



2009-07-15

# Differences in Joint Moments at the Hip, Knee, and Ankle While Wearing Running Shoes and Distance Spikes

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DIFFERENCES IN JOINT MOMENTS AT THE HIP, KNEE,  
AND ANKLE WHILE WEARING RUNNING SHOES  
AND DISTANCE SPIKES

by

Aared D Sampson

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Exercise Sciences

Brigham Young University

August 2009

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BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Aared D Sampson

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the thesis of Aared D Sampson in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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## ABSTRACT

### DIFFERENCES IN JOINT MOMENTS AT THE HIP, KNEE, AND ANKLE WHILE WEARING RUNNING SHOES AND DISTANCE SPIKES

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Master of Science

For years track and field athletes have worn spiked shoes to enhance performance. This study was conducted to determine the effect of track spikes on hip, knee, and ankle peak joint moments (PJM) in collegiate and elite athletes while running. To measure differences in joint moments, ten intercollegiate and post graduate male distance runners from Brigham Young University ran at a four-minute-mile pace (6.7 m/s) across a force plate synched with infrared cameras tracking body positioning in each shoe condition. Repeated measures ANOVA ( $p < 0.05$ ) revealed no significant peak joint differences between running shoes and track spikes. The minimum hip and peak knee PJM approached significance ( $F = 3.221$ ,  $P = 0.116$  and  $F = 2.875$ ,  $P = 0.134$  respectively). The high variability of joint moments between trials made it difficult to detect differences between conditions. The variability may be explained by any number of factors

including: biomechanical differences in running form, running at high speeds, type of subjects, and potentially other factors.

## ACKNOWLEDGMENTS

I would like to thank my chair, Dr. Iain Hunter, for all of your help and advice. I would also like to thank my committee members for your good feedback. Thank you to the track and cross country team members who made this study possible. I would also like to thank Brigham Young University's faculty and staff for this great experience in learning and for introducing me to my wife, Barbara, for which I am eternally grateful!

Thank you Barbara for the love, encouragement and support you have given me. Also to Camilla and Colleen for your laughs and smiles that kept me going. Thank you to all my family for what you have done for me.



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DIFFERENCES IN JOINT MOMENTS AT THE HIP, KNEE, AND  
ANKLE WHILE WEARING RUNNING SHOES AND  
DISTANCE SPIKES

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### Abstract

For years track and field athletes have worn spiked shoes to enhance performance. This study was conducted to determine the effect of track spikes on hip, knee, and ankle peak joint moments (PJM) in collegiate and elite athletes while running. To measure differences in joint moments, ten intercollegiate and post graduate male distance runners from Brigham Young University ran at a four-minute-mile pace (6.7 m/s) across a force plate synched with infrared cameras tracking body positioning in each shoe condition. Repeated measures ANOVA ( $p < 0.05$ ) revealed no significant peak joint differences between running shoes and track spikes. The minimum hip and peak knee PJM approached significance ( $F = 3.221$ ,  $P = 0.116$  and  $F = 2.875$ ,  $P = 0.134$  respectively). The high variability of joint moments between trials made it difficult to detect differences between conditions. The variability may be explained by any number of factors including: biomechanical differences in running form, running at high speeds, type of subjects, and potentially other factors.

## Introduction

Track and field is one of the world's oldest and most physically demanding sports. The events require the body to be in peak physical condition in order to perform at the highest level. In the last few decades there have been significant improvements in track surfaces, running shoes, and track spikes to aid athletes in their individual performances. Track spikes are designed to be light weight and provide increased traction on track surfaces. In contrast, running shoes protect the lower leg and ankle by absorbing the ground reaction forces (GRF) and provide more comfort during running (Nigg, 1986).

In running, the amount of force applied to the ground is highest when running at faster speeds (Weyand, Sternlight, Bellizzi, & Wright, 2000). In distance running the GRF of each ground contact can reach up to two to three times the runner's weight (Clarke, 1983). This can add up because competitive distance runners can run well above 50 miles a week. Muscles, tendons, bones, and ligaments along with the running shoe absorb these repetitive forces.

Similar to GRF, hip and knee joint moments increase with running speed. Ogata, Manabe, and Takamoto (2005) showed that when sprinting at 9.78 m/s, hip extension peak joint moments (PJM) reached  $4.140 \pm 0.400$  Nm/kg and knee extension PJM reached  $1.803 \pm 0.232$  Nm/kg. While running at 7.31 m/s, hip and knee extension PJM reached  $2.590 \pm 0.604$  Nm/kg and  $1.260 \pm 0.242$  Nm/kg, respectively. They also found that during fatigue there is a decrease in joint moments.

Logan (2007) found that due to the lower amount of cushioning in track spikes GRF are higher while wearing track spikes Than while wearing running shoes.

Consequently, higher PJM should also be seen at the hip, knee, and ankle while wearing track spikes compared to running shoes.

After a comprehensive search of the literature only one study investigated joint moments in track spikes, and this study only looked at average runners rather than elite or even collegiate athletes. The purpose of this study was to determine the effect of spikes on peak hip, knee, and ankle PJM in collegiate and elite athletes while running.

## Methods

### *Subjects*

10 intercollegiate and post graduate male distance runners from the Brigham Young University cross country and track and field teams were recruited and participated in this study (age  $25.1 \pm 4.25$  years). Only those who identified themselves as heel strikers were chosen to participate. Qualified subjects had been training and injury free for at least 8 weeks prior to testing. Each subject signed a consent form approved by Brigham Young University's institutional review board.

### *Testing Procedures*

The subjects were instructed to use their traditional warm-up. Following their warm-up each subject ran three successful trials in both the running shoes and track spikes. The subjects ran across a force plate (9287BA, Kistler, Amherst, NY) synched with infrared tracking cameras (Vicon, Centennial, CO) with running shoes (Nike air Pegasus) and distance track spikes (Nike Rival D Plus II) at a four-minute-mile pace (6.7 m/s). Shoe order was randomized. Timing lights (Brower, Draper, UT) positioned at head height were used to verify that four-minute-mile pace  $\pm 2.5\%$  was achieved through the

10-meter section of the track where the force plate was positioned. Starting and finishing positions were marked with cones. Each subject ran a 30-meter approach, allowing them to reach four-minute-mile pace. Subjects continued that pace through a 10-meter section of capture, where the timing lights, force plate, and vicon cameras were located.

Following the section of capture, subjects sustained the pace for 10 meters before they slowed down. Samples were only saved when the left foot landed completely on the force plate and four-minute-mile pace  $\pm 2.5\%$  was achieved. Trials were recorded at the end of summer.

*Vicon.* Force and position data were recorded and processed with Vicon Nexus 1.3 with the OLGA module (Vicon, Centennial, CO) (Charlton, 2004). The subjects were marked with a total of 16 reflective markers according to Vicon's plugin-gait model. Six MX13+ cameras recorded marker positions at 240 Hz. A calibrated volume 6 meters long, 2 meters wide, and 2.5 meters high was created around the force plate. The data were filtered using a woltring filter that automatically selected a cut off frequency.

*Force plate.* A Kistler force plate (9287BA, Amherst, NY) embedded in the Brigham Young University's Smith Fieldhouse indoor track was used. The force plate is covered by a Mondo Super-X track surface. The sampling rate for force was set at 1200 Hz. Joint moments were calculated by the Nexus program using force and position data. Joint data were normalized by body weight. In this study a positive hip moment represents hip flexion, a positive knee moment represents knee extension, and a positive ankle moment represents plantar flexion. Although, other studies have shown that a positive ankle moment to represents dorsal flexion (see figure 3).



*Shoes.* All runners wore Nike Air Pegasus and Nike Rival D Plus II (Figure 4) for this study. These shoes are typically worn by collegiate athletes. The Air Pegasus is designed to be comfortable with sufficient cushioning. The mid-sole is comparatively soft and is neutral in terms of motion control. The Rival is a distance racing spike. The outer sole is constructed of hard plastic with no mid-sole. The heel contains a heel wedge composed of ethylene-vinyl acetate (EVA) covered with a rubber outer sole. Track spikes do not provide rear foot motion control (Logan, 2007).

### *Statistical Analysis*

Differences between shoe types for the following variables were compared: minimum and peak hip joint moments, minimum and peak knee joint moments, and minimum and peak ankle joint moments. A repeated measures ANOVA was used to determine differences between shoe conditions. Alpha was set at ( $p < 0.05$ ). All statistical calculations were performed using SPSS 17.0 program (SPSS, Chicago, IL).

### *Results*

No significant PJM differences were found between running shoes and track spikes (Table 1). The minimum hip and peak knee PJM approached significance ( $F = 3.221$ ,  $P = 0.116$  and  $F = 2.875$ ,  $P = 0.134$  respectively). The hip joint exhibited the most variability. In running shoes the hip joint registered the highest average PJM and greatest standard deviation ( $4.970 \pm 2.336$  Nm/kg), followed by the knee ( $4.565 \pm 1.606$  Nm/kg) and ankle ( $3.748 \pm 1.829$  Nm/kg). PJM while rearing track spikes followed the same pattern as running shoes. Track spikes averaged higher PJM, except at peak ankle and minimum knee, which showed higher average PJM in running shoes.

## Discussion

The purpose of this study was to find the differences in PJM at the hip, knee, and ankle while wearing running shoes and track spikes. We expected that peak joint moments would be higher while wearing track spikes than while wearing running shoes. However, high variability of joint moments between trials made it difficult to detect differences between conditions and no significance was found.

A runner's movement is like a finger print, every runner varies one from another. Differences between runners' movements were also found by Reinschmidt and Nigg (1995). The variability may be explained by any number of factors including biomechanical differences in running form, running at high speeds, type of subjects, and potentially other factors.

Distance runners' form differs while running at race pace verses maximum speeds. When distance runners go from race pace to sprinting, there is an 11-degree difference regarding the minimum hip angle (Bushnell 2007). This large increase in joint angle may account for the high standard deviation seen at the hip joint.

PJM are higher when running at faster speeds (Winter, 1983; Weyand, et al., 2000; Simpson & Bates, 1990; Reinschmidt and Nigg, 1995; Ogata, Manabe, and Takamoto, 2005). When running at higher speeds, individuals make different biomechanical adjustments or variations to adjust to the higher speed. These compensations may be different for each joint.

Our study was conducted during the summer when the athletes were training for cross country. It may be more beneficial to conduct the study at the end of track season

when the runners are better conditioned to run at four-minute-mile pace. We selected distance runners from Division I NCAA current and alumni track teams. Our subjects are competitive athletes in their field. The athletes tested include runners that concentrate on the middle distance events such as the 800 and 1500 meters, and athletes that concentrate on long distance events that include the steeplechase, 5,000 and 10,000 meters. Middle distance runners regularly train at or faster than four-minute-mile pace. Whereas long distance runners regularly train at a pace slower than four-minute-mile pace. Therefore, long distance runners' form may vary more than middle distance runners' form while running at four-minute-mile pace. Mann (1981) believes the patterns and magnitudes of PJM may be influenced by skill level. In our study runners ranged from freshmen to seniors and professional. Some variability may have occurred as a result of age and experience.

It is believed that biomechanical differences in running form is the dominant factor of why there was such a high variability of PJM in this study. However, it is possible that a combination of factors explain the variability found.

In this study we found that the hip produced the highest average PJM compared to knee and ankle in both running shoes and track spikes. The hips also displayed the highest standard deviation, which is supported by Simpson and Bates (1990). They demonstrated that compared to the knee and ankle, the hip showed the greatest number of significant increases when compared to slower running speeds. Mann and Sprague (1980) suggest that the hip plays an important role during the support phase due to its ability to

adapt to changes in speed. One reason for the higher PJM seen at the hip may be due to the greater musculature about the hip joint.

In a study that looked at ground reaction forces between running shoes, racing flats, and track spikes, significant differences between running shoes and track spikes were found (Logan 2007). However, this study included body positioning along with ground reaction forces to obtain PJM. This inclusion likely led to the increased variability that reduced our ability to detect significant results.

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Table 1. Means and standard deviation for PJM variables in the two shoe conditions.

	<u>Running Shoes</u>	<u>Track Spikes</u>	<u>F Value</u>	<u>P Value</u>
	Mean±SD	Mean±SD		
Min Ankle (Nm/kg)	-.19±.52	-.27±6.45	0.702	0.631
Peak Ankle (Nm/kg)	3.74±1.82	3.11±1.40	0.252	0.434
Min Knee (Nm/kg)	-1.88±3.61	-1.47±1.95	0.297	0.603
Peak Knee (Nm/kg)	4.56±1.60	5.56±1.92	2.875	0.134
Min Hip (Nm/kg)	-4.46±2.34	-6.30±3.77	3.221	0.116
Peak Hip (Nm/kg)	4.97±2.33	6.54±4.03	1.045	0.341

Appendix A

Prospectus



## Chapter 1

### Introduction

Track and field is one of the world's oldest and most physically demanding sports. The events require the body to be in peak physical condition in order to perform at the highest level. In the last few decades there have been significant improvements in track surfaces, running shoes, and track spikes to aid athletes in their individual performances. Track spikes are designed to have less padding than running shoes, and aid the runner by adding a better grip on track surfaces. In contrast, running shoes protect the lower leg and ankle by absorbing the ground reaction forces (GRF) and provide more comfort during running (Nigg, 1986).

The amount of force applied to the ground is highest when running at faster speeds (Weyland, Sternlight, Bellizzi, & Wright, 2000). In distance running the GRF of each step can reach up to two to three times the runner's weight (Clarke, 1983). This can add up because competitive distance runners can run between 50 and 80 miles a week. Muscles, tendons, bones, and ligaments along with the running shoe absorb these forces.

Comparative to GRF, hip and knee joint moments increase with running speed. Ogata, Manabe, and Takamoto (2005) showed that when sprinting at 9.78 m/s hip extension peak joint moments (PJM) reached  $4.140 \pm 0.400$  Nm/kg and knee extension PJM reached  $1.803 \pm 0.232$  Nm/kg. While running at 7.31 m/s, hip and knee extension PJM reached  $2.590 \pm 0.604$  and  $1.260 \pm 0.242$ , respectively. They also found that during fatigue there is a decrease in joint moments.

Logan (2006) found that due to the lower amount of cushioning in track spikes GRF are higher while wearing track spikes compared to running shoes. I believe that higher PJM will also be seen at the hip, knee, and ankle while wearing track spikes compared to running shoes.

After a comprehensive search of the literature only one study investigated joint moments in track spikes, and this study only looked at average runners rather than elite or even collegiate athletes. The purpose of this study is to determine the effect of spikes on peak hip, knee, and ankle PJM in collegiate and elite athletes while running. Information from this study may help coaches and athletes determine how often and for how long track spikes should be used during training.

### *Hypothesis*

At a given speed, peak joint moments will be higher while wearing track spikes than running shoes.

### *Null Hypothesis*

At a given speed there will be no differences in joint moments between track spikes and running shoes.

### *Assumptions*

Each subject will report truthfully about injuries on their assessment form.  
The shock absorbing capabilities of the shoes will not be affected during the trials.

### *Delimitations*

The participants are NCAA Division I athletes or professional runners.  
Only male runners will be recruited.

One type of running shoe and one type of track spike will be used.

Only one speed will be analyzed during the study.

### *Limitations*

Subjects may not report injury or training status accurately.

### *Operational Definitions*

Peak Joint Moment (PJM) - The greatest joint moments observed during stance.

These will be measured in the sagittal plane at the hip, knee, and ankle of the support leg.

Ground Reaction Forces - The force applied from the ground on a person during the stance phase of running.

Running shoes - defined for this study as a specific type of shoe that is designed for long-distance training.

Track spikes - defined for this study as track and field distance racing spikes.

### *Independent Variable*

The type of shoe worn.

### *Dependent Variable*

Hip, knee and ankle peak flexion and extension moments during stance of the support leg.

## Chapter 2

### Review of Literature

In order to compare track spikes and running shoes it is important to understand their differences and when they are used. In middle and long distance running, the majority of training is done in running shoes. This training is usually medium to high intensity, long in duration, and performed at or below race pace. The training done in track spikes focuses on running at high intensities for a short duration of time, at or above race pace. Racing is done in track spikes. This allows the athlete to run at their maximum pace.

Few researchers have considered track spikes, and little is known about the effects of running in spikes. Before looking at the differences in footwear, we will look at PJM while running, then the effects of different speeds on PJM. We will also evaluate PJM at the hip, knee, and ankle. The differences in shoes will then be addressed, and finally we will discuss PJM and injury.

#### *Joint Moments & Running*

The PJM that are primarily responsible for running are hip extension and flexion, knee extension and flexion, ankle plantar flexion, and dorsiflexion. Smaller peak joint moments such as ankle inversion and adduction and external knee rotation are responsible for the stability of the lower extremities (Reinschmidt et al., 1995). Mann and Sprague (1980), and Reinschmidt et al. (1995) attribute the high amount of force at foot strike directly to subject weight, and inversely related to subject horizontal velocity loss during ground contact.

*Peak Joint Moments and Running Speed*

Fast walking and slow jogging represents a movement towards a higher level of force compared to walking at a natural cadence (Winter, 1983). Weyand, Sternlight, Belizzi, and Wright (2000) found that faster top running speeds are due to a greater transmission of force from the muscle to the ground rather than increased frequency of limb movement.

Studies indicate that PJM are positively correlated with speed. Running speed affects the magnitude and absolute time of critical joint moments (Simpson & Bates, 1990). Reinschmidt and Nigg (1995) noted that when subjects ran about 2.7 m/s, ankle joint moments were 30% less than when they ran at 4.6 m/s. They believe these differences may be explained by the lower running speed.

Ogata, Manabe, and Takamoto (2005) demonstrated that hip flexion and extension and knee extension PJM were lower at the end of a fatiguing sprint compared to a maximal sprint. This would indicate that fatigue might be a factor in the inability to maintain PJM. Although the joint moment patterns were similar when comparing a fatiguing sprint to a maximal sprint, PJM were significantly greater in the maximal sprint (Ogata, 2005). Ito, Saito, and Fuchimoto (1997) focused on the first 20 steps of a sprint start. They found that there was no sign of decreasing PJM with increased sprint velocity. According to Simpson and Bates (1990), overall PJM were found to increase with increased speed. When running at different speeds PJM at the hip exhibited the greatest number of significant differences.

Mann and Sprague (1980) suggest that differences in PJM may be due to the differences in the speed of the runners analyzed. Mann (1981) believes the patterns and magnitudes of PJM may be influenced by skill level. Simpson and Bates (1990) Argues that speed could have a differential effect on subjects even if they are at the same skill level.

It has been shown that there may be many things that affect the pattern and magnitude of PJM. It is conclusive that the faster the running speed the higher the PJM will be.

#### *Peak Joint Moments at the Hip*

Sagittal-plane hip joint moments during running are depicted in Figure 1 (Mann, 1981). At foot strike the hip joint and center of mass are behind the center of pressure, which is where the heel contacts the ground. The hip extensors are used to halt anterior rotation and initiate posterior rotation of the thigh. During mid-stance the center of mass moves and is located above the foot. The center of pressure shifts in front of the hip joint. These changes initiate the shift from hip flexors to hip extensors, which provide the propulsion force at toe-off (Winter, 1983, Mann, 1981, Mann & Sprague, 1980, Simpson & Bates, 1990). Winter (1983) suggests that the hip flexors dominate during toe-off in order to rotate the upper body forward into the approaching air phase. He also suggests that the hip flexor moments decelerate the thigh in preparation for the recovery phase. The flexor moment decelerates the backward rotation of the thigh, while the extensor moment serves to decelerate the thigh to prepare for the next foot strike (Winter, 1983).

The PJM at the hip behaved differently than the knee and ankle. During foot strike the hip extensors showed positive work, followed by a period of negative work by the hip flexors. Hip extensors are the prime forward movers of the body (Belli, Kyrolainen, & Komi, 2002). The purpose of the increased hip extensor moments during foot strike could also be to dampen the impact shock to the trunk (Simpson & Bates, 1990). When looking at speed changes, Simpson and Bates (1990) demonstrated that compared to the knee and ankle, the hip showed the greatest number of significant increases. This suggests that the hip plays an important role during the support phase due to its ability to adapt to changes in speed. Mann and Sprague (1980) suggest that muscle activity about the hip was the greatest contributor to success in sprinting. When looking at maximal sprint, (50-100 meters,) compared to fatiguing sprint, (400 meters,) Ogata, et al. (2005) found a correlation between the ability to maintain hip extension moments with muscular endurance of hip flexors and extensors. Mann (1981) saw hip extensors PJM reach 4.70 Nm in sprinters running at maximum speed (9-10 m/s).

#### *Peak Joint Moments at the Knee*

Sagittal-plane knee joint moments during running are depicted in Figure 2 (Mann, 1981), which shows that the knee is comparable to the hip at foot strike. The center of mass is located behind the knee, although the knee joint is directly above the center of pressure. From foot descent through foot strike knee flexors are dominant. Knee flexors act to stop the forward momentum of the lower leg and decrease the horizontal breaking ground force. This flexor moment continues only for a short time when knee extensors take over during mid-support and continue through toe-off. Approaching toe-off, we see a

decrease in extensor activity, which may act to protect the knee from hyperextension. After toe-off as the knee begins the swing phase, the knee joint moments shift from extensor to flexor (Mann & Sprague, 1980, Mann, 1981). The joint moment at the knee is dominated by the knee extensors (Mann, 1981). The ankle and knee joint moments behaved similarly despite changes in speed. Knee extensor PJM of sprinters running at 9-10 m/s reached 3.75 Nm.

If we divide the ground contact time into two periods we find that during the first period the knee extensor muscles perform negative work. During the last period of contact time the knee extensors performed positive work. These two periods could be associated with braking and propulsion (Belli, et al., 2002, Mann & Sprague, 1980). The surprising knee flexor dominance during foot strike is generated to limit the braking action created during this period of the ground contact. The increase in knee extensor moments contributes to the increase in the vertical and horizontal propulsive forces. Belli (2002) suggests that the role of the ankle and knee extensors is to create high joint stiffness before and during the contact phase. The knee flexors could function to attenuate the vertical GRF (Simpson & Bates, 1990). The reversing of extensor to flexor dominance at the end of take-off serves to protect the knee from injury (Mann & Sprague, 1980).

#### *Peak Joint Moments at the Ankle*

An initial dorsiflexion moment at foot strike is found in some studies (Reinschmidt et al., 1995, Winter, 1983, Simpson & Bates, 1990, Mann & Sprague, 1980), but it is absent in other studies (Mann, 1981, Scott & Winter, 1990). Reinschmidt



et al. (1995) suggests that the differences in the dorsiflexion moment may be explained by different locations of joint centers, or running styles of subjects. Reinschmidt (1995) reported that plantar flexion PJM averaged 240 Nm at the ankle when running at 4.6 m/s, while the dorsiflexion PJM averaged 20 Nm. Adding a heel insert significantly affected the initial dorsiflexion moment. The thicker the heel insert the higher the initial dorsiflexion moment and the later it occurred. There was not a significant effect of heel inserts on plantar flexor moments. This suggests that changes in heel height only affect the beginning of the stance phase (Reinschmidt et al., 1995).

Sagittal-plane Ankle joint moments during running are depicted in Figure 3 (Mann, 1981). During the swing phase there is a balance between plantar and dorsiflexors where there are very little plantar or dorsal moments (Winter, 1983; Mann & Sprague, 1980; Mann, 1981). At foot strike the center of pressure is directly below the heel with the center of mass behind the ankle. The plantar flexors act as a first class lever, and are activated to attenuate the downward movement of the foot (i.e. prevent foot slap). When the center of pressure shifts from the heel toward the toe the ankle acts as a second-class lever. Winter (1983) describes the ankle as primarily an energy generator. It is during mid-stance that plantar flexor PJM in sprinters running at 9-10 m/s reach 2.20 to 3.10 Nm (Mann, 1981). Nearing toe-off the PJM decreases until neither plantar flexors nor dorsiflexors dominate (Mann & Sprague, 1980, Mann, 1981, Simpson & Bates, 1990). The plantar flexors then create positive horizontal and vertical velocity.

*Effects of Shoe Modifications on Joint Moments*

Running shoes are designed with a cushioned heel which absorbs some of the impact forces during running, whereas track spikes are designed to be lightweight and have very little heel cushioning. Heel lifts have been used to treat runners suffering from Achilles tendonitis. It is thought that lifting the heel will decrease the strain on the Achilles tendon. Reinschmidt (1995) examined the influence of heel height on the ankle joint moments found that the initial dorsiflexion PJM was significantly affected by changes in heel height. The heel lift did not significantly decrease plantar flexor moments. (Reinschmidt et al., 1995).

Another study looked at knee and ankle PJM by adding a lateral or medial shoe insert. They found a relatively small change in joint moments at the ankle (plantar flexion) and in knee (extension). However, there was a substantial effect for ankle inversion and adduction joint moments. This indicates that medial and lateral inserts do not affect the joint moments responsible for running, but affect the joint moments related to stability. Furthermore, subject specific reactions to shoe inserts on ankle and knee PJM were not consistent. They found that PJM both increases and decreases compared to neutral insert condition. They concluded that subjects produce substantially different results when using the same inserts but there may be groups that produce similar changes with shoe inserts (Nigg, Stergiou, Cole, Stefanyshyn, Mundermann & Humble, 2003). Nigg et al. (2003) found significant changes in the path of the center of pressure (COP) with the use of a full lateral insert. Nigg et al. (2003) also found that a full lateral insert

shifted the COP laterally and not medially. All other insets were inconsistent in shifting the COP into a desired path.

### *Barefoot vs. Shod Running*

Because there are some similarities between running barefoot and running with track spikes (i.e. lack of protection), we will consider the differences between running barefoot and in running shoes. Results have been noted in studies looking at GRF in barefoot verses shod conditions. Komi, Gollhofer, Schmidtbleicher, and Frick (1987) reported a higher impact force in barefoot conditions compared to running shoes. De Wit, De Clercq, and Aerts (2000) found multiple peaks in the ground reaction force curve in barefoot conditions, and that the loading rate increased. When looking at GRF in running shoes and track spikes, Logan (2007) found that the lack of cushioning in track spikes contributed to less shock absorption, resulting in a greater force on impact. These studies indicate that when a person switches from running in a cushioned running shoe to a uncushioned track spike higher GRF are seen due to a lack of cushioning. Therefore, PJM may increase while running in track spikes compared to running shoes.

### *Joint Moments and Injuries*

50-70% of Americans who run will suffer from a running related injury, (Gudas, 1980). Joint moments can be useful indicators of the amount of physical stress placed on the neuromuscular system Winter (1983). About 75% of all chronic running injures, including tendonitis, shin splints, stress fractures, plantar fasciitis, and chondromalacia, appear to be related to the high forces that occur at toe-off (Winter, 1983b, Mann, 1981, Simpson & Bates, 1990). In order to identify the high forces associated at foot strike,

Mann & Sprague (1980) found that joint moments were directly related to the subject's weight. The most critical factor in sprint running is when the foot contacts the ground. The high forces combined with poor running form may lead to injury. In order to minimize the horizontal braking forces, sprinters produce larger hip extensor and knee flexor impulses. These impulses have been related to the occurrence of hamstring injuries (Mann, 1981). Inadequate heel wedging in running shoes has been thought to be related to Achilles tendonitis (Reinschmidt et al., 1995). The knee is the most common site of chronic running injuries (Novacheck, 1998). Stefanyshyn, Stergiou, Lun, Meeuwisse and Nigg (1999) showed that there is a strong possibility that increased knee joint moments are a contributing factor in patellofemoral pain syndrome. Stefanyshyn, Stergiou, Nigg, Lun, and Meeuwisse (2000) examined the relationship between impact forces and running injuries. They found a trend that showed a decrease in injuries with high impact loading rates. These findings contradict other studies.

## Chapter 3

### Methods

#### *Subjects*

Ten male distance runners from the Brigham Young University cross country and track and field teams will be recruited to participate in this study. Only those who identified themselves as heel strikers will be chosen to participate. The age of the athletes will range from 18 to 28. The subjects will have been injury free for and training for at least 8 weeks prior to testing. Each subject will sign a consent form that has been approved by Brigham Young University's institutional review board.

#### *Testing Procedures*

The subjects will be instructed to use their traditional warm up. Following their warm up each subject will run three trials in both the running shoes and track spikes. Should any subject require more than 16 run-throughs, they will be asked to return at another time to avoid the affects of fatigue. The subjects will run across a force plate (9287BA, Kistler, Amherst, NY) and infrared tracking system (Vicon, Centennial, CO) with running shoes (Nike air Pegasus) and distance track spikes (Nike Rival D Plus II) at a four-minute-mile pace (6.7 m/s). Shoe order will be randomized. Timing lights positioned at head height will be used to verify that four-minute-mile pace  $\pm 2.5\%$  is achieved during the capture at the force plate. Each subject will have a 30-meter approach, allowing them to reach four-minute-mile pace. They will continue that pace through the 10-meter section of capture where the timing lights, force plate, and vicon

cameras are located, then continue that pace for 10-meters before slowing down. Samples will only be saved when the left foot lands completely on the force plate.

*Vicon.* Force and position data will be recorded and processed with Vicon Nexus 1.3 with the OLGA module (Vicon, Centennial, CO) (Charlton, 2004). The subjects will be marked with a total of 16 reflective markers on the hips, legs, and feet according to the OLGA module. Six MX13+ cameras will record marker positions at 240 Hz. A calibrated volume 6 m long, 2 m wide, and 2.5 m high will be created around the force plate. The data will be filtered using a low-pass filter that will automatically select a cut off frequency. Vicon Nexus will be used to calculate joint moments.

*Force plate.* A Kistler force plate (9287BA, Amherst, NY) that is imbedded in the Brigham Young University's Smith Fieldhouse indoor track will be used. The force plate is covered by a Mondo Super-X track surface. The sampling rate will be 1200 Hz. Joint moments will be calculated by the nexus program using force and position data. Joint data will be normalized by body weight and leg length (Hof, 1999).

*Shoes.* All runners will wear the same type of shoes. The shoes chosen for this study are the Nike Air Pegasus and Nike Rival D Plus II (Figure 4) which are typically worn by collegiate athletes. The Air Pegasus is designed to be comfortable with sufficient cushioning. The mid-sole is comparatively soft, and is neutral in terms of motion control. The Rival is a distance racing spike. The outer sole is constructed of hard plastic, with no mid-sole. The heel contains a heel wedge composed of ethylene-vinyl acetate (EVA) covered with a rubber outer sole. Track spikes do not provide rear foot motion control (Logan, 2007).

*Normalization*

In order to compare studies Hof suggests that the data should be normalized. We will follow Hof's procedure (Hof 1996) by dividing the Peak Joint Moment by the subjects' body weight and then dividing by the subjects' leg length.

*Statistical Analysis*

Differences at the hip, knee, and ankle, with the different types of shoes will be analyzed with a repeated measure ANOVA. Alpha will be set at 0.05. All statistical calculations will be used by the SPSS program.

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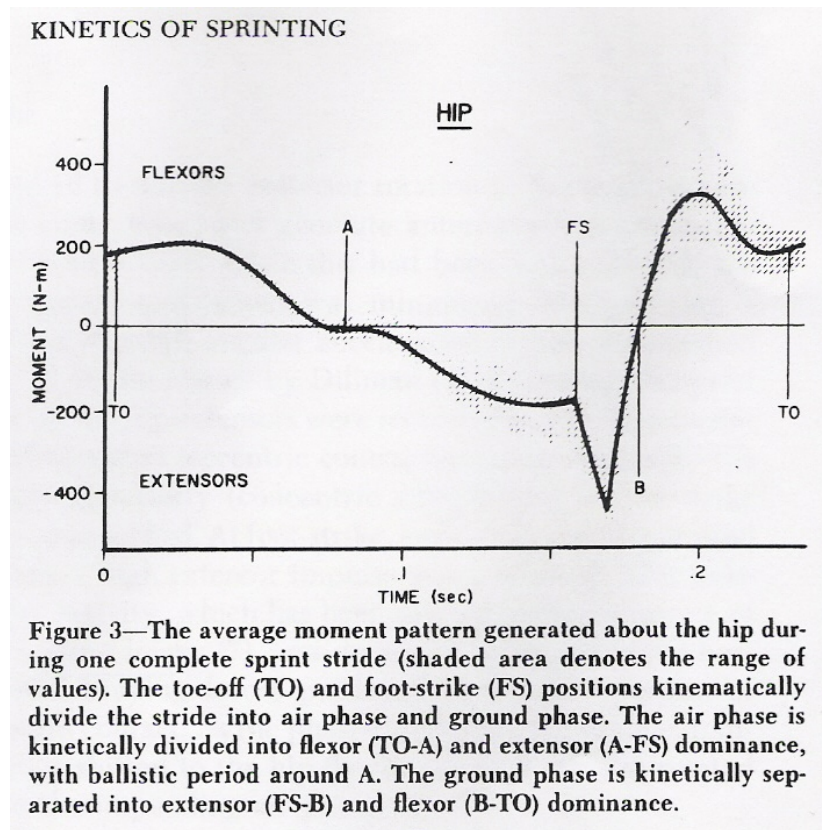


Figure 1. A typical Peak joint moment at the hip

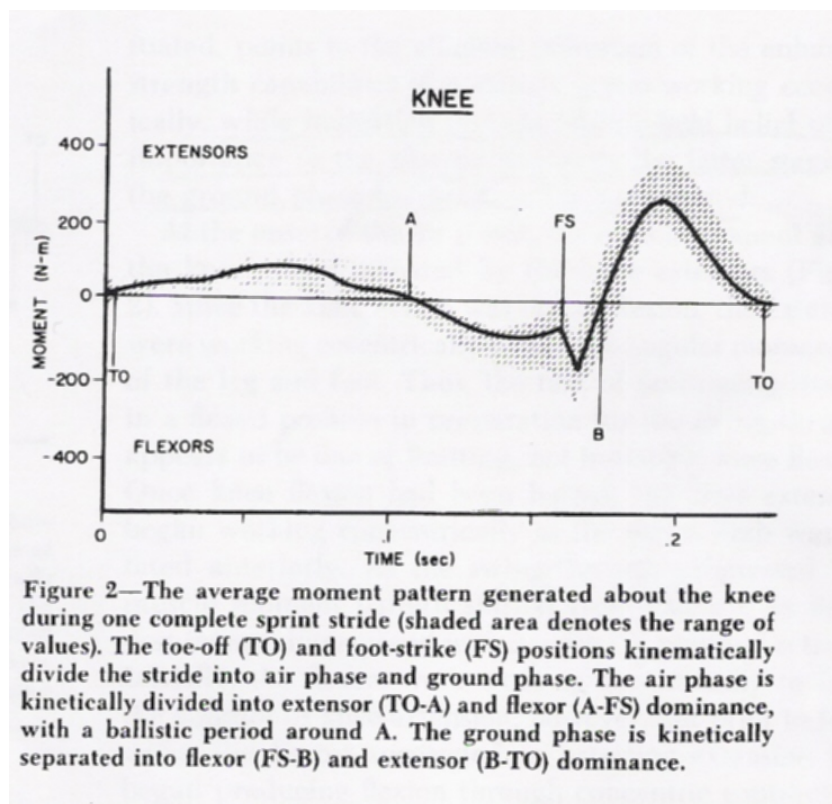


Figure 2. Typical Peak joint moment at the knee

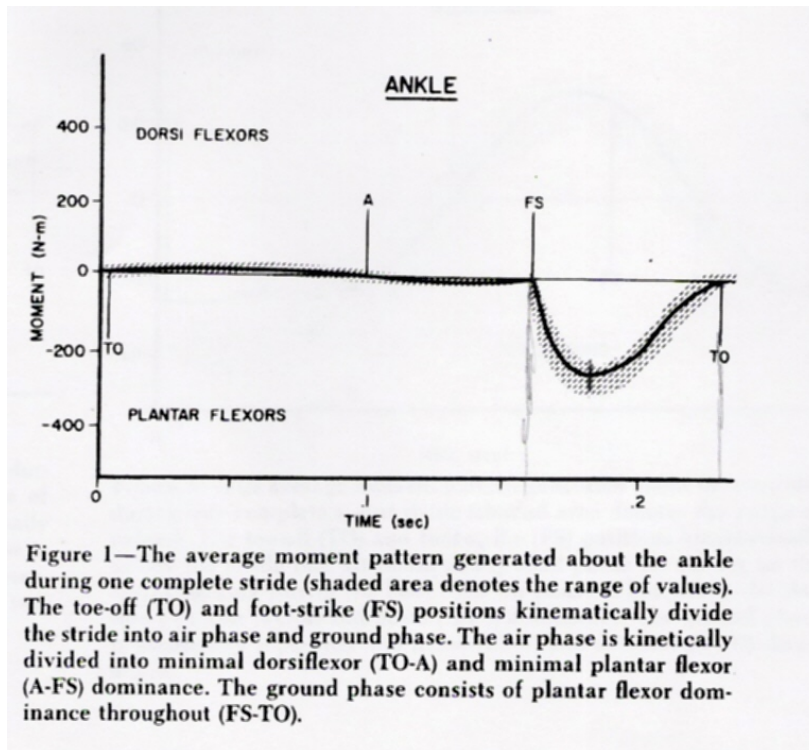


Figure 3. Typical Peak joint moment at the ankle



Nike Air Pegasus



Nike Rival D Plus II

Figure 4. Shoes typically worn by colligate runners

Appendix B  
Additional Results

**Subject 1: Average joint moments for each condition measured in Nm/kg**

Condition	PeakAnkle	MinAnkle	Peak Knee	MinKnee	Peak Hip	Min Hip
Trainers	2.41	-1.01	6.63	-1.06	5.99	-8.00
Spikes	3.71	-2.29	8.44	-2.87	9.33	-12.10

**Subject 3: Average joint moments for each condition measured in Nm/kg**

Condition	PeakAnkle	MinAnkle	Peak Knee	MinKnee	Peak Hip	Min Hip
Trainers	3.69	0.09	2.17	-1.37	2.47	-2.81
Spikes	3.11	0.22	5.50	-2.43	13.76	-10.33

**Subject 4: Average joint moments for each condition measured in Nm/kg**

Condition	PeakAnkle	MinAnkle	Peak Knee	MinKnee	Peak Hip	Min Hip
Trainers	5.87	-0.17	3.86	-2.45	7.73	-4.29
Spikes	1.50	-0.37	6.89	-1.54	5.33	-3.56

**Subject 5: Average joint moments for each condition measured in Nm/kg**

Condition	PeakAnkle	MinAnkle	Peak Knee	MinKnee	Peak Hip	Min Hip
Trainers	2.20	-0.27	5.44	-0.92	3.25	-4.03
Spikes	4.23	0.00	3.83	-1.70	4.87	-4.63

**Subject 6: Average joint moments for each condition measured in Nm/kg**

Condition	PeakAnkle	MinAnkle	Peak Knee	MinKnee	Peak Hip	Min Hip
Trainers	3.97	0.13	5.15	-1.03	5.24	-3.15
Spikes	2.83	-0.09	5.69	-0.50	3.14	-2.96



**Subject 7: Average joint moments for each condition measured in Nm/kg**

<b>Condition</b>	<b>PeakAnkle</b>	<b>MinAnkle</b>	<b>Peak Knee</b>	<b>MinKnee</b>	<b>Peak Hip</b>	<b>Min Hip</b>
Trainers	5.08	-0.78	4.45	-0.57	3.42	-5.82
Spikes	4.39	-1.41	5.10	0.77	2.97	-6.43

**Subject 8: Average joint moments for each condition measured in Nm/kg**

<b>Condition</b>	<b>PeakAnkle</b>	<b>MinAnkle</b>	<b>Peak Knee</b>	<b>MinKnee</b>	<b>Peak Hip</b>	<b>Min Hip</b>
Trainers	3.44	0.15	4.36	-1.68	5.94	-5.63
Spikes	3.25	-0.07	3.99	-2.52	6.47	-5.09

**Subject 10: Average joint moments for each condition measured in Nm/kg**

<b>Condition</b>	<b>PeakAnkle</b>	<b>MinAnkle</b>	<b>Peak Knee</b>	<b>MinKnee</b>	<b>Peak Hip</b>	<b>Min Hip</b>
Trainers	3.45	0.32	4.45	-5.98	5.71	-2.00
Spikes	1.91	-0.25	5.06	-0.96	6.46	-5.37