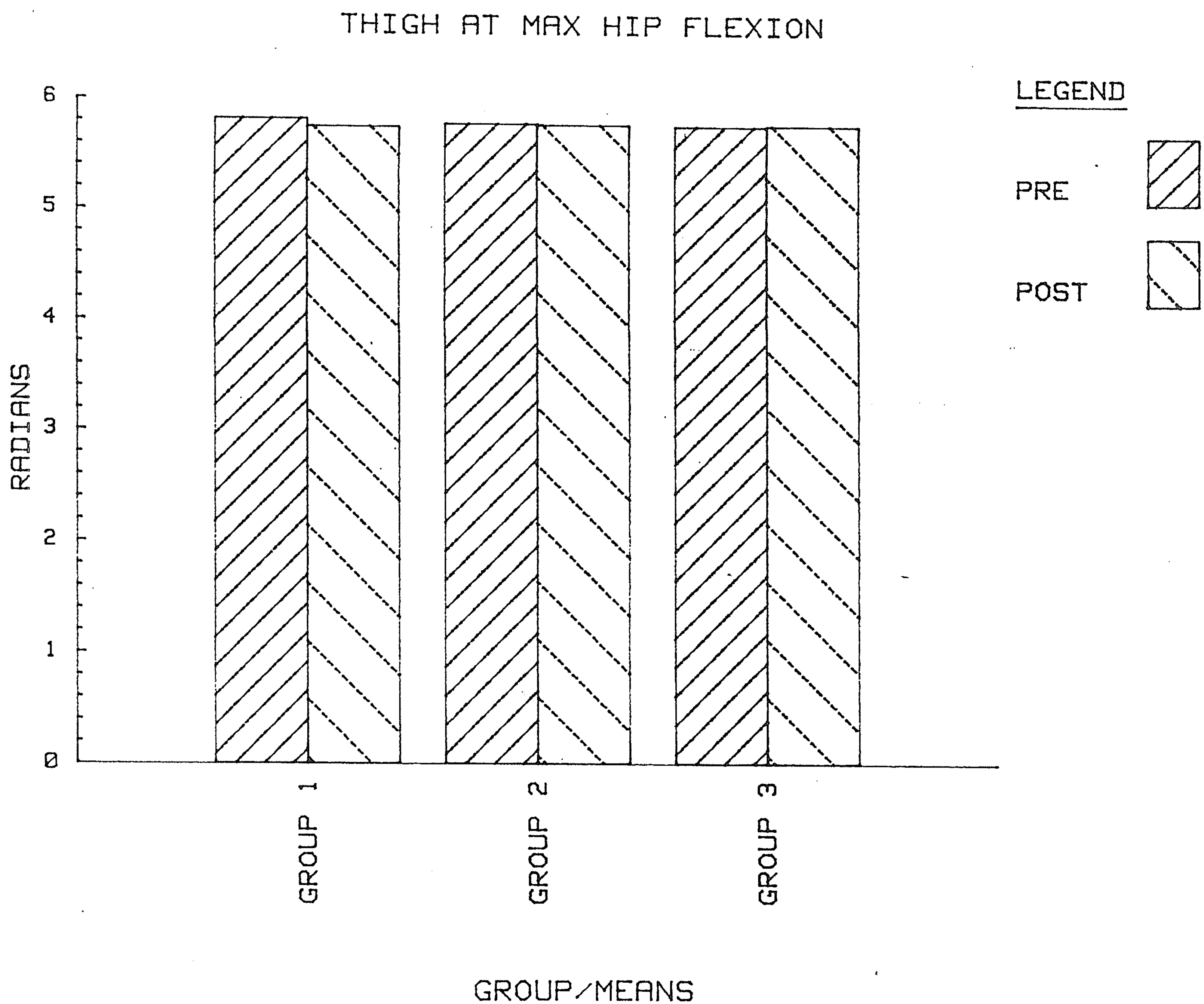

Figure 7: Change in thigh inclination at maximum hip flexion

TABLE 5

Thigh Kinematics Level of Sig. Dif.

VARIABLE	ANCOVA (p)	LEAST SQUARE MEANS 1/2	1/3	2/3
Pos 1	ns			
Pos 2	ns			
Pos 3	.009	.9226	.2640	.1913
Pos 4	ns			

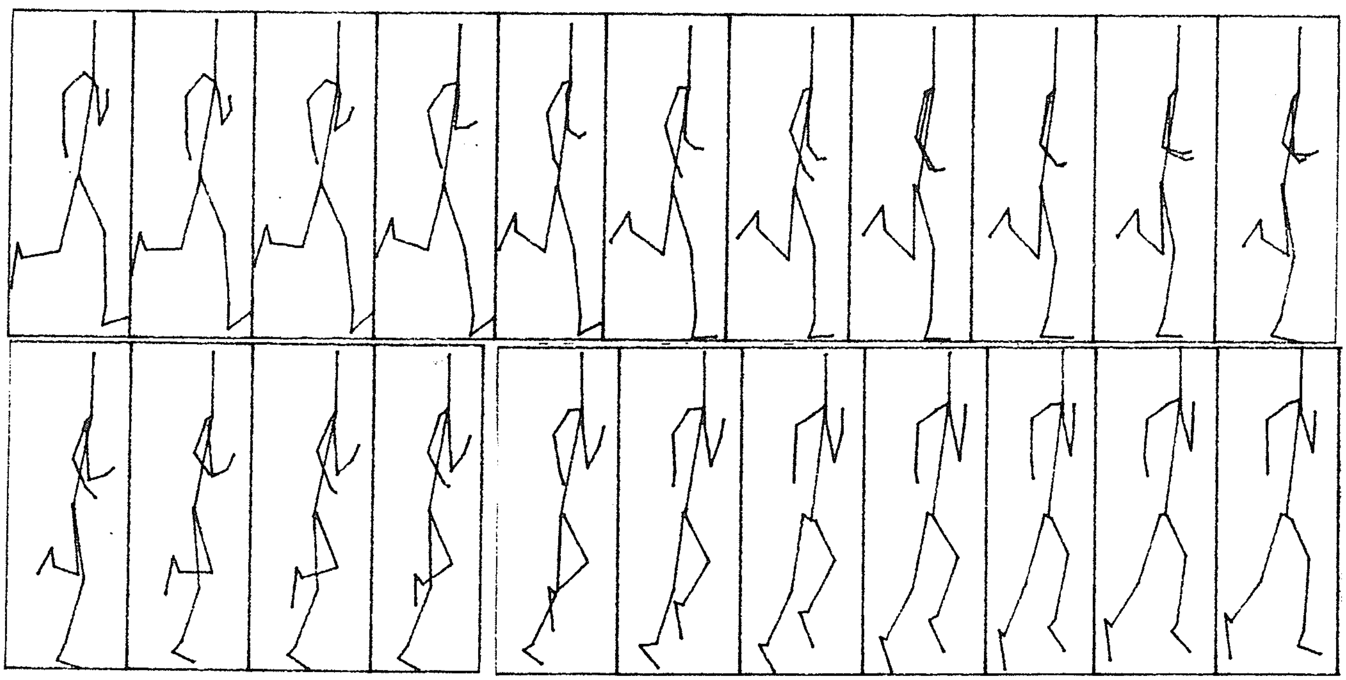

Figure 8: The recovery leg

Dillman (1975) found that at ground contact skilled runners have greater hip flexion of the supporting leg. However, no significant differences were found between the before and after scores between the different groups for the thigh position at touchdown.

4.3.7.2 Lower Leg

Measurements for the lower-leg were performed at five locations during a stride. These locations were, the position of the lower-leg at takeoff (position 1), the position of the lower-leg at maximum hip extension (position 2), the position of the lower-leg at maximum knee flexion (position 5), the position of the lower-leg at maximum hip flexion (position 3), and the position of the lower-leg at touchdown (position 4) (See Figure 9 and Table 6). Although non-significant differences between the pre and post test scores were found, the post test values portrayed less lower leg extension than the pre test values. Mann and Herman (1985) used a different reference point (thigh inclination) to measure lower leg inclination at various stages during a sprint. Relative comparisons between the elite sprinters of the Mann and Herman (1985) study and the football athletes of this study portrayed that at takeoff lower leg inclination was approximately similar (220 degrees using the same reference point used in this study).

Dillman (1975) suggested greater lower leg inclination is observed in "better" runners during the swing cycle during sprint running. In contrast, Armstrong , Costill, and Gehlson (1984) found no significant difference in the lower leg recovery angle between collegiate sprinters and marathoners. Mann (1985) noted that the superior performer minimizes the lower leg angle during the recovery phase to make the task of recovering the leg both faster and easier. Although no

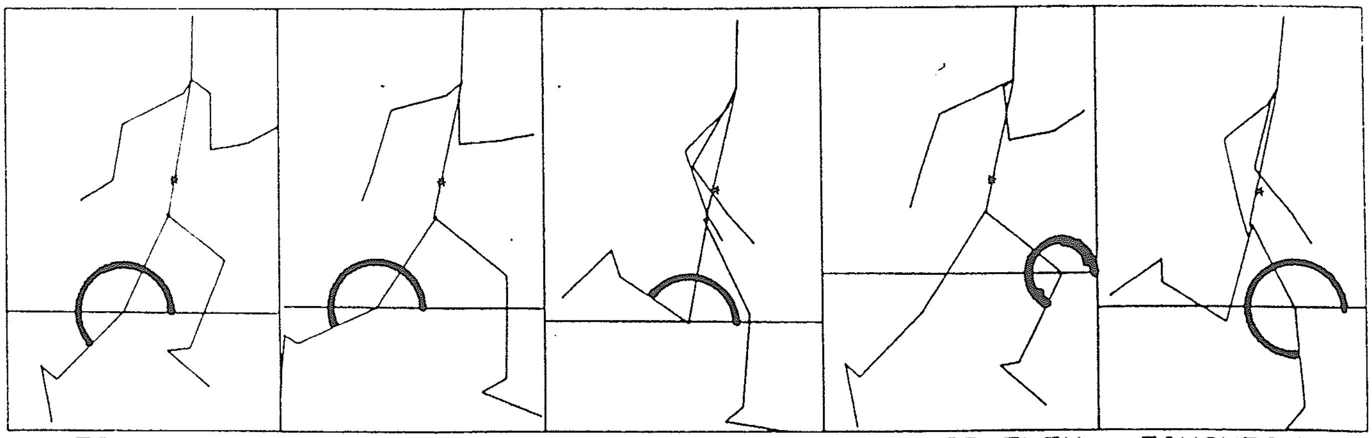

Figure 9: Lower-leg measurements

TABLE 6

Lower-Leg Kinematic Results

VAR (r)	GROUP MEAN±S.D. VALUES (PRE/POST) 1	2	3
Pos 1	3.81±0.06	3.86±0.10	3.83±0.06
	3.78±0.05	3.73±0.09	3.75±0.07
Pos 2	3.53±0.08	3.48±0.09	3.41±0.29
	3.60±0.08	3.45±0.23	3.62±0.11
Pos 5	2.56±0.17	2.42±0.13	2.62±0.12
	2.48±0.13	2.30±0.12	2.38±0.13
Pos 3	4.29±0.17	4.25±0.13	4.17±0.14
	4.21±0.16	4.50±0.12	4.31±0.21
Pos 4	4.73±0.10	4.75±0.11	4.83±0.11
	4.69±0.03	4.70±0.07	4.71±0.07

significant differences occurred, the mean values for lower leg inclination during recovery did decrease after the training period.

The position of the lower leg at maximum hip flexion did not show a significant difference between the before and after test scores. Although non-significant the least square means test revealed that the differences found between the pre and post scores of the overload/overspeed trained group (Group 3) were less likely due to error than the differences found between the pre and post scores of the control group (Group 1) and the overspeed group (Group 2). The increased lower limb inclination adopted by the athletes of group three prepared them for ground contact more readily than the athletes in the other groups.

The mean group scores for the lower leg at touchdown before and after the six week training program are reported in Table 6. No difference was found, however the mean scores displayed that lower leg inclination did increase after the training, indicating greater lower leg flexion at contact. This agrees with the review of Dillman (1975) on the kinematics of sprinting. With a straighter leg a sprinter applies more braking force to the ground (Dillman 1975). The athletes decreased the braking force by decreasing the angle of inclination of the lower limb at touchdown (also demonstrated by the shorter horizontal foot displacement).

4.3.7.3 Rotational Speed

At the completion of the six week training period, no significant changes occurred in the upper leg peak angular velocity from maximum hip extension to maximum hip flexion of the recovery leg. The peak angular thigh velocity during recovery before and after the training program was: 12.10/11.70 (±2.61/1.12) radians per second for C, 11.83/11.82 (±1.49/1.90) radians per second for OS and 10.22/10.74 (±3.91/1.32) radians per second for OSW. The average peak angular velocity for the three groups was approximately 650 degrees per second. Mann (1985) found the maximum thigh rotational speed for "good" male elite athlete 100-meter sprinter to be approximately 550 degrees per second. From Mann's study, the "good" elite sprinter displayed the fastest leg recovery. However the less skilled sprinters of this study appear to have achieved a greater peak velocity than the elite sprinters. Of the three groups involved in the experiment, group three (the fastest group) obtained the slowest angular velocity. Before accurate comparisons are made for one particular variable all other variables must be constant. To suggest that the sprinters of this study have superior upper-leg rotational speed during the recovery phase of sprinting than elite sprinters would be erroneous. Given the same ground force better sprinters exhibit greater leg recovery peak angular velocity, might be a more accurate or precise way to explain this phenomenon. Mann and Herman (1985) found that upper leg rotational speeds during recovery did not correlate with sprint performance.

Shank angular velocity before and after the training program at touchdown for C was 8.39/8.56 (±1.28/1.16) radians per second, for OS it was 8.76/8.85 (±5.18/2.09) radians per second and for OSW it was 7.48/10.01 (±4.16/2.22) radians per second. There was also no significant changes in the lower leg angular velocity at touchdown, contrary to what the research suggests. Mann and Herman (1985) found no significant difference in lower leg velocity during the recovery phase until just before foot contact, in comparing skilled versus unskilled sprinters. The average peak angular velocity for the lower-leg at touchdown was approximately 500 degrees per second for the subjects of this study. The "good" elite sprinter in Mann's (1985) study peaked at approximately 300 degrees per second. Lower-leg rotational speed is critical as touchdown occurs since it indicates the amount of braking (slowing down) that occurs during ground contact. "The better sprinters are able to complete lower-leg extension in sufficient time during the air phase to be able to produce a significant amount of lower-leg flexion speed at touchdown" (Mann, 1985).

4.4 SUMMARY OF DISCUSSION

In summation of the research (Dillman, 1975; Radford, 1978; Mann, 1985) it appears that the most critical component involved in sprinting is the ability of the athlete to produce a rapid rate of force development. This increased ground force could mean less time is needed on the ground, resulting in an abbreviated range of motion of the contact leg (Mann & Herman, 1985). This decreased range of motion translates to a decreased braking force. A decreased retarding force equates to less ground force needed to sustain the horizontal velocity. Less force needed to sustain horizontal velocity equals less leg extension required at takeoff. Decreased leg extension at takeoff aids in a quicker leg recovery during the flight stage of running. A quicker recovery facilitates preparation for ground contact sooner. This early preparation for ground contact assists in a rapid rate of force development.

This cycle illustrates the relationship the individual components of sprinting have with the entire motion of sprinting. Everything is inter-related, as Mann (1985) stated, "...that a very good angle at one position is only beneficial if the other results are acceptable."

Sprinting is too complex a skill to analyze in its entirety. Unfortunately the information obtained by analyzing these independent parameters could often be misleading unless it is referred to the whole skill. Emphasizing one area of the skill could result in detrimental effects on the entire skill. Athletes, coaches, and researchers interested in obtaining an "edge" in sports have to be careful of over-emphasis on one aspect of technique. An ideal model or an optimal standard containing all the critical components involved in sprinting need to be developed. Before this can be established agreement has to be reached among the researchers. Too much controversy exists in the literature pertaining to the "best" way to obtain maximal horizontal velocity. With the variety of body types and the diverse running gaits involved in sprinting it may be impossible to produce this ideal form in non-elite sprinters. In order for certain basic parameters to be established, it would take a collaboration of all the "top" researchers combined with all the "top" athletes using all the "top" research facilities and equipment.

Chapter V

SUMMARY, CONCLUSIONS & RECOMMENDATIONS

5.1 SUMMARY

The purpose of this study was to determine the effects of combining overspeed and overload running on the sprinting speed of college male athletes. Eighteen subjects, comprising three separate groups of six subjects per group, were each subjected to their own separate training regime. Three different types of training were employed in the training protocol: a control group which trained free of any external loading; group two, in which the athletes underwent assisted overspeed training; and group three which did the same overspeed tow training while supporting a ten pound weight vest. Each subject performed a test before and after the six week training program. The test included a timed maximum effort forty meter sprint. A high speed (100 frames/second) movie film was used to measure certain kinematic parameters involved in sprinting. The parameters included horizontal velocity, vertical velocity, stride length, stride rate, stride time, support time, non-support time, horizontal foot displacement, the position of the upper and lower leg at takeoff, the position of the upper and lower leg at maximum hip extension, the position of the upper and lower leg at maximum hip flexion, the position of the upper and lower leg at touchdown, the position of the lower leg at maximum knee flexion, the peak angular velocity of the upper-leg during recovery and the angular velocity of the lower-leg at touchdown.

An analysis of covariance (ANCOVA) was employed to determine whether there were significant differences among the pre/post test scores as a result of the different training modalities. From the twenty kinematic sprinting variables measured in this study, only five exhibited significant differences at the prescribed $p<0.05$ level.

The direct performance indicators that were significantly improved with training were: stride length (decreased), stride rate (increased) and support time (decreased). Of the lower body kinematic variables that were measured, the position of the upper leg at maximum hip flexion portrayed a significant ($p<0.01$) difference (increased) after the treatment sessions.

The variables that revealed significant differences as a result of the different training intensities were treated with a least square means test. The least square means (LSM) calculations was used to determine which group significantly differed from the others. Only horizontal velocity displayed a significant LSM value at the $p<0.05$ level between OSW and C.

Some evidence exists to infer changes occurred as a result of the different training techniques, although statistical significance was not always obtained. The overload, overspeed trained group witnessed the most change, with respect to having a positive effect on the sprinting variables involved in increasing sprinting speed. The evidence suggests that further research in this area has merit.

5.2 CONCLUSIONS

1. Sprinting speed can be improved.
2. The overspeed, overload training technique had the greatest tendency to improve sprinting speed.
3. The increase in stride rate or the decrease in ground contact caused the increase in sprinting speed.
4. The overspeed , overload trained group exhibited the least amount of decreased stride length.

5.3 RECOMMENDATIONS

5.3.1 GENERAL

We do not know exactly how to train athletes to increase the capacity of the muscles to apply force in a dynamic situation. This indicates the need for more fundamental studies of human motion in which the dynamic response to different types of training should be studied. The difficulty in distinguishing between subject specific or task specific characteristics in human performance makes the indentification of optimal mechanics for running a difficult task. Because the movements of the body cannot be separated from neural and physiologic functions, there is also a need for interdisciplinary research with those in exercise physiology, exercise metabolism, mathematical modeling, and motor behavior.

The athletes of this study represented a large somewhat homogeneous group. However, a larger sample size, with a higher skill level would be recommended to obtain more reliable or valid results. Although the football athletes were becoming more skilled as the treatment session progressed, they did not reach the skill level necessary for the nature of this experiment. This study required athletes who had already approached or maintained their maximal or near to maximal sprinting speeds, without fault in their sprinting mechanics (elite sprinters).

5.3.2 SPECIFIC

1. A larger homogeneous sample size should have been employed.
2. Elite sprinters should have been used.
3. A longer training period should be incorporated.
4. A need to discover the ideal stride length/rate ratio for optimal sprinting performance.
5. Greater sophistication required in the overspeed training device.

6. Filming could have been done at higher speeds (200 vs. 100 frames/sec).
7. Some kinetic analysis could have been performed.
8. The critical sprinting variables need to be recognized and established.
9. Greater sophistication in digitizing needs to be developed.
10. Strength tests could be incorporated into the study to determine any strength gains as a result of the different training procedures.
11. A film analyses of the overspeed running with and without the weight vest compared with normal sprinting mechanics need to be studied.
12. A fourth group of just overload sprint training could have also been employed for further comparisons.

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Appendix A

ATTENDANCE-1987

SUBJECTS	FEBRUARY								MARCH								
	10	12	15	17	19	22	24	26	1	3	5	8	10	12	15	17	19
ANDREWS J.	X	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LLOYD J.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BES D.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DRAGO M.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DRAGO I.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DREGIER D.	X	X	Ø	X	X	X	X	X	X	X	X	Ø	X	X	X	X	X
GALANTE J.	0	X	X	X	X	X	0	X	X	X	X	0	X	X	X	X	X
WLISON G.	0	0	X	X	X	X	X	X	X	X	X	X	0	X	X	X	X
BURGESS B.	X	X	X	X	X	X	0	X	X	X	X	0	X	X	X	X	X
NEILSON G.	X	X	X	X	0	X	X	X	X	X	X	X	X	X	X	X	X
JEPPESON J.	X	X	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MAJDELL R.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SEARS G.	X	X	0	X	X	X	X	X	0	X	X	X	X	X	X	X	X
WATSON M.	X	X	X	X	0	X	X	0	X	X	X	X	0	X	X	X	X
ERICKSON E.	X	X	X	X	0	X	X	X	0	X	X	X	X	X	X	X	X
ANDERSON D.	X	X	0	X	X	0	X	X	X	X	X	X	X	X	X	X	X
PURA P.	X	X	X	X	X	X	0	X	X	0	X	X	X	X	0	X	X
WAZNEY B.	X	X	X	X	X	X	X	X	X	0	X	X	X	X	X	X	X

Appendix B

THE SPRINT MASTER

B.1 OPERATIONAL INSTRUCTIONS

1. Fill the crankcase with oil to point of overflow, or to "full" mark if engine is equipped with a dipstick.
2. Use clean, fresh regular grade gasoline.
3. Check remote throttle control and carburetor adjustment.
4. Pull the kill switch away from the spark plug.
5. Pull the choke out half way.
6. Grasp the starter pulley handle with the right hand and pull firmly, while the left hand pushes down on the joy stick to keep the spool from reeling in the rope.
7. When the engine starts, push the choke in and allow engine to idle for 1-1.5 minutes before towing an athlete. The Sprint Master's engine has been adjusted at the factory to idle and not reel in the rope.
8. After the engine has been started, have a runner grasp the tow handles and jog away from the machine for approximately 85 yards. The idling engine will provide enough drag to prevent snarling of the line. In order to release the brake (so the line can be

reeled out) lift the joy stick slightly but not high enough to engage the throttle of the engine. Be certain that the runner has completed a thorough warm-up routine consisting of stretching, jogging, striding and sprinting prior to being towed.

9. As the operator lifts the joy stick (increasing the RPM's and reeling in the rope) the runner will notice a slight "tug" on the line. It is at this point the runner begins to accelerate to the machine. Until the runner reaches maximum speed, lift the Joy Stick only enough to keep the rope off the ground. The rope will appear to have a wavy motion during the tow. This wavy motion is caused by the arm movement of the runner.

10. When the runner reaches maximum speed, raise the Joy Stick higher to produce a slight pull to aid the runner in sprinting at a pace approximately 3/10 of a second faster than his best 40-yard dash time with a flying start.

11. When the runner is approximately 25-30 yards from the SPRINT MASTER, lower the Joy Stick to stop the pull and allow the runner to decelerate. You will also notice the rubber ball attached to the tow line approaching. The runner should not release the tow rope until he notices slack in the line.

12. The rubber ball also acts as an automatic brake should the "operator" forget to lower the Joy Stick.

The Ball will automatically contact the eyelet and stop the pull. This is only a safety device for emergency situations and is not to be used as a method to stop the tow.

13. If the runneur lets go of the rope during a tow, the machine should be braked immediately to prevent snarling of the line. A runner should not be encouraged to let go of the rope unless it is an emergency.
14. To stop the engine, push the kill switch downward until it contacts spark plug.