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Kinematic Analysis of Sprinting With and Without the Speed Chute

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KINEMATIC ANALYSIS OF SPRINTING WITH AND WITHOUT THE SPEED CHUTE

by

Douglas Roy West

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Health, Physical
Education, and Recreation

Western Michigan University
Kalamazoo, Michigan
June 1994
The problem under investigation was to determine if kinematic differences existed when sprinting with and without the speed chute. Eight Western Michigan University Track and Field Athletes were filmed at 100 frames per second as they sprinted two trials with and without the speed chute.

Three ANOVAs and descriptive statistics were used to evaluate the effects of sprinting with and without the speed chute. Descriptive statistics provided information for numerous dependent variables. Although statistically significant differences ($p < .05$) existed between sprinting with and without the speed chute, those differences may not be practical for the coach to use in terms of evaluation of sprinting technique, because the differences would be difficult for the human eye to see. Therefore, the speed chute may be a viable training tool as kinematics were only minimally affected.
ACKNOWLEDGMENTS

There are a few special people who I would like to thank for their contributions and support. I would like to thank the Western Michigan University Men’s Track and Field Coaches, especially assistant coach Dr. Paul Turner, for without their support this research could not have been carried out. I would also like to pay tribute to my thesis committee who guided me through the thesis process. Dr. Pat Frye was a thorough resource for statistical information and APA format. Dr. Mary Dawson’s tenacity for biomechanics made my graduate experiences more bountiful. Dr. Bob Moss, my advisor and committee chair who encouraged me to "fire-up" throughout my graduate education.

I would like to thank my fiance, Dr. Michele Finn, whose perseverance through her entire graduate career encouraged me to perform to the best of my capabilities, even when the light did not seem to burn as brightly as I thought it might. Finally, I am for ever thankful for my family. My brother, Greg, and my parents, Ann and Gary West, who all taught me at a very young age that I can accomplish what ever I wish with hard work, discipline, and determination. This is for you, enjoy.

Douglas Roy West

ii
TABLE OF CONTENTS

ACKNOWLEDGMENTS .......................................................... ii
LIST OF TABLES ................................................................. vi
LIST OF FIGURES ............................................................... vii

CHAPTER

I. INTRODUCTION ................................................................. 1
   Statement of the Problem ............................................... 5
   Delimitations ............................................................. 5
   Limitations ............................................................... 5
   Assumptions .............................................................. 6
   Hypotheses ............................................................... 6
   Definition of Terms .................................................. 7

II. REVIEW OF LITERATURE .................................................... 9
   Introduction ............................................................ 9
   Landing Phase ......................................................... 11
   Midstance Phase ...................................................... 15
   Pushoff Phase ......................................................... 15
   Flying Phase .......................................................... 16
   Sprinting Cycle ....................................................... 18
   Summary ............................................................... 19

III. METHODS AND PROCEDURES ............................................ 20
   Introduction .......................................................... 20
   Subjects ............................................................... 20
   Filming Procedures .................................................. 21
Table of Contents--Continued

CHAPTER

| Instrumentation Processing              | 22 |
| Data Acquisition                        | 23 |
| Research Design                         | 24 |
| Phases of Motion                        | 24 |
| Categorical Variables                   | 24 |
| Dependent Variables                     | 25 |
| Analysis of Data                        | 28 |

IV. RESULTS AND DISCUSSION.................. 30

| Introduction                             | 30 |
| Results                                  | 31 |
| ANOVA                                    | 31 |
| Descriptive Statistics                   | 37 |
| Discussion                               | 46 |
| ANOVA                                    | 47 |
| Descriptive Statistics                   | 50 |

V. SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS.............. 58

| Summary                                  | 58 |
| Findings                                 | 59 |
| Conclusions                              | 59 |
| Recommendations                          | 60 |

APPENDICES

A. Letter of Request to Carry Out Research... 62

B. Human Subjects Institutional Review Board Acceptance Form........ 64
Table of Contents--Continued

APPENDICES

C. Heights, Weights, and Ages of Subjects.... 66

BIBLIOGRAPHY................................. 68
LIST OF TABLES

1. ANOVA Summary Table for Trajectory Angle With and Without the Speed Chute.......................... 32
2. Means for Trajectory Angle of the Left and Right Legs for Trials 1 and 2............................... 33
3. Simple Effects ANOVA of Side x Chute for Trajectory Angle................................................ 35
4. Simple Effects ANOVA of Chute x Trial for Trajectory Angle.................................................... 36
5. ANOVA Summary Table for Horizontal Velocity With and Without the Speed Chute.................... 37
6. ANOVA Summary Table for Trunk Inclination With and Without the Speed Chute...................... 38
7. Means and Standard Deviations for the Right and Left Leg Angles About the Hip, Knee, and Ankle Joints................................................................. 39
8. Greatest Leg Separation When Sprinting With and Without the Speed Chute.............................. 41
9. Speed Chute Position and Range of Motion When Sprinting With the Speed Chute........................ 42
10. Vertical and Horizontal Displacement of the Center of Gravity.................................................... 43
11. Strides per Second When Sprinting With and Without the Speed Chute........................................ 43
12. Takeoff, Flight, and Landing Distance When Sprinting With and Without the Speed Chute........ 44
13. Takeoff, Flight, Landing, Support, and Nonsupport Times When Sprinting With and Without the Speed Chute................................................................. 46
LIST OF FIGURES

1. Graphic Representation of Disordinal Means..... 33
CHAPTER I

INTRODUCTION

Speed enhancement is a component of most athletes' training regimens. In recent times there have been a variety of products marketed that claim to increase an athlete's speed. Basically, the products rely on one of two concepts: (1) those that add a resistance when sprinting, and (2) those that assist the sprinter. Pulling a resistance is accomplished by increasing the weight that a body will tow; examples are weights around the ankle, wrist, or thorax. Other variations of resistance training include pulling a resistance in the form of dragging weights or running with a harness that is attached from the back of the sprinter via a bungee-cord-type apparatus to a stationary object.

Speed-assisted sprinting is another means of speed enhancement that involves overspeed training. This involves two runners with a bungee cord attached to both. The first runner stretches the cord out by sprinting away from the assisted runner. When the cord has been stretched to a desired length, the assisted runner begins to sprint. The assisted runner has his own forces and the force of the stretched elastic bungee-cord, propelling his body forward.
Hence, speed-assisted sprinting is achieved because the athlete is running faster than he would be without the device.

Only recently has there been a device that claims to achieve both speed-resistance and speed-assisted training. This device resembles a parachute, which is the reason it is called the speed chute (SC) (Tabachnik, 1992). With different utilizations of the SC and different sizes of SCs, different resistances can be attained.

Running with resistance is not a new concept to those attempting to increase speed. However, when towing an increased resistance, one may sacrifice proper sprinting technique because the forces are excessive, the forces are applied a distance away from the center of gravity (CG), and/or the resultant resistance forces are applied in a plane other than a horizontal plane. The SC allows sprinters to maintain better technique by incorporating the three following parameters. First, the SC comes in three different sizes, thus the resistance can be changed, depending on the needs of the athlete. Hence, the athlete can begin with minimal resistance and increase the resistance as he becomes accustomed to the resistance. Second, the SC attaches around a sprinter’s waist, very close to the sprinter’s CG. This helps minimize the CG displacement during locomotion, enabling the athlete to
better maintain his normal sprinting gait. Finally, the SC only weighs a few ounces, which increases the likelihood that all of the resistance that the sprinter tows is applied in a horizontal plane. This is advantageous to the sprinter because he does not have to absorb and propel the entire resistance of the SC in the vertical plane. Instead, the sprinter can spend more energy pulling the resistance in the horizontal plane. Pulling a resistance in the horizontal plane increases the likelihood that the athlete will sprint in his usual fashion because the resistance is applied near the sprinter’s CG. Other resistance devices, like weight vests, add weight and resistance in the vertical plane, which can increase the braking forces and are more likely to change one’s normal sprinting gait. Increasing the resistance an individual tows increases the potential that more power can be delivered by the individual, as the individual adapts to the new, increased resistance. This may result in more speed (Breizer, Tabachnik, & Ivanov, 1988; Tabachnik, 1992).

The SC can provide a variety of training conditions, depending upon the size of the SC the sprinter is using, the direction of the wind during a particular workout, and/or the velocity of the sprinter when using the SC. Larger SCs provide a greater resistance that the sprinter
must tow because more air is being collected by the SC. Resistance can also be increased as a sprinter increases his velocity because the amount of air being collected in the SC will increase. The SC provides a resistance, yet allows the sprinter to better maintain his normal sprinting technique because the resistance is applied near the CG (Tabachnik, 1992).

The manufacturers of the SC also claim that speed-assisted training can be achieved by releasing the chute while running (Breizer et al., 1988; Tabachnik, 1992). During a sprint, when an athlete detaches the SC, the sprinter goes from a state of sprinting with resistance to a state of sprinting with no resistance. This sudden decrease in the amount of resistance being towed gives the sprinter a sensation of overspeed training. If, in fact, the SC serves as both a speed-resistive and speed-assisted device, it is revolutionary because no other device on the market claims to provide both an overspeed and resistance component in one training device. The scope of this thesis, however, is not to judge all of these components; instead, it is to examine the effects of the SC on sprinting technique.
Statement of the Problem

The problem is to describe and compare the kinematic similarities and differences among sprinting with and without the SC of National Collegiate Athletic Association (NCAA) Division I male college track and field athletes.

Delimitations

The delimitations for this research were as follows:

1. This research was focused exclusively on one type of resistance, the SC, and one size of the SC, the small, or 9-lb resistance size.

2. The subjects were NCAA Division I male track and field participants.

3. The participating athletes included sprinters, multi-event athletes, and horizontal jumpers.

4. All but 1 of the 8 subjects had sprinted with the SC prior to the day of filming.

Limitations

The limitations for this research were as follows:

1. Other forms of resistance training exist and might produce different results.

2. Middle-distance runners, long-distance runners, and weight throwers might provide different results when sprinting with the SC.
3. One athlete did not have prior experience sprinting with the SC as a form of resistance.

4. Natural conditions like wind and sunlight could not be controlled because data collection was performed outside.

5. Extraneous movements of the SC and the effects of these movements on the sprinter could not be controlled.

Assumptions

Basic assumptions in this research include the following:

1. The subjects were properly warmed up at the time of all trials.

2. The subjects performed to the best of their capabilities.

3. The camera, digitizer, computer, and software were all operating properly, and human error in operating the equipment was minimal.

4. The participating athletes were truthful when reporting that they have or have not had past experience running with the SC.

Hypotheses

The manufacturers of the SC claim that the SC is better at allowing proper sprinting technique than other
resistive and assistive sprint training devices on the market (Tabachnik, 1992). However, there must be changes in the sprinter’s kinematics or the device would not provide a great enough resistance to cause an effect on the sprinter. It was hypothesized that when subjects sprinted with the SC there would be a longer stance time, larger vertical angle of the torso, smaller horizontal velocity, smaller trajectory angle of takeoff, greater distance between the CG and the foot at the moment of foot contact, greater hip extension and greater hip flexion of the supporting and nonsupporting leg, greater knee flexion, smaller plantar flexion, and larger leg separation than when the subjects sprinted without the SC.

Definition of Terms

The following terms were defined as they were used in the research:

1. A step is the distance that is covered between the landings of opposite feet (Chapman, 1982).

2. A stride is the distance between successive landings on the same foot (Chapman, 1982).

3. A speed plateau is characterized by psychological and physical fatigue due to repetitive workouts performed at identical intensities and distances over a prolonged period of time (Tabachnik, 1992).
4. Landing phase begins the moment that the foot makes contact with the ground and ends when the hips are over the arch of the foot.

5. Midstance phase begins when the hips are over the arch of the foot and ends at heel-off.

6. Pushoff phase begins at heel-off and ends at toe-off.

7. Flying phase begins with toe-off and ends with touchdown of the opposite foot.

8. Touchdown occurs when the forefoot is flat.

9. Hips-over-arch is the point when the center of the hips is over the arch of the foot.

10. Heel-off is the point when the heel reaches its highest point off the ground before the forefoot begins the action of toeing off.

11. Toe-off is the point following pushoff that the toe is not in contact with the ground.

12. Stance period is composed of the stance phase, midstance phase, and pushoff phase.

13. Trajectory angle at takeoff is the angle formed by a horizontal line through the CG at toe-off and the intersection of a line which goes through the CG at toe off and the next frame.
CHAPTER II

REVIEW OF LITERATURE

Introduction

Speed development is an objective of most physical training programs because it aids athletes in gaining an advantage over their opponents. Currently there is a training device on the market that claims to increase speed, the SC. It was first introduced as a speed-enhancement device for track and field athletes, but it has since been adapted for use in a variety of other sports, e.g., basketball, hockey, soccer, football, and baseball. The purpose of this research is not to determine how much the SC may improve an athlete’s speed; instead, it is to determine how sprinting with the SC may change the kinematics of one’s sprinting gait.

This chapter will focus on literature involving sprinters who are sprinting in a nonfatigued state. A nonfatigued state of sprinting involves races which are 100 m or shorter. Although towing a resistance has been done for several years as a means of developing speed, the literature search was unsuccessful in finding published research that deals with the kinematics of towing a resistive device. Thus, there will be no review of
literature pertaining to sprinting with a resistance. Sprinting can be defined as the maximum horizontal velocity that an individual can travel. The following terms describe important points or frames during a sprinter's stride: (a) touchdown, (b) hips-over-arch, (c) heel-off, and (d) toe-off. The four phases defined by these segments are (1) landing phase, which begins with touchdown and ends with hips-over-arch; (2) midstance phase, which begins with hips-over-arch and ends with heel-off; (3) pushoff phase, which begins with heel-off and ends with toe-off; and (4) flight phase, which begins with toe-off and ends with touchdown of the opposite foot. The landing phase, midstance phase, and pushoff phase combine to form the stance period.

It is important to note the various segments and phases of sprinting, however, it must be remembered that sprinting is a continuous activity. Consequently, it is imperative to discuss factors, e.g., stride length, stride rate, vertical change in CG, and stride period, that fit into more than one phase. For this reason, after the phases have been discussed, those factors that fit into more than one phase or deal with sprinting as an integrated motion will be discussed in a section titled sprinting cycle. Finally, references to measurements in English units, i.e., inches or pounds, were converted to their metric counterpart,
i.e., centimeters or kilograms.

Landing Phase

The foot should be anterior to the frontal plane that contains the CG at touchdown. However, the optimal distance that the foot is placed in front of the frontal plane, which contains the CG at touchdown, is disputed. Hay (1978) hypothesized that the foot only needs to be directly under the CG at the point of touchdown, yet Hoskisson and Korchemny (1991) studied junior national caliber sprinters and found that the foot made contact anywhere from 15.24 cm to 30.48 cm in front of the CG at touchdown. Blount, Hoskisson, and Korchemny collected data on 12 male athletes, 17 to 20 years of age, who specialized or excelled in the 100-m, 200-m, and 400-m races at The Athletic Congress (TAC) 1990 Junior National Championships for men, which took place in Fresno, CA (Blount et al., 1990; Hoskisson and Korchemny, 1991).

The literature search conducted did not find researchers who stated that it would be advantageous for the foot to make contact behind the CG at touchdown. If at foot strike the foot touches down behind the CG, the sprinter is likely to have too short a stance period and will be un-able to generate the necessary forces for the athlete to be propelled forward (Hoskisson & Korchemny,
When the foot touches down in front of the CG, enough time is allowed for the foot to be in contact with the ground, enhancing the ability to create forces needed during the pushoff phase (Hoskisson & Korchemny, 1991; Terauds, Barthels, Kreighbaum, Mann, & Crakes, 1984).

Greater braking forces are demanded the further the foot is in front of the CG at touchdown. These greater braking forces slow down the momentum of the sprinter, causing a decrease in horizontal speed (Alexander, 1989). Alexander conducted research on 14 elite male sprinters, who were filmed while performing a maximal sprint for the 100-m dash. Ground contact times increased the farther the foot landed in front of the CG at touchdown. Stride length also increased as the distance between the foot and the CG at the point of touchdown increased. This is advantageous only if stride frequency remains at the same frequency or stride frequency increases. If stride frequency slows down as the result of a greater stride length, the net result is likely to be a slower horizontal speed (Mann, 1985). Mann selected male Olympic-caliber athletes competing in the 100-m, 200-m, and 400-m events. These athletes were filmed in top level competitions from one up to five times.

At the time of touchdown there is a need to decrease braking forces in order to maintain horizontal speed
(Hoskisson & Korchemny, 1991). Hoskisson and Korchemny gathered the following angles from data collected at the 1990 TAC Junior National Championships for males in the 100-m event. The following angles may or may not be duplicated by those athletes representing the Western Michigan University Track and Field Team. They do, however, provide a baseline from which the data can be examined. The angles for the supporting leg of the athletes sprinting 100-m event were (a) ankle joint, 107.25°; (b) knee flexion, 138.25°; and (c) hip extension, 183°. The appropriate angle of the ankle joint is somewhat disputed. Baughman, Takaha, and Tellez (1984) suggested that the ankle should be at 90° to decrease braking forces and allow one to maintain horizontal speed. The following angles have been recorded for the swinging leg when the supporting leg is at touchdown: (a) ankle joint, 130.53°; (b) knee flexion, 54.25°; (c) hip extension, 183° (Hoskisson & Korchemny, 1991). The trunk-to-vertical angle measured -0.25°. Thus, the trunk of those subjects was slightly extended (Hoskisson & Korchemny, 1991).

Hoskisson and Korchemny (1991) noted the importance of the horizontal distance between the foot and CG at touchdown. Armstrong and Cooksey (1983) stated that the anatomical site on the foot that makes contact with the ground at touchdown is also important. Armstrong and
Cooksey studied 9 male sprinters participating at Ball State University on the varsity track team. Data were collected at four different velocities. Equivalent pace times for these velocities from slowest to fastest in the 100-m dash were 26.2, 22.9, 14.7, and 11.3 m/s, respectively. Armstrong and Cooksey (1983) noted "both the mid foot and ball of the foot sites were observed in equal numbers at the two fastest velocities (p. 13)." Woicik (1983) suggested that foot contact occurs on the outer or lateral aspect of the ball of the foot. If the foot makes ground contact in this position, the entire leg can better absorb ground contact forces, reducing the deceleration of the sprinter's horizontal velocity. Also, there should be slight flexion in the hip, knee, and ankle joints to help absorb ground contact forces more readily (Hoskisson & Korchemny, 1991; Woicik, 1983).

During the landing phase it is important to have proper positioning of the leg in order to allow the athlete to absorb ground contact forces at touchdown. However, it is critical that the sprinter has enough strength in his muscular system and that the neuro-muscular system is functioning correctly to absorb ground contact forces. The angles of the hip, knee, and ankle are of little consequence if these systems are not trained properly to react appropriately.
Midstance Phase

Another key point in the running cycle is when the hips are over the arch of the supporting leg. According to Hoskisson and Korchemny (1991), average angles for the supporting leg when the hips are over the arch are as follows: (a) ankle joint, 92.75°; (b) knee flexion, 151.7°; and (c) hip flexion, 157°. Again these data come from the 1990 TAC 100-m sprinters. Average angles for the swinging leg when the hips are over the arch were recorded as follows: (a) ankle joint, 128.2°; (b) knee flexion, 32.4°; and (c) hip extension, 205°. The mean trunk to vertical axis measured 0.75°, representing only slight flexion at the trunk.

Pushoff Phase

The supporting leg for sprinters was found to have these average joint angles at heel-off in the Hoskisson and Korchemny (1991) study: (a) ankle flexion, 95°; (b) knee flexion, 144°; and (c) hip flexion, 127.7°. Mean angles in the swinging leg were (a) ankle flexion, 90°; (b) knee flexion, 39.5°; and (c) hip extension, 191.7°. The trunk to vertical angle had a 1.75° angle, which is slightly flexed.
Flying Phase

In elite sprinters 50% to 64% of one’s stride is spent in the flying phase (Atwater, 1980). Atwater completed two studies in successive years, each with 12 male subjects of Olympic-level performance potential. The subjects performed under a simulated competitive condition. Data were collected at 50 m in 1978 and at 30 m and 60 m in 1979. The 12 subjects in the 1978 group had the following means and standard deviations, respectively: (a) height, 178.2 cm, 4.7 cm; (b) weight, 71.1 kg, 6.8 kg; (c) age, 20.6 years, 2.5 years; and (d) best 100-m time, 10.18 s, 0.12 s. The 12 subjects in the 1979 group had the following means and standard deviations, respectively: (a) height, 178.6 cm, 4.3 cm; (b) weight, 73.7 kg, 5.5 kg; (c) age, 20.5 years, 2.7 years; and (d) best 100-m dash time, 10.19 s, 0.15 s.

A sprinter’s time in the air is determined by the combination of horizontal and vertical forces that form the trajectory angle (Hoskisson & Korchemny, 1991). The trajectory angle is the angle formed by a horizontal line through the CG at toe-off with the path of the CG between toe-off and the next frame. A greater trajectory angle increases the height an athlete assumes while in the air. This increases the time in the air, preventing the athlete from getting down to the ground quickly, reducing the
sprinter’s speed (Hoskisson & Korchemny, 1991). Mann (1985) reported that the successful sprinter in the pushoff phase needs only enough vertical movement to allow the swinging leg to recover and to prepare the leg for ground contact.

Hoskisson and Korchemney (1991) found the following mean extremity joint angles at the point of toe-off for the supporting leg: (a) ankle flexion, 104.2°; (b) knee flexion, 155.7°; and (c) hip extension, 157.5°. Angles for the swinging leg were (a) ankle extension, 86.75°; (b) knee flexion, 60.25°; and (c) hip flexion, 106.5°. The trunk-to-vertical-axis angle was measured at 3.75°.

It is important that the swinging leg in the flying phase has high knee lift. If the angle of hip flexion remains large, stride length will be reduced. Also, high knee lift is advantageous because, when combined with knee flexion, the swinging leg’s foot can better pass next to the support leg’s knee (Mann, 1985).

The flying phase is characterized by two angles. An angle representing leg separation in the sagittal plane, measured 110.2° in the study by Hoskisson and Korchemny (1991). A second angle is the measurement of the trunk to a vertical line through the CG. This measured 0.5° in the 1991 TAC athletes (Hoskisson & Korchemny, 1991).
Sprinting Cycle

Only two ways exist by which a sprinter can run faster. One is to increase stride length, and the other is to increase stride frequency. Atwater (1980) noted that sprinters who run faster do so because of increases in stride frequency instead of stride length. Mann (1985) noted that improvements in one's stride frequency and length are done primarily in the ground contact phase. Atwater (1980) also reported that when "velocity increases it is due to a shorter stance period rather than a shorter flight phase" (p. 311).

Thus, one can deduce that to increase speed one should spend less time in the stance period yet yield as equal or greater contractions of the involved musculature. If as strong or stronger contractions occur one must be careful not to increase the flying phase time. Otherwise, the increase in the flying phase will offset the decrease in the stance period. The net result for the sprinter will be slower sprinting. Slower sprinting will occur because the increase in flight time that the sprinter had just gained is lost by spending less time in the stance period.

Atwater (1980) broke the sprinting cycle down into phases and calculated percentages of time spent in each phase. Atwater noted that 22% to 30% (M = 26%) of the stride was spent with the toe behind the CG. Atwater’s
study also determined that 12% to 20% (M = 17%) of the stride was spent with the toe in front of the CG. An average of 43% of the sprinters' stride was spent in the stance period for those sprinters who were measured at 50 m (Atwater, 1980). It was the stance period that the sprinter should reduce while maintaining stride length to increase speed, according to Atwater. Mann (1981) and Williams (1985) stated that the time elite sprinters are in contact with the ground is only about 100 ms.

Summary

This chapter should be used as a guideline to aid the reader and researcher in determining what might occur when the subjects sprint with the SC and without the SC. During the landing phase it is most important that the site of touchdown be in front of the CG and that the landing site of the foot be the forefoot. It is important to compare the angles of the lower extremity kinematics during the midstance phase and takeoff phase and to note any differences that occur when sprinting with the SC and without the SC. It is noted if the flight phase makes up 50% to 60% of the entire stride and if the trajectory angle remains the same when sprinting with and without the SC.
CHAPTER III

METHODS AND PROCEDURES

Introduction

This research project was performed at the request of the WMU men’s track coaching staff. All data were collected by the coaching staff, who then asked the researcher to analyze and interpret the data. The purpose of this research was not to determine how much the SC may improve an athlete’s speed, but rather to determine how sprinting with the SC changed the kinematics of one’s sprinting gait.

The following areas will be covered in this chapter: (a) subjects; (b) filming procedures; (c) instrumentation processing; (d) data acquisition; (e) research design; and (f) analysis of data.

Subjects

The 8 subjects participating in this study were NCAA Division I male track and field athletes at Western Michigan University (WMU), Kalamazoo, MI. There were two multi-event athletes, four sprinters, one triple jumper, and one pole vaulter. The letter of request to carry out this research is located in Appendix A. The letter of
approval from the Human Subjects Institutional Review Board is located in Appendix B. The heights and weights of the subjects were provided by the WMU assistant track and field coach and are located in Appendix C. The means for age, height, and weight are 19.9 years, 182.88 cm, and 77.40 kg, respectively.

Filming Procedures

The athletes were filmed in one session that took place at the outdoor track at Western Michigan University. The surface on which the filming took place was a Martin surface (Hunt Valley, MD). All filming was done on October 6, 1992, between 2:30 and 4:30 PM. The subjects wore shorts or above-the-knee tights and were asked to remove their shirts. However, some of the subjects did wear shirts. The weather conditions were favorable for sprinting. The temperature was 22°C, the sky condition was mostly sunny, and a light tail wind of less than 2.25 m/s was present.

Due to conflicting class schedules, not all subjects arrived at the track at the same time. When the athletes did arrive at the track they were given these instructions:

1. Prepare yourself to sprint for 65 m at maximum speed as if it were a track meet and you were preparing to compete in your event.
2. Each of you will sprint two trials with and two trials without the SC.

Once an athlete was ready, he started sprinting on his own command. Each athlete sprinted at maximal speed for 50 m before reaching the point where filming began and for 15 m beyond the filming area. At 65 m a marker was placed to let the athlete know he could slow down at the end of each trial.

Each athlete performed a total of four trials, two with the SC and two without the SC. The first subject to be filmed ran his first two trials without the SC and then his second two trials with the SC. The second subject performed his first two trials with the SC and his second two trials without the SC. For each succeeding subject the conditions were alternated in this fashion.

Due to the subjects arriving at the track at different times, the amount of time between each two successive trials was greater than 2 min but remained less than 10 min. This was enough time for each athlete to recover between trials, yet stay warm and ready to sprint when it was his turn to be filmed.

Instrumentation Processing

High speed cinematography was used to record the sprinters running with and without the SC. The camera used
for data gathering was a Photosonic 1-PL (Burbank, CA), 16-mm camera, with the F-stop set at 8. The speed of the camera was 100 frames per second. Film used in the camera was Video News Film model 7250 (Ektrachrome high speed film), produced by Kodak. The digitizer used was a Neumonic, Model 1224 (Langeford, PA). It was interfaced with a Zenith model number Z-386-20 computer (Stevensville, MI). The software used was Peak Performance Technology program 3-D, model number 5.1 (Englewood, CO).

Data Acquisition

The camera was set to film in a line perpendicular to the running lane, 16.92 m away from the center of lane 9, where the athletes sprinted 65 m on a standard 400-m track. A meter stick was filmed as a scale factor to be used later in the digitizing process. After a trial run was filmed, it was determined by the researcher that at least two complete strides were recorded on film. The subject number was also filmed in each trial.

The points chosen for marking in the digitizing process were as follows: (a) big toe, (b) lateral malleolus, (c) knee joint midline, (d) greater trochanter of femur, (e) distal end of the third digit of the hand, (f) distal radioulnar joint, (g) lateral epicondyle of the humerus, (h) acromion process, (i) sternum, (j) tragus of ear, and
(k) crotch. Both left and right sides of the body were digitized.

The points were digitized every frame beginning with first foot contact on the side closest to the camera. One complete stride was digitized. This process was repeated for each of the trials performed by the athletes. Key frames were designated as touchdown, hips-over-arch, heel-off, and toe-off.

Research Design

Phases of Motion

It was determined that four phases of motion would be studied. They are as follows: (1) landing phase, which begins at point of touchdown or foot flat and ends at hips-over-arch; (2) midstance phase, which begins with hips-over-arch and ends at heel-off; (3) pushoff phase, which begins with heel-off and ends with toe-off; and (4) flight phase, which begins with toe-off and ends with touchdown of opposite foot. The stance period is composed of the landing, midstance, and pushoff phases.

Categorical Variables

The categorical variables in this experiment are the SC, trials, and side. The SC is a registered trademark of Atletika Sports International. All patents were pending
(Tabachnik, 1992). There are three sizes of the SC that could have been used in a variety of combinations. Each subject in this experiment used the small SC, which is the equivalent of 9-lbs of resistance (Brunner & Tabachnik, 1990). Each subject ran two trials with and two trials without the SC. Trials were identified by a six- or seven-digit code. For example, Subject 1 Trial 1 with the SC was identified S1T1SC and Subject 6 Trial 2 with no SC was identified S6T2NSC. Sides were identified as being left and right.

**Dependent Variables**

Kinematic variables were measured to aid in determining differences in gait that may exist between sprinting with and without the SC. Each of these variables was measured for each of the athlete's four trials. Following each variable is an explanation as to how it was calculated.

1. Stride length was found by calculating the horizontal distance covered by the CG between touchdowns of opposite feet.

2. Stride rate (strides per second) was found by multiplying the total number of frames it took to complete one stride by the time that passed between the frames (0.01 s).
3. CG horizontal velocity (absolute speed) was calculated by multiplying stride length by stride rate.

4. CG vertical displacement was calculated by subtracting the minimum Y value from the maximum Y value using the parameter vertical displacement of CG.

5. Support time was calculated by counting the number of frames between touchdown and toe-off, then multiplying by 0.01 s.

6. Nonsupport time was calculated by counting the number of frames between toe-off and touchdown, then multiply by 0.01 s.

7. Angle of trajectory was determined by calculating the arc tangent of the angle formed by a horizontal line through the CG at toe-off with the path of the CG between toe-off and the next frame.

8. Supporting and nonsupporting knee flexion were measured by recording the knee flexion at touchdown, hips-over-arch, and toe-off. Knee flexion was defined as the angle formed by the intersection of two lines, one representing the thigh and the other representing the leg. The angle measured was the angle formed by the posterior aspect of the knee.

9. Supporting and nonsupporting hip flexion were measured by recording the hip position at touchdown, hips-over-arch, and toe-off. Hip flexion was defined as the
angle formed by the horizontal to the boney landmarks of the thigh.

10. Supporting and nonsupporting ankle flexion were measured by recording the ankle position at touchdown, hips-over-arch, and toe-off. The angle was determined by bony landmarks of the foot, ankle, and leg. The angle measured was formed by the front of the ankle joint.

11. Trunk inclination was determined by calculating the mean trunk inclination angles for all frames measured over the two steps digitized. Trunk inclination was measured by the posterior vertical vector intersecting the trunk's longitudinal axes of the right and left thighs.

12. Leg separation in the sagittal plane was determined by recording the greatest angle of separation in the sagittal plane during the flight phase. The angle for leg separation was determined by measuring the smaller angle of the longitudinal axis of the right and left thighs.

13. Take off time (T1) was represented by the amount of time it took the CG to travel from the hips-over-arch position to the toe-off position of the same foot.

14. Flight time (T2) was represented by the amount of time it took the CG to travel from the toe-off position to the touchdown position of the same foot.

15. Landing time (T3) was represented by the amount of time it took the CG to travel from the touchdown
position to the hips-over-arch position of the same foot.

16. Take off distance (D1) was the distance that the CG traveled from the hips-over-arch frame to the toe-off frame.

17. Flight distance (D2) was the distance traveled by the CG from toe-off to touchdown.

18. Landing distance (D3) was the distance traveled by the CG from touchdown to the hips-over-arch.

19. Chute angle was the angle determined by recording the mean chute angle during the two steps that were digitized. The mean chute angle was the intersection of the longitudinal axis of the chute and a positive vertical angle.

Analysis of Data

The kinematics were described by means and standard deviations. The two conditions for this research were trials with the SC and trials without the SC. Each subject was represented by a number. The descriptive statistics were given for each of the variables measured. ANOVA was used to evaluate the effects of the SC on the trajectory angle, horizontal velocity, and trunk inclination. For missing data the corresponding value in the recorded trial was substituted. The means of the variables of the two conditions were tested for statistically significant
differences at a .05 level of probability.
CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The problem was to describe and compare the kinematic differences and similarities among sprinting with and without the SC of NCAA Division I male college track and field athletes. The results obtained in the present study were summarized and discussed. All subjects' data were collected and analyzed except those unidentifiable on the film. They were Subject 2, Trial 1, with SC; Subject 3, Trial 2, without SC; Subject 7, Trial 2, with SC; and Subject 7, Trial 2, without SC. For these missing data the corresponding value in the recorded trial was substituted. Subject 3 was omitted from the dependent variables of trajectory angle and vertical displacement CG. All the participants were members of the Western Michigan University Track and Field Team and were participating in fall workouts. Categorical variables, each with two levels were the SC, trials and side of the body. In this chapter the researcher first reported the results of the three ANOVAs and the descriptive statistics, and then discussed the results in the same order they were presented.
Results

ANOVA

Three ANOVAs were performed. The ANOVAs were performed on trajectory angle, horizontal velocity, and trunk inclination to determine if significant differences existed for these dependent variables when sprinting with and without the SC.

Trajectory Angle

This ANOVA consisted of three main effects: SC/no-SC, trials 1 and 2, and right and left sides. The dependent variable was trajectory angle. Refer to Table 1 for the ANOVA summary. A significant difference existed between sprinting with (M = 1.92°) and without (M = 2.45°) the SC, $F(1,6) = 15.40, p < .05$. The interaction effect, Trial x Side, was significant, $F(1,6) = 13.79, p < .05$.

The means for the simple main effects were calculated for Trials 1 and 2 at the left side with and without the SC and Trials 1 and 2 at the right side with and without the SC and were reported in Table 2. The numbers in this table indicate that a disordinal interaction occurred. This is evident in Table 2; for the right side from Trial 1 to Trial 2 the mean trajectory angle increased and for the left side from Trial 1 to Trial 2 the mean trajectory angle
Table 1

ANOVA Summary Table for Trajectory Angle
With and Without the Speed Chute

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
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<td>Chute</td>
<td>4.74</td>
<td>1</td>
<td>4.74</td>
<td>15.40*</td>
<td>.008</td>
</tr>
<tr>
<td>Error</td>
<td>1.85</td>
<td>6</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial</td>
<td>0.92</td>
<td>1</td>
<td>0.92</td>
<td>1.13</td>
<td>.329</td>
</tr>
<tr>
<td>Error</td>
<td>4.91</td>
<td>6</td>
<td>0.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side</td>
<td>0.12</td>
<td>1</td>
<td>0.12</td>
<td>0.07</td>
<td>.795</td>
</tr>
<tr>
<td>Error</td>
<td>9.42</td>
<td>6</td>
<td>1.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute x Trial</td>
<td>1.39</td>
<td>1</td>
<td>1.39</td>
<td>3.18</td>
<td>.125</td>
</tr>
<tr>
<td>Error</td>
<td>2.61</td>
<td>6</td>
<td>0.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute x Side</td>
<td>0.23</td>
<td>1</td>
<td>0.23</td>
<td>0.25</td>
<td>.637</td>
</tr>
<tr>
<td>Error</td>
<td>5.46</td>
<td>6</td>
<td>0.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial x Side</td>
<td>1.34</td>
<td>1</td>
<td>1.34</td>
<td>13.79*</td>
<td>.010</td>
</tr>
<tr>
<td>Error</td>
<td>0.58</td>
<td>6</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute x Trial x Side</td>
<td>6.51</td>
<td>1</td>
<td>6.51</td>
<td>5.93</td>
<td>.051</td>
</tr>
<tr>
<td>Error</td>
<td>6.59</td>
<td>6</td>
<td>1.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

decreased. The means of main effect trials were Trial 1, right side (M = 1.99°); Trial 1, left side (M = 2.23°); Trial 2, right side (M = 2.39°); and Trial 2, left side (M = 2.18°). Figure 1 graphically demonstrates the interaction effect.

Table 1 displayed that Trial x Side was significant, therefore, further statistical analysis was needed to
Table 2
Means for Trajectory Angle of the Left and Right Legs for Trials 1 and 2

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th></th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>M</td>
<td>1.99</td>
<td>2.23</td>
<td>2.39</td>
</tr>
<tr>
<td>SD</td>
<td>1.03</td>
<td>1.22</td>
<td>1.11</td>
</tr>
</tbody>
</table>

Note. All measurements in degrees.

Figure 1. Graphic Representation of Disordinal Means.

determine why this occurred. Upon looking at simple effects of Trial x Side, with SC and no-SC conditions combined, there were no significant differences. Because of this, and because the probability of the three-way interaction was so close to the stated alpha level of .05, it was decided to treat the three-way interaction as a
significant interaction and see if the SC and no SC difference was masking the Trial x Side simple effects.

Table 3 summarizes the ANOVA for the simple effects of Side x Chute for Trial 1 and for Trial 2. At Trial 1, a significant difference existed with the SC (M = 1.651°) and without the SC (M = 2.505°), F(1,6) = 21.89, p < .05. Also, because in Table 1 Trial x Side was significant, further statistical analysis was needed to determine why this occurred. Upon looking at the simple main effects of trial and side, with SC and no-SC conditions combined, there were no significant differences. Because of this, and because the probability of the three-way interaction was so close to the stated alpha level of .05, it was decided to treat the three-way interaction as a significant interaction to see if Trial 1 and Trial 2 differences were masking differences between side and chute simple effects.

Table 4 summarizes the ANOVA for the simple effects of Chute x Trial. A significant difference existed between SC (M = 2.003°) and no-SC (M = 2.395°) for the left side F(1,6) = 10.38, p < .05. However, no significant difference existed between SC (M = 1.831°) and no-SC (M = 2.508°) for right side F(1,6) = 1.83, p > .05.
Table 3

Simple Effects ANOVA of Side x Chute for Trajectory Angle

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At Trial 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Side</td>
<td>.33</td>
<td>1</td>
<td>.33</td>
<td>0.31</td>
<td>.597</td>
</tr>
<tr>
<td>Error</td>
<td>6.40</td>
<td>6</td>
<td>1.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute</td>
<td>5.63</td>
<td>1</td>
<td>5.63</td>
<td>21.89*</td>
<td>.003</td>
</tr>
<tr>
<td>Error</td>
<td>1.54</td>
<td>6</td>
<td>.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side x Chute</td>
<td>2.16</td>
<td>1</td>
<td>2.16</td>
<td>3.49</td>
<td>.111</td>
</tr>
<tr>
<td>Error</td>
<td>3.71</td>
<td>6</td>
<td>.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>At Trial 2</strong></td>
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<td>Side</td>
<td>.50</td>
<td>1</td>
<td>.50</td>
<td>1.03</td>
<td>.350</td>
</tr>
<tr>
<td>Error</td>
<td>2.92</td>
<td>6</td>
<td>.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute</td>
<td>1.12</td>
<td>1</td>
<td>1.12</td>
<td>1.86</td>
<td>.221</td>
</tr>
<tr>
<td>Error</td>
<td>3.60</td>
<td>6</td>
<td>.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side x Chute</td>
<td>4.58</td>
<td>1</td>
<td>4.58</td>
<td>3.29</td>
<td>.120</td>
</tr>
<tr>
<td>Error</td>
<td>8.34</td>
<td>6</td>
<td>1.39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

**Horizontal Velocity**

An ANOVA was computed for two main effects: SC/no-SC and trials. The dependent variable was horizontal velocity. Table 5 summarizes the ANOVA that determined there was a significant difference between sprinting with the SC (M = 8.456 m/s) and without the SC (M = 9.347 m/s) $F(1,7) =$
Table 4  
Simple Effects ANOVA of Chute x Trial for Trajectory Angle

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At Right Side</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute</td>
<td>.01</td>
<td>1</td>
<td>.01</td>
<td>.02</td>
<td>.905</td>
</tr>
<tr>
<td>Error</td>
<td>3.49</td>
<td>6</td>
<td>.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial</td>
<td>2.29</td>
<td>1</td>
<td>2.29</td>
<td>3.27</td>
<td>.121</td>
</tr>
<tr>
<td>Error</td>
<td>4.20</td>
<td>6</td>
<td>.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute x Trial</td>
<td>.97</td>
<td>1</td>
<td>.97</td>
<td>1.83</td>
<td>.225</td>
</tr>
<tr>
<td>Error</td>
<td>3.20</td>
<td>6</td>
<td>.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>At Left Side</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute</td>
<td>.33</td>
<td>1</td>
<td>.33</td>
<td>.17</td>
<td>.690</td>
</tr>
<tr>
<td>Error</td>
<td>11.39</td>
<td>6</td>
<td>1.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial</td>
<td>.02</td>
<td>1</td>
<td>.02</td>
<td>.04</td>
<td>.884</td>
</tr>
<tr>
<td>Error</td>
<td>3.33</td>
<td>6</td>
<td>0.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute x Trial</td>
<td>6.87</td>
<td>1</td>
<td>6.87</td>
<td>10.38*</td>
<td>.018</td>
</tr>
<tr>
<td>Error</td>
<td>3.97</td>
<td>6</td>
<td>.66</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

18.79, p < .05. The main effect trial and the interaction effect Chute x Trial, were not significant, $F(1,7) = 3.24$, $p > .05$ and $F(1,7) = 3.10, p > .05$, respectively.
Table 5
ANOVA Summary Table for Horizontal Velocity
With and Without the Speed Chute

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chute</td>
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<td>1</td>
<td>7.19</td>
<td>18.79*</td>
<td>.003</td>
</tr>
<tr>
<td>Error</td>
<td>2.68</td>
<td>7</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial</td>
<td>0.26</td>
<td>1</td>
<td>0.26</td>
<td>3.24</td>
<td>.115</td>
</tr>
<tr>
<td>Error</td>
<td>0.57</td>
<td>7</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute x Trial</td>
<td>0.09</td>
<td>1</td>
<td>0.09</td>
<td>3.10</td>
<td>.122</td>
</tr>
<tr>
<td>Error</td>
<td>0.20</td>
<td>7</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

Trunk Inclination

Table 6 summarizes the results for the ANOVA performed to detect if significant differences in trunk inclination existed when sprinting with and without the SC. A significant difference was found between sprinting with (M = 8.400°) and without (M = 5.467°) the SC, F(1,7) = 14.51, p < .05. The main effect of trial and the interaction effect of Chute x Trial were not significant.

Descriptive Statistics

Table 7 displays the means and standard deviations for angles about the hip, knee, and ankle joint for the right and left legs when sprinting with and without the SC.
Table 6
ANOVA Summary Table for Trunk Inclination With and Without the Speed Chute

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chute</td>
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<td>61.62</td>
<td>14.51*</td>
<td>.007</td>
</tr>
<tr>
<td>Error</td>
<td>29.74</td>
<td>7</td>
<td>4.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial</td>
<td>2.13</td>
<td>1</td>
<td>2.13</td>
<td>3.46</td>
<td>.105</td>
</tr>
<tr>
<td>Error</td>
<td>4.30</td>
<td>7</td>
<td>0.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chute x Trial</td>
<td>3.12</td>
<td>1</td>
<td>3.12</td>
<td>2.62</td>
<td>.149</td>
</tr>
<tr>
<td>Error</td>
<td>8.32</td>
<td>7</td>
<td>1.19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

Those angles are given for the following event frames: touchdown, hips-over-arch, and toe-off and for both the supporting leg and the nonsupporting leg. It should be noted that at touchdown the angle for the right nonsupporting hip was comparable for sprinting with (85.05°) and without (85.12°) the SC. However, at touchdown for the SC trial, the left nonsupporting leg was 77.24° about the hip joint, and the no-SC trial for the left leg about the hip joint was 73.73°. Thus, there were differences of 7.79° sprinting with and 11.39° sprinting without the SC. There were no major differences noted for sprinting with and without the SC for the knee or ankle at the touchdown, hips-over-arch, or toe-off event frames.

Table 8 represents the amount of leg separation that
Table 7
Means and Standard Deviations for the Right and Left Leg Angles About the Hip, Knee, and Ankle Joints

<table>
<thead>
<tr>
<th>Joint/Event/Leg</th>
<th>Chute</th>
<th>No Chute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Hips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At Touchdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>66.03 (2.32)</td>
<td>67.65 (3.70)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>85.03 (9.01)</td>
<td>77.24 (9.23)</td>
</tr>
<tr>
<td>At Hips-Over-Arch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>71.63 (2.20)</td>
<td>72.79 (4.47)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>71.71 (8.61)</td>
<td>69.05 (9.47)</td>
</tr>
<tr>
<td>At Toe-Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>120.51 (3.44)</td>
<td>121.28 (3.43)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>26.47 (7.26)</td>
<td>27.42 (6.45)</td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At Touchdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>147.42 (4.18)</td>
<td>151.86 (6.27)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>51.94 (7.97)</td>
<td>45.54 (7.35)</td>
</tr>
<tr>
<td>At Hips-Over-Arch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>144.53 (3.64)</td>
<td>147.94 (4.36)</td>
</tr>
<tr>
<td>Joint/Event/Leg</td>
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<tr>
<td></td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>(SD)</td>
<td>(SD)</td>
</tr>
<tr>
<td>At Hips-Over-Arch</td>
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<td></td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>43.55 (7.13)</td>
<td>43.48 (5.87)</td>
</tr>
<tr>
<td>At Toe-Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>155.39 (4.49)</td>
<td>154.78 (5.56)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>85.47 (11.28)</td>
<td>94.89 (11.38)</td>
</tr>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At Touchdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>108.71 (4.02)</td>
<td>116.65 (10.97)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>134.22 (7.51)</td>
<td>140.23 (7.35)</td>
</tr>
<tr>
<td>At Hips-Over-Arch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>102.14 (11.04)</td>
<td>106.79 (6.21)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>131.60 (8.54)</td>
<td>137.56 (6.29)</td>
</tr>
<tr>
<td>At Toe-Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support Leg</td>
<td>138.83 (4.06)</td>
<td>139.93 (5.33)</td>
</tr>
<tr>
<td>Nonsupport Leg</td>
<td>110.00 (8.08)</td>
<td>115.27 (5.25)</td>
</tr>
</tbody>
</table>

**Note.** All measurements in degrees.
occurred during the flying phase when sprinting with and without the speed chute. There was a difference of 1.82° between sprinting with and without the SC. A greater variability existed without the SC than with the SC, as seen by the standard deviations of 6.51 and 3.54, respectively.

Table 8

Greatest Leg Separation When Sprinting With and Without the Speed Chute

<table>
<thead>
<tr>
<th></th>
<th>Speed Chute</th>
<th>No Speed Chute</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>M</strong></td>
<td>96.14</td>
<td>94.32</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>3.54</td>
<td>6.51</td>
</tr>
</tbody>
</table>

Note. All measurements in degrees.

Table 9 represents the means and standard deviations for the position of the chute and range of motion of the chute. The mean and standard deviation of the SC position were 79.51° and 15.6°, respectively. The mean and standard deviation for the range of motion of the SC were 28.83° and respectively. The mean range of motion of the SC was determined by measuring the number of degrees that the SC was displaced during the two strides digitized and taking a mean for all subjects.

The position of the SC was measured to the vertical.
A positive vector was equal to 0° and a negative vector was 180°. If the SC was at 90°, the SC would have been directly behind the sprinter. The standard deviation for the position (15.61°) and range of motion (12.07°) of the SC were large due to movement of the SC.

Table 9

<table>
<thead>
<tr>
<th></th>
<th>Speed Chute Position and Range of Motion</th>
<th>When Sprinting With the Speed Chute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position</td>
<td>Range of Motion</td>
</tr>
<tr>
<td>M</td>
<td>79.51</td>
<td>28.83</td>
</tr>
<tr>
<td>SD</td>
<td>15.61</td>
<td>12.07</td>
</tr>
</tbody>
</table>

Note. All measurements in degrees.

Table 10 provides the means and standard deviations for the displacement of CG. The mean for vertical displacement of CG when sprinting without (0.072 m) the SC was 0.002 m more than when sprinting with the SC (0.070 m). The means for horizontal displacement when sprinting with and without the SC were 4.012 m and 4.269 m, respectively. The mean for horizontal displacement when sprinting without the SC was 0.257 m longer than sprinting with the SC.

Table 11 represents the means and standard deviations for strides per second when sprinting with and without the SC. The means for strides per second when sprinting with
Table 10

Vertical and Horizontal Displacement of the Center of Gravity

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Chute M (SD)</th>
<th>No Chute M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Displacement of CG</td>
<td>0.070 (0.014)</td>
<td>0.072 (0.017)</td>
</tr>
<tr>
<td>Horizontal Displacement of CG</td>
<td>4.012 (0.292)</td>
<td>4.269 (0.276)</td>
</tr>
</tbody>
</table>

Note. All measurements in meters.

and without the SC were 2.106 Hz and 2.191 Hz, respectively. The trials for sprinting without the SC were 0.085 Hz more than when sprinting with the SC.

Table 11

Strides per Second When Sprinting With and Without the Speed Chute

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Chute M (SD)</th>
<th>No Chute M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strides per Second (Hz)</td>
<td>2.106 (0.048)</td>
<td>2.191 (0.140)</td>
</tr>
</tbody>
</table>

Note. All measurements in Hertz.
Table 12 reported the distances for the takeoff, flight, and landing phases. The horizontal distances for the takeoff phase when sprinting with the SC and without the SC were similar. The flight distance means varied the greatest. For the right leg during the flight phase sprinting with the SC was 0.191 m shorter than sprinting without the SC. For the left leg during the flight phase sprinting with the SC was 0.197 m shorter than sprinting without the SC. A difference between the right and left legs, during the flight phase, was only 0.006 m. The differences between takeoff and landing for the right leg when sprinting with and without the SC were smaller than

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Chute</th>
<th>No Chute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Takeoff Distance</td>
<td>0.691 (0.055)</td>
<td>0.696 (0.058)</td>
</tr>
<tr>
<td>Flight Distance</td>
<td>0.911 (0.279)</td>
<td>0.910 (0.265)</td>
</tr>
<tr>
<td>Landing Distance</td>
<td>0.224 (0.046)</td>
<td>0.243 (0.064)</td>
</tr>
</tbody>
</table>

Note. Distances are in meters.
0.48 m. It took the left leg of the landing phase a longer distance to land in the no-SC trial than it did in the SC trial; the difference was 0.051 m.

Table 13 reports the times for the left and right legs during the takeoff, flight, and landing phases when sprinting with and without the SC. The difference of the mean values for the right and left leg were similar, thus there was only a very small difference in the total time. The SC trial was 0.016 s slower than when sprinting without the SC.

This table reported the time that the left and right legs were touching (supporting) and not touching (nonsupporting) the ground. Again, these times were very similar to one another. The total time for the nonsupporting and supporting legs when sprinting with the SC was 0.693 s and 0.253 s, respectively. Thus, in the SC trials the sprinters spent 2.7 times more time in the nonsupporting phase than in the supporting phase. The total times for the nonsupporting and supporting legs when sprinting without the SC were 0.678 s and 0.227 s, respectively. Thus, in the no-SC trials, the sprinters spent 2.99 times more time in the nonsupporting phase than in the supporting phase.
Table 13
Takeoff, Flight, Landing, Support, and Nonsupport Times When Sprinting With and Without the Speed Chute

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Chute</th>
<th>No Chute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right M (SD)</td>
<td>Left M (SD)</td>
</tr>
<tr>
<td>Takeoff Time</td>
<td>0.095 (0.007)</td>
<td>0.095 (0.009)</td>
</tr>
<tr>
<td>Flight Time</td>
<td>0.117 (0.008)</td>
<td>0.117 (0.008)</td>
</tr>
<tr>
<td>Landing Time</td>
<td>0.020 (0.004)</td>
<td>0.021 (0.007)</td>
</tr>
<tr>
<td>Nonsupport Time</td>
<td>0.341 (0.009)</td>
<td>0.352 (0.011)</td>
</tr>
<tr>
<td>Total Time</td>
<td>0.693</td>
<td></td>
</tr>
<tr>
<td>Support Time</td>
<td>0.130 (0.015)</td>
<td>0.123 (0.008)</td>
</tr>
<tr>
<td>Total Time</td>
<td>0.253</td>
<td></td>
</tr>
</tbody>
</table>

Note. All measurements in seconds.

Discussion

The discussion of results will follow the order in which the results were presented. Where appropriate, the results will be compared to results found in the literature. Finally, the results will be analyzed to see if they
support the research hypotheses.

ANOVA

Trajectory Angle

The trajectory of the sprinter at takeoff was found to be significantly lower for the SC trial than for the no-SC trials. This result was consistent with the research hypothesis. The researcher believed that there would be a lower trajectory angle because the subject was not covering as much horizontal distance with each step. Thus, when the subject attempted to sprint at maximum speed while towing the SC, he took off at a lower trajectory angle. That statement was similar to what Mann (1985) believed, that a successful sprinter needs only enough vertical movement to complete swinging the nonsupporting leg through and to prepare the leg for ground contact.

An interesting result occurred when the ANOVA was performed on the data for trajectory angle. The trial by side was close to being significant, thus, further analysis of the data was performed. It was determined that a difference existed between the right and left legs of the subjects when sprinting with the SC. Although this finding was not expected by the researcher, it was believed that the position of the SC may have caused differences between the right and left legs when sprinting with the SC. For
instance, if the SC was abnormally high, the SC may lift
the sprinter. Similarly, if the SC was low, there may be
enough of an increase in negative lift that the SC pulls
the sprinter down. Many of the subjects were jumpers, they
may have had one leg that was stronger than the other. No
tests were performed to determine leg strengths, thus there
is no means to determine if this is or is not the case.

Another interesting result was that significant dif­
ferences occurred between Trials 1 and Trials 2. Because
the testing was done in a relative short time period (2
hours), wind conditions did not change, and participants
were recovered before each trial, the researcher is not
sure what could have caused this outcome other than the
angle of the SC.

**Horizontal Velocity**

A significant difference was found in the horizontal
velocities when sprinting with and without the SC. This
finding coincided with the research hypothesis that the
subjects would sprint faster when not towing the SC. Horiz­
ontal velocity was determined by multiplying stride fre­
quency by stride length. Stride length for the no-SC trial
was 0.257 m longer. However, the number of strides per
second was similar. For the SC trials, the mean was 2.106
strides per second, and for the no-SC trials the mean was
2.191 strides per second. The no-SC trials mean for strides per second was only 1.04 times as fast as the SC trial. Thus, it was determined that the frequency of strides does not account for the slower horizontal velocity of the SC trial. Instead, it was the longer length of the horizontal displacement in the no-SC trials that was accountable for the decreased speed that occurred in the SC trials.

**Trunk Inclination**

A significant difference was found in the angle of trunk inclination when sprinting with and without the SC. This finding was consistent with the research hypothesis. Trunk inclination was 1.54 times as much as when sprinting with the SC than when not sprinting without the SC. No literature was found by the researcher that discussed trunk inclination when towing an object. However, in Hoskisson and Korchemny's (1991) research, trunk inclinations in each of the phases studied were calculated while sprinting. In the present research, the researcher only noted a mean for the trunk inclination that occurred during the two steps being digitized. It is important to note that the mean trunk inclination in the present research was greater than any key event frame noted in the research conducted by Hoskisson and Korchemny.
The following are reasons why the trunk inclinations in the research may not have been similar to those in the research carried out by Hoskisson and Korchemny (1991). First, Hoskisson and Korchemny conducted their filming during competition, and in the present research data were collected during practice. Second, conditions such as wind were not reported in the Hoskisson and Korchemny study. Thus, those subjects may have been exposed to different environmental conditions than the subjects in the current study. Finally, although the ages of subjects in Hoskisson and Korchemny's research were similar to the present research, the skill level may have been different.

Descriptive Statistics

Angles About the Hip, Knee, and Ankle Joints

This next segment of discussion will revolve around Table 5. The table presented the mean angles for hip, knee, and ankle joints during touchdown, hips-over-arch, and toe-off positions. No information in the literature was found that dealt with angles about the hip, knee, and ankle when towing a resistance. However, the researcher was able to determine how similar the subjects in the present research were to those subjects that participated in Hoskisson and Korchemny's (1991) study.

Comparisons could not be made between hip range of
motion in the present study to Hoskisson and Korchemny’s (1991) ranges of motion. In the present research hip flexion and extension were measured between the thigh and a horizontal axis, but in Hoskisson and Korchemny’s research the hip angle was measured between the thigh and the trunk.

It was hypothesized that there would be greater hip flexion and hip extension in the supporting and non-supporting legs. However, the angles for sprinting with and without the SC were very similar. Thus, that hypothesis was not supported.

It was hypothesized that there would be greater knee flexion about the knee when sprinting with the SC. There were only small differences about the knee when comparing sprinting with and without the SC. The differences were small, and no trends could be established. Therefore, the hypothesis was not supported. The knee joint in the present research was similar to the findings of Hoskisson and Korchemny (1991). At touchdown the nonsupporting knee was flexed more in the present study than in Hoskisson and Korchemny’s. However, at hips-over-arch this researcher’s findings indicated that the WMU track and field athletes were unable to maintain the degree of flexion that Hoskisson and Korchemny’s subjects had at touchdown. This may have occurred because the WMU track and field athletes were
not as technically sound as the athletes were in Hoskisson and Korchemny's study, subjects who were invited to participate in a junior national camp. Differences may also have existed because different locations may have been used for determining the angle of trunk inclination. The supporting knee at touchdown was more extended in the current research than in Hoskisson and Korchemny's research. However, at hips-over-arch the WMU athletes' knees were less extended than the knees of Hoskisson and Korchemny's subjects. A large difference occurred at toe-off in the nonsupporting knee. In the present study the knee was flexed to almost 90°, however, in Hoskisson and Korchemny's research the knee was flexed to 39.5°.

It was hypothesized that the ankle joint would be plantar flexed to a lesser degree when sprinting with the SC than when sprinting without the SC. However, the differences were small. Thus, the hypothesis was not supported. For the most part there was more ankle plantar flexion in the WMU track and field athletes than was present in the athletes Hoskisson and Korchemny studied.

Leg Separation

Table 6 represented the amount of leg separation for sprinting with and without the SC. When sprinting with the SC, the greatest leg separation was 1.82° larger than
sprinting without the SC. Thus, there was not a great difference in leg separation between sprinting with and without the SC. The researcher found no support for the hypothesis that there would be less leg separation when sprinting with the SC.

**Speed Chute Position**

Table 7 represented the SC position and range of motion for the SC trials. A mean of 79.51° indicated that the chute for the most part was about 10° above the horizontal. A large standard deviation was reported. The range of motion of the SC for the two steps digitized had a mean of 28.83° and standard deviation of 12.07°. These results were due to the movement of the SC in the sagittal plane. Although there was virtually no wind on the day of filming, the SC still moved up, down, left, and right a substantial amount for the two strides analyzed. The large standard deviations were due to the gross movement of the SC during filming. The SC moved so much that at times it could be seen colliding with the track.

**Displacement of the CG**

Table 8 provided the data that may be of most interest to the coach or those interested in practical application. Vertical displacement of the CG was almost equal for the SC
and no-SC trials. However, the trajectory angle for sprinting with the SC was significantly smaller than the trajectory angle for sprinting without the SC. When sprinting with the SC, the subjects’ takeoff angle was smaller. However, the vertical displacement of the CG remained about the same. The trunk inclination was significantly greater in the SC trials. This would lower the CG. However, the vertical displacement was still very small.

One manufacturer of the SC claimed that the SC has a lifting component that affects the sprinter. If this is true, it may explain why the subjects sprinting with the SC have lower takeoff angles and greater trunk inclination, which would lower their CG, yet have almost the same amount of vertical displacement when sprinting with and without the SC.

**Strides per Second**

Strides per second were almost equal, 2.106 Hz with the SC and 2.191 Hz without the SC. However, the horizontal displacement covered by the CG during the two strides analyzed was 0.257 m longer for the no-SC trials. Thus, the horizontal velocity was 0.891 m/s faster without the SC. That result was consistent with the hypothesis of the researcher that the SC trials would be slower.
However, it is important to note that the difference in the horizontal velocities between sprinting with and without the SC were primarily due to the fact that the horizontal displacement of the CG while sprinting without the SC was greater than sprinting with the SC.

Time of Phases

Data regarding the make-up of the stride time, in terms of the takeoff, flight, and landing phases, were intended to aid in the explanation of the similarities and differences between sprinting with and without the SC. It should be noted that there are only small differences recorded for sprinting with and without the SC in terms of time for the takeoff, flight, and landing phases. In fact it took 0.023 s longer for the subjects to travel two steps with the SC. Thus, as previously stated the frequency of the stride only changed minimally.

Atwater’s (1980) subjects were elite sprinters with Olympic-level performance potential. Those subjects spent 26%, 57%, and 17% of their stride in takeoff, flight, and landing phases, respectively. In the present research the subjects sprinting without the SC spent 37.2%, 53.5%, and 9.4% of their stride in the takeoff, flight, and landing phases, respectively. The subjects sprinting with the SC spent 40.9%, 50.3%, and 8.8% of their stride in the
takeoff, flight, and landing phases, respectively. Because Atwater’s subjects were elite sprinters, the higher skill level in her study may explain the differences in percentages between the two studies. Subjects sprinting with the SC spent more time in the takeoff phase, less time in the flight phase, and a comparable amount of time in the landing phase. The researcher believed that the subjects would spend more time in the takeoff phase because they were towing a resistance, thus they spent more time in this phase to create a larger force at takeoff. The researcher believed that the subjects spent less time in the flight phase because there was an external force, the SC, acting on the sprinter’s momentum. Thus, the athlete landed more quickly after taking off when sprinting with the SC. Finally, a difference of only 0.6% existed between the landing phases when sprinting with and without the SC. Measurement error could account for this small difference.

**Distance of Phases**

It was of utmost importance to look at the breakdown of the stride into takeoff, flight, and landing distances to determine where the differences in horizontal displacement of the CG took place between sprinting with and without the SC. The distance at takeoff for the SC trial was greater by 0.28 m and 0.48 m for the right and left
legs, respectively. The flight distance was greater for the no-SC trials by 0.191 m and 0.197 m for the right and left legs, respectively. The landing distances for the SC were greater for the right leg by 0.007 m, but less than the no-SC trials for the left leg by 0.051 m. When all of these numbers are considered, subjects in the no-SC trial covered a mean of 0.356 m farther per stride.

It was hypothesized that the landing distance would be greater for the SC trials. That hypothesis was not supported because the right leg’s landing distance was greater, but the left leg’s landing distance was less when sprinting without the SC. This difference is difficult to explain, especially because strength testing was not done to determine if differences in strength existed between right and left legs. However, differences in leg strength may account for differences in the length of the landing distance.

Most of the increase in horizontal displacement was made during the flight phase. Thus, the SC apparently provided enough resistance to adversely affect the flight phase, but it did not provide a great enough resistance to affect the landing or takeoff phases.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This research was undertaken to determine the kinematic differences and similarities that exist between sprinting with and without the SC. It was believed that because the subjects were towing a resistance in an attempt to increase resistance, changes in their gait must occur or the resistance they were towing was not great enough to decrease their speed.

The subjects were Western Michigan University Track and Field Athletes participating in fall workouts. Each subject performed two trials with and two trials without the SC.

ANOVA\'s were performed on three dependent variables: (1) trajectory angle, (2) horizontal velocity, and (3) trunk inclination. The remaining dependent variables were compared for sprinting with and without the SC, and where appropriate, the research findings were compared to the findings in the literature.
Findings

An alpha level of .05 was used to determine significance in the present study. The ANOVAs comparing of the SC and no-SC trials indicated the following:

1. There was a significantly lower trajectory angle when sprinting with the SC.
2. There was a significantly slower horizontal velocity when sprinting with the SC.
3. There was a significantly lower trunk inclination when sprinting with the SC.

Conclusions

It was the belief of the researcher that differences would exist in the kinematics of subjects when sprinting with and without the SC. Statistically significant differences existed for takeoff angle, horizontal velocity, and trunk inclination, however, the statistical significance does not imply that there is a practical difference. For instance, the differences of the means for trajectory angle, horizontal velocity, and trunk inclination were small, 0.53°, 0.891 m/s, and 2.93°, respectively. Furthermore, the descriptive statistics revealed small differences between sprinting with and without the SC. This was illustrated by the minimal differences that existed in angles about the hip, knee, and ankle for the nonsupporting
and supporting legs. It was difficult to note differences between sprinting with and without the SC. Because the differences were very small and varied between the right and left sides. It is the belief of the researcher that the SC applying a 9-lb resistance does not provide a large enough resistance to practically change the kinematics of those subjects when sprinting with the SC in comparison to when they sprinted without the SC. This is paramount, for if the SC did practically change the kinematics of the subjects, it may not be beneficial for them to use the SC. However, this is not the case. The SC provides a resistance without practically changing the kinematics of those subjects who sprinted with the SC as compared to sprinting without the SC.

Recommendations

Many dependent variables related to sprinting technique were analyzed and discussed for the first time to the researcher’s knowledge. Future studies in this area need to discuss the following:

1. A three-dimensional study needs to be done to determine what effects the movement of the chute has on lateral movement of the sprinter.

2. A larger number of subjects should be used to better determine what is normal and abnormal when
sprinting with the SC. However, future research should not sacrifice the quality of the subjects used in order to increase the sample size.

3. In the current research it may have appeared that the SC provided a lifting component. In the future force plates should be used to determine if in fact this is occurring.

4. At the present time there are many different sizes and types of SCs being marketed. Prospective researchers should look at the effects of different sizes and styles of SCs. Some SCs have fins on the inside in an attempt to stabilize the motion of the SC. Research could be done to determine if fins help stabilize the SC.

5. Most SCs have a device to release the SC from around one's waist while sprinting. The manufacturers of these SCs claim that this allows the sprinter to do over-speed training. If, in fact, this is true, research should be done to determine what are the kinematic changes that take place at the time when the SC is released.
Appendix A

Letter of Request to Carry Out Research
TO: Human Subjects Review Committee

FROM: Paul Turner, PhD

DATE: February 16, 1994

During the fall of 1992, I collected biomechanical data on student-athletes concerning running with and without resistance. This data collection occurred as a part of a normal varsity track and field practice. Upon the completion of the data collection, I requested that Mr. Doug West analyze the data for me.

If you have any further questions, please feel free to contact me.

[Signature]
Appendix B

Human Subjects Institutional Review Board Acceptance Form
Date: March 9, 1994
To: Doug West
From: M. Michele Burnette, Chair
Re: HSIRB Project Number 94-03-04

This letter will serve as confirmation that your research project entitled "Kinematic analysis of sprinting with and without the speed chute" has been approved under the exempt category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

You must seek reapproval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: March 7, 1995

xc: Moss, HPER
Appendix C

Heights, Weights, and Ages of Subjects
### Heights, Weights, and Ages of Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Height in cm</th>
<th>Weight in kg</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>187.96</td>
<td>83.92</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>172.72</td>
<td>77.11</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>180.34</td>
<td>70.31</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>182.88</td>
<td>74.84</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>187.96</td>
<td>86.18</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>177.80</td>
<td>72.58</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>185.42</td>
<td>79.38</td>
<td>18</td>
</tr>
<tr>
<td>8</td>
<td>187.96</td>
<td>74.84</td>
<td>21</td>
</tr>
</tbody>
</table>

| M       | 182.88       | 77.40        | 19.9 |
| SD      | 5.60         | 5.48         | 1.5  |
BIBLIOGRAPHY


