CAN UNSHOD RUNNING REDUCE RUNNING INJURIES?

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Can running unshod reduce running injuries? In this thesis, unshod is defined as barefoot or a minimalist running shoe. Running barefoot or wearing Vibram Five Fingers(VFF) are examples of running unshod. Within the last year, *The Army Times* published several articles regarding unshod running. The Army banned the wear of popular minimalist shoes like Vibram Five Fingers. Other services have made decisions in the wear of VFFs. The Marine Corps and Air Force approved the wear minimalist shoes during physical training, but The Army officially banned service members from wearing minimalist shoes. The Navy approved wearing minimalist shoes during physical training while writing this thesis. Outside of the military, the running community is also divided. Opinions have sparked articles, books, and entire web sites for and against unshod running. Shoe manufacturers recognize the debate but did not pick a side. Instead, shoe makers started marketing and producing minimalist shoes to get into the new market, while continuing to produce traditional shoes. With all of this debate, why would people and soldiers run unshod?

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

CAN UNSHOD RUNNING REDUCE RUNNING INJURIES?, by Major Brian Hallam, 87 pages.

Can running unshod reduce running injuries? In this thesis, unshod is defined as barefoot or a minimalist running shoe. Running barefoot or wearing Vibram Five Fingers(VFF) are examples of running unshod. Within the last year, *The Army Times* published several articles regarding unshod running. The Army banned the wear of popular minimalist shoes like Vibram Five Fingers. Other services have made decisions in the wear of VFFs. The Marine Corps and Air Force approved the wear minimalist shoes during physical training, but The Army officially banned service members from wearing minimalist shoes. The Navy approved wearing minimalist shoes during physical training while writing this thesis. Outside of the military, the running community is also divided. Opinions have sparked articles, books, and entire web sites for and against unshod running. Shoe manufacturers recognize the debate but did not pick a side. Instead, shoe makers started marketing and producing minimalist shoes to get into the new market, while continuing to produce traditional shoes. With all of this debate, why would people and soldiers run unshod?

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ACRONYMS

FFS	Forefoot Strike
MFS	Midfoot Strike
RFS	Rearfoot Strike
TC	Training Circular
VFF	Vibram FiveFingers

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CHAPTER 1

INTRODUCTION

Within the last year, the *Army Times* published several articles about running Vibram Five Fingers or other minimalist running shoes. While deployed to Afghanistan, I read one specific article in October 2010. The article is titled "On Your Toes" and it discusses the services' differences of policy for wearing Vibram FiveFingers.[1] Another article was published by the *Army Times* in August 2011 discussing the policy differences between the services and the likelihood of The Army banning the wear of Vibram Five Fingers.[2] Shortly after this last article, The Army published the All Army Activities message 239/2011 and it bans the wear of shoes that have individual compartments for each toe like the design the Vibram Five Fingers use.

The articles in *The Army Times* raised several questions. Why do soldiers want to wear the shoes or no shoes? Why is The Army banning the wear of Vibram Five Fingers? What benefits do the other services see in allowing their members to wear them? These questions are what generated the problem for this thesis and highlight the pros and cons of running unshod. The Army restricted soldiers from wearing Vibram Five Fingers in the physical fitness uniform while the other uniformed services allow their members to wear them. Outside of the military, the same difference of opinion has spurred articles, books, and web sites by running groups, pediatricians, and researchers. With all of the debate about a single kind of shoe, why would people or soldiers run unshod?

Over the last year, *The Army Times* has published articles about running unshod. These articles have been prompted by an increase of soldiers wearing minimalist running shoes, like Vibram FiveFingers. The premise for wearing these shoes is that they improve

running and prevent injuries. The civilian running community echoes these benefits as shown by the popularity of running unshod increases.

The purpose of this thesis is to determine if there is any lessons soldiers and leaders can learn from unshod runners to prevent injuries caused from running. The primary research question is can unshod running minimize running injuries? In this thesis, unshod is defined as barefoot or a minimalist running shoe. Running barefoot or wearing Vibram FiveFingers are examples of running unshod.

In the US, there are approximately 36 million runners, and every year about 65 percent of the runners suffer from trips, falls, blisters, shin splints, hip pain, back pain, knee pain, Plantar Fasciitis, pulled muscles, and a myriad of other injuries.[3] Fitness magazines carry numerous articles about how to prevent many of the injuries listed above. One debated topic is whether or not unshod running is beneficial. More and more runners are leaving their traditional running shoes behind and stepping out either barefoot or with a minimal shoe and yet there is no definitive answer on the benefits of unshod running.

Books published in the last few years also discuss running barefoot and running without injury. Some books focus on the form that is used when running for both shod and unshod runners. Many authors base their books on personal experiences instead of experiments or studies. One author ran marathons barefoot for over twenty years and another ran ultra-marathons for 20 years and neither claim to have any of the common running injuries that plague the general running population today.

Basic Training running injuries show that a large population of trainees are injured due to running. In 1996, the Armed Forces Epidemiological Board conducted a

study that correlated running with a high number of lower extremity injuries.[4] The Injury Prevention Work Group estimates that injuries in the Army result in an annual loss of 550,000 work days of which 75 percent are caused by vigorous PT. Another study in 2002 examined injury rates among Light Infantry soldiers. The study found that running injuries made up 30 percent of the injuries examined.[5]

Background

I am a military officer with 15 years of running experience. The first half of my Army career was in combat units where there is an expectation that officers are physically fit and able to run with their soldiers. Army units like the 10th Mountain Division have a culture with high physical fitness standards because the unit is light infantry and it moves on its feet. During my two years as a Company Commander in the 10th Mountain Division, one major expectation was to achieve, maintain, and surpass the physical fitness standard. The command used 2 mile and 4 mile runs to evaluate soldier's physical readiness. The readiness rate evaluates physical fitness test scores, the number of soldiers on profile, the number of overweight soldiers, and the number of soldiers that did not pass the fitness test. I also commanded a recruiting company where the culture placed less emphasis on the Army Physical Fitness standards.

Another qualification is due to my experiences over the last four years. When I arrived at my last duty station in 2008, I was suffering ankle, knee, and back pain. That winter, Army doctors explained that the pain was due to extensive running and rock marching and that the way to make the pain subside was to stop doing both activities. I sucked up the pain since I could not accept this answer because I did not want to stop running. As the spring weather got better, I ran more. After waking up several days with

a stabbing pain in my left foot, I decided to have a doctor look at it. The doctor determined the pain was due to Plantar Fasciitis, where the Plantar Tendon pulls away from the heal. The doctor prescribed physical therapy, after two months of it the pain did not go away. I explained to the therapist that the PT was not helping, and I decided to not continue with it. As I began to leave, the therapist suggested I should try running barefoot since nothing else had helped.

I began running barefoot through the city over the next several months. The first runs were only about a quarter of a mile long. By the time winter came I was running four or five miles three to four times a week. During the winter time and my deployment to Afghanistan, I used a simple pair of water shoes to run in. Currently, I run four to five days a week using a minimalist shoe without any foot pain. Was this change normal? What did I change? Why did I not change sooner? These questions challenged me until I read a recent article in *The Army Times* about wearing minimalist running shoes.

Why We Run

The military profession is a physical business where physical fitness is not for recreation or a fad. Soldiers, marines, sailors, and airmen are required to remain physically fit to be able and ready for their war time missions. Physical fitness for The Army became a major focus after The American Civil War in 1885 at West Point.

The Civil War brought the lack of physical training within The Army a renewed focus. In 1885, West Point hired it's first professional education instructor. Herman Koehler changed the academy's methodology and focus towards physical education. His *Manual of Callisthenic Exercises* addressed the problem of the poor physical conditioning of Civil War recruits by educating officers. The manual progressively built

on physical activities such as swimming, fencing, boxing, climbing, and weights. Senior classman's last year at the academy dealt with the theories of physical training and taking charge of training in future assignments. The manual has no documented running program.[6]

After World War II, physical fitness continued to develop. In 1946, Field Manual 21-20, Physical Training, expanded on Koehler's manual. The program took lessons learned from World War II and created a comprehensive manual for physical training. Exercises include rifle, log, and guerilla exercise for strength training and built a cardiovascular exercise program. This program included marching, grass drills, and running. The manual explains that running is an effective way to develop circular-respiratory endurance and should be included into daily physical training.[7]

During the Cold War, physical fitness matured beyond the 1946 physical fitness manual. The 1998 version of Field Manual 21-20, Physical Fitness Training, included much of the same activities from the post World War II version. The new fitness program added flexibility, nutrition, circuit drills and other activities. A main tenant for the manual is FITT; Frequency, Intensity, Time, and Type. Units and leaders used the FITT acronym to build a 3-5 day physical fitness training program. One change in this manual is that cardio respiratory endurance activities are only done 3 times a week. Muscular strength and endurance conditioning is done the other days. The intent is to give soldiers recovery days between running days. Running continued to remain a facet of The Army's physical fitness program.[8]

The current manual for Army physical fitness is Training Circular 3-22.20 and it was published in August 2010. Chapter 10 is focused on endurance and running. The

chapter specifically identifies various types of runs to be completed as an individual or in a formation. The running regiment calls for running sprints, shuttle drills, hills, ability group runs, unit formation runs, release runs, and terrain runs. The running program varies distance, run time, and type based on what phase of training a unit is in. Running frequency is similar to the 1998 manual and running is recommended for 3 days a week. The types of running varies depending on where the unit is within the training cycle and table 1 displays this cycle by phase. Although the Army is changing how fitness tests are being conducted, running will remain a part of the test and culture.

Table 1. TC 3-22.20 Running Program Chart

Endurance and Mobility Activities					
Activities	**Toughening Phase** (BCT&OSUT-R/W/B)	**Sustaining Phase** (AIT&OSUT-B/G)	**Sustaining Phase ARFORGEN** (Reset)	**Sustaining Phase ARFORGEN** (Train/Ready)	**Sustaining Phase ARFORGEN** (Available)
MMD 1	1 rep	1 rep	1 rep	1 rep	1 rep
MMD 2	N/A	1 rep	1 rep	1 rep	1 rep
30:60s	6-8 reps	6-10 reps w/wo load	6-10 reps w/wo load	10-15 reps w/wo load	10-15 reps w/wo load
60:120s	6-10 reps	6-10 reps	6-10 reps	6-10 reps	6-10 reps
300-yd SR	1 rep	1-2 reps w/wo load	1-2 reps	1-2 reps w/wo load	1-2 reps w/wo load
HR	N/A	6-8 reps uphill or downhill	6-10 reps uphill or downhill	6-10 reps uphill or downhill	6-10 reps uphill or downhill
AGR	10-30 min	20-30 min	10-30 min	10-30 min	10-30 min
UFR	20-30 min	20-30 min	30 min	30 min	30 min
RR	20-30 min	20-30 min	30 min	30 min	30 min
TR	N/A	20 min	20-30 min	20-30 min	20-30 min
FM	2-15 Km	2-15 Km	10 Km or less	10-30 Km	10-30 Km
CDOC	1 rep	1 rep	1 rep	1 rep	1 rep
ETM	N/A	N/A	20-30 min	20-30 min	20-30 min
Abbreviations	MMD-Military Movement Drill UFR-Unit Formation Run CDOC-Conditioning Obstacle Course	SR-Shuttle Run RR-Release Run ETM-Endurance Training Machines	HR-Hill Repeats TR-Terrain Run	AGR-Ability Group Run FM-Foot March (fl/aml/eaml)	

Source: U.S. Army, TC 3-22.20, *Army Physical Readiness Training* (Washington, DC: Government Printing Office, August 2010), 10-2.

The Army is a physical business that requires soldiers to remain physically fit and ready. Since the military requires members to be physically fit, one of the major ways of achieving this is running. Physical fitness encompasses more than pace and distance for runners, it is also about preventing running injuries. The Army made several efforts in the past to reduce soldiers' injuries from running. One example is how the Army transitioned from running in combat boots to running shoes in the 1970s and 80s. Another example is the use of matching a person's foot type with the right style of shoe. I personally experienced this method when I in-processed to the 10th Mountain Division at Fort Drum, New York, in October 2000. The medical station had a large mat in front of it that determined your "foot type." You were given a sheet that showed what style of shoes and boots you should purchase based on your foot type. Later, I asked our battalion's medical Non Commissioned Officer what was the purpose of the test. He explained that the Army was trying to reduce the number of injuries caused by running and ruck marching by ensuring soldiers knew what style of shoe went with their foot type.

Injury rates for infantry soldiers in basic combat training were examined in 1990. It was found that lower extremity injury rates ranged from 25.6 percent to 44.3 percent. The study concluded that injury risk increased as the frequency of running and marching increased.[9] The US Army Research Institute of Environmental Medicine conducted a study conduct in 1993 and observed infantry soldiers and their injury rates during basic combat training. The study observed that soldiers could have more than one injury during the six month observation period and that 51 percent of the soldiers became injured at least once for a lower extremity injury. The study concluded that 212 injuries resulted in 1764 limited duty days during the six month study.[10]

Part of a brigade combat team's readiness gauge is the number of soldiers on medical profiles. A Brigade Combat Team is made up of about 5,000 soldiers performing various jobs. If 10 percent of those soldiers have injuries caused by running, the BCT could face a critical readiness problem that jeopardizes the BCT's mission. Since all soldiers are expected to be able to run then what is the impact on the BCT if 10 percent of the brigade's force suffered from running injuries? The answer is a BCT that is not ready to perform its mission and this was the answer that the leadership at Fort Drum was not willing to accept. The effort at Fort Drum focused on injury prevention by educating soldiers on the proper style of shoes to wear for running, teaching how to stretch and cool down, and a solid physical therapy program to support folks who did get injured.

This thesis examines if unshod running can reduce running injuries. Unshod runners claim that running without shoes can prevent injuries and improve a runner's ability to run greater distances with less effort. A meta study methodology is used for this thesis to determine if unshod running reduces injury rates. The data for the study includes running shod or unshod, running injuries, and injury prevention. Information will be examined that compares runner's form and mechanics, the designs of conventional running shoes, possible association of injuries between shod and unshod runners.

The scope of this thesis is to compare the running mechanics of shod and unshod runners and determine if running injuries can be prevented. I will utilize studies on running injuries for both shod and unshod runners. The thesis also looks at the decisions that led to how the current traditional running shoe was designed and why. Data will be gathered from existing documents and experiments, but no new experimentation or case studies will be conducted.

The primary research question is supported by three secondary research questions. The first secondary research question looks into the association of injuries between shod and unshod runners. The question examines current running injury rates and common running injuries while discussing running evolution within humans.The next secondary research question explores if conventional running shoes have been designed to prevent injuries. This exploration will look into the science of running shoes and what they provide a runner. The question will also look at the history and purpose of running shoe design, mass affect and stability, and if conventional running shoes prevent injuries. The final secondary research question determines if running unshod changes a runner's form and mechanics. Research for this question includes comparative studies on running form, impact characteristics, and foot strike patterns.

Assumptions

One assumption is that this thesis comply with the uniform guidelines of The Army. Also, all soldiers constitute the running population of The Army's formations. Finally, the Army will not adopt a barefoot running program.

Limitations

The major limitation for this thesis is that the author is unable to conduct experimentation due to lack of resources and time.

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[1]Jon Anderson, "On Your Toes," *Army Times*, 7 October 2010.

[2]Jon Anderson, "Services Split on Toes Shoes for PT," *Army Times*, 4 August 2011.

[3]Amby Burfoot, "The 10 Laws of Injury Prevention," *Runners World* (March 2010).

[4]B. H. Jones, “Injury group conclusion. In injuries in the Military: A Hidden Epidemic” (Technical Report ,USALHPPM 29 HA 4044 97, Armed Forces Epidemiological Board, 1996), 2.1-2.12.

[5]Tracy Smith, “The Incidence of Injury in Light Infantry Soldiers,” *Military Medicine* 167, no. 2 (2002): 104.

[6]War Department, *Manual of Callisthenic Exercises* (Washington, DC: Government Printing Office, 1892). 7.

[7]War Department, FM 21-20, *Basic Field Manual, Physical Training* (Washington, DC: Government Printing Office, 1941). 173.

[8]Department of the Army, FM 21-20, *Physical Fitness Training* (Washington, DC: Government Printing Office, 1998). 28.

[9]K. Reynolds, “Frequency of Training, and Past Injuries as Risk Factors for Injuries in Infantry Soldiers,” *Army Research Inst of Environmental Medicine* (13 November 1990).

[10]J. Knapic, “Physical Fitness, Age, and Injury Incidence in Infantry Soldiers,” *Journal of Occupation Medicine* 35, no. 6 (June 1993): 598-603.

CHAPTER 2

LITERATURE REVIEW

Chapter 2 is organized around the three secondary research questions created to answer the thesis question. This organization was chosen since each question has sources that range from a narrative description to a technical study. The intent is to arrange the sources in a manner that is logical and places the material in alignment with the questions that are being asked. The sources reviewed for this thesis focus on the question of whether or not barefoot running can prevent injuries The first secondary question is whether there is an association between unshod and shod running injuries. Next, the second question is whether or not shoes were designed to prevent injuries. The final question asks if running unshod changes a runners' form and mechanics.

Injury Rates

The first secondary research question determines if there is an association between shod and unshod running injuries. Dr. Bramble from the University of Utah's Department of Biology and Dr. Lieberman of Harvard's Skeletal Biology Laboratory researched endurance running and runner's foot strike. The team specifically asked how and why humans were able to run long distances in the past without conventional running shoes. They looked at the impact of foot strikes and how the foot lands when running. Their efforts produced a study that quantitatively evaluates running impact and the effect it has on the human body. Also, Dr. Lieberman's team looked into the evolution of humans and looked at the barefoot running question from an anthropological view. They examined how humans differ from other animals within the animal kingdom when it

comes to running and why humans were successful as hunters. The study of evolution is quantitative but takes a scientific approach to comparing humans and other species. Two graphs are utilized from this study. The first compares endurance running performance in humans and quadrupeds. The second graph compares the metabolic cost of transport in humans and ponies.

In 2002, J. E. Taunton conducted a analysis of 2000 running injuries to conduct an update of an injury database at the Allan McGavin Sports Medicine Center. He examined contributing factors to running injuries and compared them to a controlled group of runners. The analysis showed various risks associated with specific running injuries. Common injuries found were pattelofermoral pain syndrome, ilioitibial band fraction syndrome, plantar fasciitis, meniscal knee injuries, and tibial stress syndrome.

Taunton conducted another study to determine the number of injuries that occurred during a running training program. The study examined 17 running clinics and 844 runners conducting training for a 10km race in Vancouver, Canada. The clinics participating in this study used the same training program and the result was an injury rate of 29.5 percent.

Captain Tracy examined the cause of muscloskelatal injuries among 3,195 infantry soldiers in the 25th Infantry Division in Hawaii. Smith examined medical records for soldiers from six battalions from June 1997 to June 1998. The records review examined how the injury occurred, diagnosis, number of visits, and the number of profile days. This record examination found that soldiers with running injuries spent seven times more days on profile than those not injured while running.

In 2004, Alan Hrejac published an article called "Impact and Overuse Injuries in Runners" in *Medicine & Science in Sports & Exercise*. The article examines the concept that tissue's adaptability to stress can be fatigued to the point where overuse injuries occur in runners. One of the main factors examined is the affect of adjusting runner's training programs to educate runners and lower the risk of lower extremity injuries. The author found that educating runners was more effective prior to injuries than during the post injury rehabilitation time. The information used from this article pertained to the affect of impact on runners and lower extremity injuries.

In 1980, D. B. Clement published an article about the prevention of running injuries called "A Guide to the Prevention of Running Injuries." The guide examined the sociological, psychological, physiological factors and hazards of running. It also provides a training method that gives examples of flexibility and strength drills while examining the biomechanics of running. Clement's goal is to educate runners about the signs and symptoms of injuries to reduce running injuries through training and fitness programs.

In 2009, The U.S. Army examined the practice of prescribing running shoes based on foot shape. J. Knapic conducted a study for the U.S. Army to determine if this technique reduced injury rates among trainees in Basic Combat Training. The study examined recruit's foot shape and the assignment of prescribed type of footwear. This study concluded that assigning running shoes based on foot shape did not have an affect on running injuries.

Adam Daoud of Harvard University conducted a study of collegiate endurance runners and the injury differences between forefoot and rearfoot striking runners. Daoud collected the history of the 52 runners and quantified their injury rates and severity based

on the runners foot strike. 59 percent of the runners used a rearfoot strike and the injury rate among all the runners was 74 percent. The conclusion was that the rearfoot striking runners have a significantly higher rate of repetitive stress injuries compared to forefoot runners.

"Running-related Injury Prevention through Barefoot Adaptions", written by Steven E. Robbins from Concodria University, hypothesizes that unshod populations have a lower extremity injury rate due to the body's natural ability to absorb shock. The study examined foot rigidity and arch function in runners while shod and unshod. This study concluded that running shoes obscure sensory feedback to the runner and this is responsible for the frequency of running injuries.

In 1990, the U.S. Army Research Institute of Environmental Medicine conduct an analysis of training injuries among infantry soldiers. The analysis examined the development of endurance through running and ruck marching. Medical records were reviewed and the first time injury rate was 25.6 percent.

In *Born To Run*, Chris McDougal starts with the problem of solving his own running injuries. The book is a personal account of his experience in Mexico with a remote tribe called the Tarahumara. McDougal writes a first person account of his journey and highlights some of the issues that brought the author to the point of wanting to discover a better way to run. The Tarahumara tribe is known for sending tribesman to several international ultra-marathons and McDougal's book is an exploration into their lives in the Sierra Madre mountains. The narratives and personal accounts are qualitative data and is an account of author's experiences in Mexico as he journey's with a tribe of people who run upwards of 30 miles daily in nothing more than a sandal.

McDougall also published an article in the *New York Times* called "The Once and Future Way to Run." Like *Born to Run*, McDougal writes a narrative about running barefoot but focuses on form. He discusses how many runners still heel strike when running and uses Dr. Liberman's running evolution study to highlight the need for better running form. In the article he discusses a training plan to help correct or reinforce form. He uses the stories of two runners to explain how the exercise works.

"Barefoot" Ken Bob is cultural icon within the barefoot running community. He has been running barefoot for over 25 years to include completing many marathons and ultra-marathons. He has a web site dedicated to the running barefoot and published *Barefoot Running* , a repository of blogs and teaching points that he communicated throughout the years. His book gets into some running form techniques, but is based on his personal experiences. The book's information is qualitative because it provides a reference on how running should feel based on personal experience.

Shoe Design

The next secondary research question is whether or not the design of conventional running shoes prevents injuries. In 1998, The US Army introduced a program called the Running Shoe Selection Program that measured a soldiers' shoe at multiple points and placed the soldier's footwear into three foot types. These foot types classified soldiers as having a low, normal, or high arch. Soldiers were given guidelines on what style of running shoes to purchase and when to replace the shoes. The purpose of the program was to raise the awareness for soldiers and attempt to reduce lower extremity injuries. I mentioned this study in the chapter one, but I was unaware that the experience at Fort Drum, New York, was a part of the Running Shoe Selection Program. In November

2010, Lieutenant Colonel Teyhen conducted a review of this program and published an article in *Military Medicine*. Her review examined the physical differences of runners, their pace, and arch types. LTC Teyhen concluded that educating service members about the guidelines for selecting and replacing running shoes could prevent running injuries.

A month prior to LTC Teyhen's article in October 2010, *Soldier's Magazine* published an article called "Studies Debunk 'sports myth' of Running Shoes." The article explained that three military studies concluded that prescribing shoes based on foot type has no effect on injury rates. Military decision makers and runners were surprised by this result. A total of 9,000 pairs of feet were measured and given a prescribed different shoes based on arch type. Low arch runners should wear motion-control shoes while high arch runners need to wear a cushioned shoe and normal arch runners should wear stability shoe. The concept was that the shoes would compensate for the foot types strike while running. The Marines also conducted a similar study with 1,400 runners and found that those with prescribed shoes did not have less injuries than those without prescribed shoes. The article concluded that shoes worn based on foot type and shape does not prevent injuries.

In 2006, Mark Bishop wrote "Athletic footwear, leg stiffness, and running kinematics," and he explores the impact of foot wear on leg stiffness and the response to changes in surface. The author collected data using force impact plates and evaluated knee and ankle angles at the initial point of foot impact while running. He conducted repeat measurements of leg stiffness at different speeds and examined the variances. The team also looked at ankle motion and leg stiffness with shoes of various cushioning. This study concluded that although additional cushioning reduces force impact it increases leg

stiffness. The leg stiffness in shod runners caused by cushioning accounted for twice as many injuries as unshod runners during the study.

In 2006, Mark Bishop conducted a comparison of leg stiffness and kinetics between unshod and shod runners. His study utilized a force plate to capture running data and evaluated knee and ankle angles at initial ground contact and peak joint excursion. The method repeatedly measured joint and leg stiffness as running speed was increased. He concluded that barefoot runners increased ankle motion to a greater extent than shod runners as speed increased and that footwear influences the stiffness within the ankles and knees when running.

"Barefoot-Shod Running Difference: Shoe or Mass Affect?," by Divert was written in 2007 and is a study that focuses on how a runner's form changes when running in a variety of foot wear. This study is a very controlled study where runners run shod and unshod on a treadmill. The team looked at a variety of factors such as stride, posture, leg stiffness, and shoe weight. The study concluded that running shod has a lower net efficiency than unshod running.

Benno Nigg conducted a comparison of unshod running and various "barefoot" shoes. His study, "Biomechanical consideration on barefoot movements and barefoot shoe concepts," examined several shoes by manufacturers who market footwear that mimics barefoot running. The author compares the Nike Free , Nike Vivo, The Feet You Wear, Earth Footwear Kalso, and MBT Masai. The study established a barefoot performance baseline and compared the various shoes against that. The baseline included biomechanical differences, training effects, oxygen consumption, and running injuries. The "barefoot" shoes are compared against the affects of running in these types of shoes

and barefoot. The author concluded that there is no significant difference between these shoes and running barefoot.

Dr. Ben Pearl gives a good general discussion about running barefoot in his article "Barefoot running, or just a minimalist shoe?" He discusses how collegiate running coaches like Johnson and Lananna use barefoot running techniques to train runners. There is a brief mention about the Nike Free and how the Stanford Running team tried to use it in training. The author also discusses Abebe Bikila's barefoot marathon run in the Rome Olympics and briefly covers Bikila's foot fall during the run. Dr. Pearl concludes that the running shoe industry is providing more minimalist shoe designs and training barefoot will make the smaller muscles of the foot stronger.

In 1982, The Journal of Orthopedic and Sports Physical Therapy published a study by Mary Rodgers that examined the effectiveness of orthotic devices in running shoes. The study compared runners while running barefoot, shod, and shod with foot orthotic devices. The main measurement for this study was the angle of foot pronation while running. Results could not prove or disprove the use of orthotic device effectiveness. This study identified that pronation is normal but recognized that further studies are needed to understand the function of pronation and running gaits.

Randy Frank published an article in 2004 about Addidas engineers and their efforts to create a smart running shoe. The article explored how Addidas designed and manufactured the Addidas 1. This shoe is constructed with a microcontroller, motor screw, effect sensor, and specially designed plastic cushioning. The design of the shoe allows the microcontroller to make adjustments to the shoe's cushioning based on the

impact the sensor picks up. Higher impact causes the processor to turn the motor screw allowing adjustments to be made based on surface, speed, and distance traveled.

The *Journal of foot and Ankle Research* published an article in 2011 about the effect of shoes on children's gait. The meta-analysis evaluated the biomechanical effects of shoes on children during walking and running. This analysis found that shod walking increased velocity, stride length, and time to toe-off while shod running decreased cadence, ankle flex, shock-wave transmission, and leg swing velocity. The analysis concluded that shoes effect children's gait while running by reducing leg swing speed and absorb shock to allow rearfoot striking.

In 2006, Robert Butler examined the premise that running shoes are designed to reduce the risk of injury by accommodating various arch types. The purpose of his study is to evaluate the effects of motion control and cushioned running shoes on the running mechanics of low and high arched runners. Butler used three-dimensional kinematics and kinetics to evaluate the effect of two different shoes and response of the runners. He found that low arch and high arch runners responded differently to both cushioned and motion control shoes. Butler concludes that runners need to select running shoes based on running mechanics versus arch type.

Brian Colleran discusses his experience with Vibram FiveFingers in "New Way to Run." This article in *Environmental Magazine* is written from a first person perspective about his test drive of FiveFingers. Colleran's initial conclusion was that the FiveFingers were not for him and tossed into the back of his closet. His second attempt at using the FiveFingers was a more gradual transition until his feet became uncomfortable in his normal walking shoes. One interesting point in the article is that Colleran discovers

that no one has published a study showing that high-heeled, cushioned running shoes prevent injury.

In 2003, Joseph Hamill studied the impact characteristics of shod and unshod runners. The study compared the impact characteristics of shoes with different sole thicknesses to a barefoot running condition. Runners foot impact characteristics at their preferred running speed and at a fixed speed. This study found that there is significant differences between the shod and barefoot running conditions. Runners altered their footstike from a shod rearfoot strike to a barefoot mid or forefoot strike. The study concluded that impact characteristics change due to changing footfall patterns rather than shoe sole thickness.

Running Form

The final secondary research question asks if running shod or unshod changes a runner's form and mechanics. The first source examined is "Oxygen cost of running barefoot vs. running shod." N. J. Hanson from the University of Nebraska conducted an evaluation of oxygen cost while running shod and unshod on a treadmill and over ground. Ten runners participated in the study and were placed in four conditions for evaluation. The conditions were barefoot on a treadmill, shod on a treadmill, barefoot over ground, and shod over ground. Each runner performed a six minute run in each condition and the researched evaluated VO, heart rate, and perceived effort. The conclusion of the study is that unshod running is more efficient than running shod on both the treadmill and over ground.

Dr. Lieberman of Harvard's Skeletal Biology Laboratory conducted a study of foot strike patterns and collision force between barefoot and shod runners. He compared

three groups of runners that ran a minimum of 20 miles a week either shod or unshod. Then, the runners' foot strike was compared by breaking the runners into groups organized by a front-foot-strike (FFS), mid-foot-strike (MFS), or a rear-foot-strike (RFS). His team focused on the difference of RFS and FFS while examining joint angles of the knee, ankle, and plantar surface at foot strike. The team then looked at the joint angle at foot strike of the knee, ankle, and the plantar plane. The study concluded that RFS runners impact with the ground with one and half to three times their body weight, while non-RFS runners experience lower impact.

The next article used for this question is "Barefoot-shod running differences" by C. Divert. This article examined the mechanics and energetic of running shod and unshod. The author used 12 running subjects on a treadmill under 6 different foot or shoe conditions. These conditions ranged from running on a treadmill barefoot to wearing a heavy running shoe. The subjects were evaluated against stride frequency, leg stiffness, and oxygen consumption. Researchers concluded that running unshod yielded a higher stride frequency and that shod running had a lower metabolic and mechanical efficiency.

"Pose Running Technique: A Beginner's Guide" is an article that was published in 2002 to give readers a brief history and overview of what the Pose running technique is. The article explains running principles and examines the difference between rearfoot strike running and midfoot striking. Ramanov's warns that runners starting his Pose technique need to develop the strength needed for the form. Nine drills are used to give the runner the lower extremity strength and a basic understanding of the Pose running technique.

Harvard's Daniel Lieberman published a study in 2010 that examines footstrike patterns in shod and barefoot runners. Lieberman's hypothesis is that human's ran barefoot or in minimalistic shoes like moccasins prior to the invention of high-heeled, cushioned running shoes. He examines how barefoot endurance runners handle running impact stresses by landing on the forefoot. The study used kinematic and kinetic analysis to show that barefoot runners using a forefoot or midfoot strike generate less collision forces than shod rearfoot striking runners. The study concludes that runners used forefoot and midfoot strike when shoes provided less cushioned protection and that this lack of cushioning may have prevented impact related injuries that are now present in a high percentage of runners.

The Journal of Athletic Training published an study called "Athletic Footwear, Leg Stiffness, and Running Kinematics" in 2006 by Mark Bishop. This study examined the affect of cushioned running shoes on leg stiffness and changing surface rigidity. The intent is to understand how leg stiffness is regulated and affected by running shoes. Different shoes had no affect on leg stiffness but there was a difference between the shod and unshod condition and leg stiffness. Bishop found that as speed increased, unshod runners landed with a flexed knee and had a greater range of motion in the ankle joint. His conclusion is that shoes affect leg stiffness and ankle motion while running.

In November 2010, The Army Physical Fitness Research Institute published an article on Vibram FiveFingers. The article highlighted the fact that Vibram FiveFinger's popularity has grown since their introduction in 2006 and the publication of *Born to Run.* It discusses the idea that the FiveFingers promote a forefoot strike and this can help reduce injuries among runners. Also, it warns that runners should be cautious of using

VFFs without a transition period. The article explains that most people have grown up wearing running shoes and that going straight to a forefoot strike will take time to adjust to. Without allowing the intrinsic and extrinsic muscles of the foot time strengthen, runners risk injuries such as strains and stress fractures.

Another book reviewed was *Chi Running* by Danny Dyer. The author discussed the idea of how to properly run without causing injuries. A large part of the book covers running form and compares good form to how young kids run. Although Dyer includes principles of Chi application in his book, the writings are not philosophical. The author's focus is instructing runners to perform their running with less effort and injuries. The comparison of running and how children run is a recurring theme throughout the book. It is explained that proper form is with midfoot strike, leaning from the ankles, and a circular foot motion.

CHAPTER 3

RESEARCH METHODOLOGY

Chapter 1 described the injury problem facing many runners. It looked at historical examples of the importance of Army physical fitness, relevance of running in the military, and established that running will remain a part of future physical fitness programs. This thesis looks at whether running unshod can reduce running injuries. The purpose of Chapter 3 is to describe the research method, how information was collected, the criteria developed and used for evaluation, and how it applies to the main thesis question.

The research method for gathering data and conducting analysis is meta-study. A meta-study gathers multiple previous studies and compares their findings. Meta-study was chosen for this thesis because the sources contain a variety of qualitative and quantitative information. The medical community conducts meta-studies to create and develop new ideas from unrelated research. One example is how Dr. Ananya Mandal examined several studies on aspirin and developed a hypothesis that aspirin can slow the growth of cancerous tumors.[1]

Gathering The Data

As stated at the start of chapter two, there are three secondary research questions that help answer the thesis question. They are: is there an association between shod and unshod running injuries, does the design of conventional running shoes prevent injuries, and does running unshod change a runner's mechanics and form. Information for the first secondary research question was collected first. Sources collected and reviewed focused

on running injury rates and causes of running injuries. The primary sources for this data were periodicals, running journals, and other professional journals. The source information is primarily quantitative, but there is a small number of sources that are qualitative in nature. Articles focused on the impacts of running mechanics and form while running shod and unshod.

Next, the information for the second secondary research question was collected. These sources looked at running shoe design, how shoes affect running injuries, and if running shoes impact running form. The information was gathered from professional periodicals, journals, and internet articles. The data has a mix of qualitative and quantitative data.

Finally, information for the last secondary research question was gathered. This last group of sources examined running mechanics and running forms. The data for this question is primarily qualitative data and was gathered through books, journals, and internet articles. The information gathered is subjective and has little scientific information, but is relevant because the information is based on what people are saying and doing.

Criteria Definitions

The next phase examines how the criteria are defined. Criterion are designed to help answer the primary research question of can running unshod reduce running injuries. The five criteria are injury rates, running form, impact, shoe design, and running efficiency.

The first criterion is injury rates of shod and unshod runners. These rates are defined by any injury caused from running and the common injury areas are hip, knee

joint, ankles, and foot areas. The data is gather by comparing injury rates from the information sources and then determining what the most common injuries are. Injury rates are measured by the total number of injuries reported compared to the total number of runners. The result is a percentage of injured runners from the running population.

The next criterion is running form. This criterion describes how runners impact the ground while running. There are three types of foot strikes; rearfoot, midfoot, and forefoot. Running form criterion weighs which foot strike type is better in the shod and unshod condition. Rearfoot strike is also commonly known as “heel strike”, and the two terms will be used interchangeably in this thesis.

The third criterion is impact while running. Impact is defined as the multiplication of the runner’s body weight at peak impact. This criterion determines whether running shod or unshod has less impact forces generated while running. The metric for this criterion is the amount of body weight a runner impacts the ground with. Jumping has an impact amount of ten times a person’s body weight. The criterion is applied by multiplying the shod and unshod impact amount by the criterion’s weight. Lower values are better for the result of this criterion.

The fourth criterion is running shoe design. This criterion examines the type of shoes worn by runners and the effect of these shoes on injury prevention. The metric for this criterion is either that “yes” shoes are effective in preventing injuries or “no” they are not.

Running efficiency is the final criterion. This criterion is constructed of several factors that are common among sources. These factors are oxygen consumption, expended energy, and stride rate. In several sources, these factors are not major

evaluation criterion independently, but are combined to evaluate an overall efficiency. Running efficiency is measured by comparing whether the individual factors support running shod or unshod.

Applying The Criteria

Applying the established criteria is the last section of chapter three, and it will explain how the criteria is used to answer the research questions. As defined above, the five criteria used to answer the primary research question are: running injuries rates, running form, impact forces, shoe impact , and natural running. Injury rates is the primary criterion and the other criteria support the primary. In chapter four, information answering the secondary research questions is presented and the criteria are applied at the end of the chapter. The criteria will be determine if the question supports shod or unshod running. Determinations of “for” are awarded a score of “1”. Determinations of “against” are awarded a score of “-1” and “neutral” determinations are awarded a score of “0”. Criteria are weighted and multiplied by the result and the assigned weight. A source that is compared against a weighted criterion scores a “1” and is multiplied by 2 results in a 2(1), with the unmodified score displayed in the parentheses. Injury rates and running form are weighted as 2 because these criteria most directly answer the primary research question. The other criteria are weighted at one.

The five criteria help compare and contrast characteristics of running shod and unshod. This comparison will determine whether running unshod can help the Army reduce running injuries among soldiers. The results will also be used to make recommendations for additional study.

[1]Ananya Mandal, “Aspirin Lowers Risk for Cancers: Meta Analysis,” http://www.news-medical.net/news/20120328/Aspirin-lowers-risk-for-cancers-Meta-analysis.aspx (accessed April 15, 2012).

CHAPTER 4

ANALYSIS

The purpose of this research is to analyze the source material against the criteria to determine if running shod or unshod can reduce running injuries. Chapter one discussed the Army's reluctance to adapt Vibram FiveFingers as a running shoe for soldiers and some of the history of running within the Army. Most people have been wearing running shoes since they were children and as recruits enter The Army and run as they always have. It also showed that current running injuries effect about 70 percent of runners a year.[1] This trend could have potential impacts on unit readiness.

This chapter is organized into sections for each secondary research question. The first section examines injury rates, causes of injuries, and then running and human evolution. The second section examines running shoe design, shoe influence on running form, and whether running shoes changes running mechanics and form. Section three examines if running shod or unshod is more efficient, impact forces, and if there is a proper running form. The chapter closes by applying the criteria developed in chapter three to the information provided in this chapter.

Is there an association between shod and unshod running injuries?

Injury Rates

Lower extremity injuries in soldiers have been identified as early as the Prussian Army in 1855. Prussian medical officers documented fracture injuries in 1897 and the Israel Defense Force identified lower extremity injuries occurred with an incident rate of 5 percent in 1975.[2] The existence of lower extremity injuries in soldiers was also

identified in post World War II soldiers. It was discovered that the injuries were caused by weak muscles that could not handle the stress created by physical activity. The preponderance of injuries occurred in new troops that led a more sedentary life prior to basic training.[3]

In 1974, The U.S. Army reported that basic training recruits had a lower extremity injury rate of 10 to 15 percent and this caused the U.S. Army to focus on injury prevention. It was hypothesized that the lack of cushioning in combat boots was a major cause of running injuries. In the early 1980s, the U.S. Army transitioned to conducting physical training in running shoes that provided the impact protection that combat boots did not have.[4]

Running injuries have continued to rise in the civilian running community since the 1980s. In 1982 the running injury rate was 35 percent and it continued to rise to 50 percent in 1992.[5] The U.S. Army has conducted studies in 1990 and 2002 that have established a lower extremity injury rate of 30 percent among Infantry soldiers in basic training.

Today, various injuries plague runners and the five most common injuries are patellofemoral pain syndrome, iliotibial band syndrome, plantar fasciitis, meniscal injuries, and patellar tendinopathy.[6] A survey in 1983 found that 58 percent of the runners in a marathon became injured while training for the race. Thirty five percent of the injured runners say the injuries impacted their performance during the marathon and six percent never recovered from the injury.[7]

A later study in 2002, by Taunton, reviewed injury rates from 1998 to 2000 and found that the most common injury was knee pain and the injury is still the most

prevalent running injury.[8] The purpose of this 2002 study was to collect recent lower extremity injury data and update a 20 year old database at Allan McGavin Sport Medicine Center of the University of British Columbia. These running injuries were caused by factors such as training errors, old shoes, poor flexibility, previous injuries and experience. The author pulled 2002 patient records for a period of eight years. The top five overuse injuries were found to the same as the top five injuries in 1983.[9] The knee was the most common injury area making up 42 percent of the injuries. Foot and ankle injuries were 16.9 percent and the lower leg made up 12.8 percent of the injuries. The rest of the injury locations are hip, Achilles tendon, upper leg, and lower back.[10] This study showed that the knee continues to be the most injured area even after 25 years of running shoes being used.

Another study in 2002, surveyed 844 recreational runners who were training for a 10 kilometer race. The Sport Medicine Council of British Columbia executed 17 running training clinics over a 13 week program. The program was a progressive schedule that required three days of running that built up from 35 minutes to 66 minutes of running. The study showed that 250 of 844 the runners during study reported an injury.[11] These injuries were reported across the 17 clinics and clinics reported injury rates as high as 48 percent while others reported injury rates as low as 20 percent. The knee was the common area of injury followed by the shin, foot, Achilles, and ankle in that order.[12]

The results surprised the Sport Medicine Council conducting the study. They expected that the injury incidence would be lower due to the controlled running regiment and focus on injury prevention. All 17 clinics used the same training program and the study found that cross training and terrain type did not influence injury rates.[13]

Another common running injury among runners is overuse injuries. A 2003 study by Hrejac estimated that 70 percent of runners suffer from overuse injury on an annual basis.[14] He found that impact forces from rear foot variables and pronation are contributing factors.[15] The author looked at the relationship between stress application and injury rates. Stress causes fatigue and there might be an optimal level of applied stress and frequency to avoid the fatigue that causes overuse injuries. Foot impact is identified as an important type of stress that affects the human body while running. The article author concluded that if runners incorporate strides that produce lower impact forces then the risk of overuse running injuries is lowered.[16]

The U.S. Army conducted several studies to identify the cause of lower extremity injuries. In 1990, the U.S. Army Research Institute conducted a study of trainees going through Infantry Basic Training. The study estimate that 29 percent of Basic Combat Training recruits are injured due to running during the eight week training cycle. It was found that soldiers with no past injuries had a lower extremity rate of 25 percent and trainees with prior lower extremity injuries had an injury rate of 45 percent.[17] This percentage of injuries is significant when compared to the 1974 basic training statistics of only 10-15 percent having lower extremity injuries when they ran in boots and we now run in running shoes.

Another study conducted for The Army by the U.S. Army Public Health Command examined training injuries and the causes of the injuries. Running caused 33 percent of all reported injuries. This study also found that an average of 13 duty days are lost per injury. The study also established that there is an association between the running injury risk factors within civilian and military running populations.[18]

What causes running injuries?

Running injuries can cause a dedicated runner to stop running immediately. Injuries generally involve micro trauma to muscles, tendons, and bones from continued exposure to running. Injuries occur when there is insufficient strength and endurance to handle the stress the body is under when running.[19] Injuries induced by training errors make up more than 50 percent of running injuries.[20]

Foot strike is a subject that several studies have explored to determine how it correlates to injuries. Despite technological advancements in shoe designs, runners are still prone to stress injuries due to running.[21] Daniel Lieberman of Harvard discusses the differences of rearfoot strike and forefoot strike in "Foot Strike Patterns and Collision Forces in Habitually Barefoot Versus Shod Runners" published in 2010. Lieberman utilized shod and unshod runners during this study. Shod runners and a portion of unshod runners used a rearfoot strike while the majority of unshod runners used a forefoot strike. Rear-foot strike generates up to three times the runner's body weight in impact forces when the foot meets the ground. Unshod runners only generate .58 times their body weight in impact forces while running and rearfoot striking generates five times the impact forces of forefoot strikes.[22]

Impact force is defined by the force of collision of two bodies over a short time. Impact forces generated while running is a significant cause for lower extremity joint injuries. Impact forces vary based on velocity, body mass, area of contact, and properties of dampening materials such as shoes or running surface. What remains constant is that runners impact the ground at about three times their body weight while running shod for 20 milliseconds. In relation to running, jumping creates impact of 10 times the body

weight for a duration of 10ms. Although 20 milliseconds is not long, runners impact the ground approximately 1,000 times for every mile they run. Over time, these thousands of repeated impact forces apply stress to the body and play a significant role in overuse injuries.[23] Thus, knees and ankle injury rates are higher than any other injury.[24] Common running injuries caused by high impact forces include stress fractures, shin splints, chondromalacia patellae, plantar fasciitis, and Achilles tendinitis.

Is running natural for humans?

One of the questions asked during the research for this thesis was why people continue to run if running injuries are so prevalent. First, physical activity has been removed during work day activities as western society progresses from an agricultural base to an industrial one with computer automated systems. As automation becomes a dominate part of society more individuals seek physical activity in recreational modes. This is highlighted by the increased number of long distance runners since 1970 when there was two million recreational runners, and today there are over 39 million runners in the U.S.[25]

Next, a significant number of people have found that distance running four to eight miles at an easy relaxed manner helps form running habits. In 2007, there were 340 marathons that took place in the U.S. alone with an estimated 407,000 runners.[26] This statistic does not include half marathons, 5km or 10km runs, triathlons, and ultra marathons. Regular running is associated with the release of endorpahic substances and research suggests that runners become restless, tense, and irritable during periods of no running. These factors are some of the psychological effects of running. People continue

to run because of the sense of enjoyment and wellbeing associated with the act of running.[27]

Finally, running has been proven to produce positive effects within the human body. Some of the physical benefits of running include improved oxygen use, increased coronary vessel diameter, improved collateral circulation, better free fatty acid mobilization, reduced chylomicron production, and insulin and triglyceride production is reduced.[28]

One author, Dennis Bramble, began examining the characteristics of endurance running in the animal world by comparing walking and running animals. Bramble wondered how humans have survived since humans are not the strongest, fiercest, or fastest animal in the animal kingdom.[29] Running animals include horses and dogs. Pigs and chimps are examples of walking animals.

A key concept that sparked Bramble's research was that there are two types of great runners: sprinters and marathoners. He deduced that humans were not the fastest animals. But what about running for distance? Bramble began examining the similarities between humans and chimps but found several key differences. He explains that two-legged gaits are unstable and running requires special mechanisms for stabilization and balance. Humans possess what is called the nuchal ligament. This ligament is present in other running animals such as horses and dogs or larger animals like elephants. The nuchal ligament is used to stabilize an animal's head while running. Pigs and chimps do not possess this ligament because they are walking animals.[30] Another unique human feature is the gluteus maximus. This muscle connects the erector spinea muscles to

enhance trunk stabilization during the forward pitch of running. Its job is to keep the upper body from falling to the ground during the forward pitch of running.[31]

Heat regulation for animals is a critical component. Running generates massive amounts of heat in an animal. Humans have two main features to dissipate and regulate heat. The first feature is our sweat glands. The reduced amount of hair that we have allows for the human sweat glands to dissipate heat, and the sweat cools the skin surface. Humans are the only mammals that shed heat by sweating.[32]

The second human feature is our respiratory system. Mouth breathing is a necessity for endurance running to allow the higher airflows needed for ventilatory demands. Chimps typically are nasal breathers but humans breath through the mouth during strenuous activity. As a point of reference, lizards can make a short quick scramble, but cannot breathe and run at the same time. When many quadrupeds run, their internal organs expand and contract like an accordion as they stride when running. As a cheetah strides forward, its lungs expand and take in air. When the cheetah compresses its stride, the lungs are collapsed and the cheetah breathes out. This take-a-step and take-a-breath cycle is the primary means that most mammals cool and regulate their temperature. It is also a limiting factor for running animals. If an animal's temperature gets to high they have to stop running or die. The human respiratory system operates independently of the thermoregulatory system, and this allows humans to undertake endurance runs for as long as the body can sweat.[33]

Dr. Bramble later brought Dr. Lieberman from Harvard into the research to gain a different perspective. Dr. Lieberman specializes in evolutionary anthropology, and he began working with Bramble to help understand how humans could have used endurance

running as an advantage. Lieberman focused on the point where Australopithecus evolved into Homo erectus. He wondered how the caveman diet of fibrous plants changed to meat.[34] Homo erectus came into existence two million years ago but the bow and arrow are only 20,000 years old and the spear 200,000 years old. How did they get a reliable meat source that provided high concentrations of calories, fat, and protein? Lieberman considered how humans could take down a boar or antelope while other predators like lions and hyenas were on the prowl. He referenced research that reported African hunters chasing antelopes and Tarahumara Indians running down deer till their hooves fell off.[35]

Lieberman compared a horse's pace with an elite marathoner's pace. He calculated that a horse gallops at 7.7 meters a second and can sustain that for about 10 minutes before it slows to a 5.8 meter a second trot. A marathoner can jog at six meters a second and maintain that pace for up to 15 kilometers. Lieberman calculated that all the runner needed to do was to keep the horse in sight and close the gap. After examining temperatures, speed, and body weight, he determined that to run an antelope to death, you simply needed to keep it in eye sight and continue scaring it into a trot for 10 to 15 kilometers when it would go into hyperthermia and collapse. Lieberman thought that if he could outrun his dog on a hot day, a group of hunters could run an antelope to the point of overheating.[36]

Dr. Bramble's and Br. Lieberman's "Running Man Theory" was put to the test in southern Africa. There, a young man named Louis Lidenberg experienced four years in the African Kalahari plains with a small group of Bushman hunters. He learned about tracking and hunting from the Bushman. Lidenberg had the opportunity to experience a

persistence hunt when the Bushmen ran down kudu. The kudu collapsed after two hours of running in the 107 degree heat, but so did Lidenberg. After multiple persistence kills through various seasons, Lidenberg discovered that the Bushmen could run 10 minute mile trots, track, and sprint when needed for persistence hunts that lasted three to five hours. What the Bushmen had discovered was that arrows and spears were not very accurate. If you did hit an animal and it bolted, other predators could smell the blood and beat you to the kill. Running the animals to exhaustion was more efficient.[37]

An example of an unshod society is the Tarahumara Tribe from Mexico. Author Chris McDougall experience with the Tarahumara experience shows that people are capable of endurance running with none or minimal shoes. In 1991, Tarahumara runners took 1st, 2nd, and 4th places in a 100 mile ultra-marathon called the Leadville 100. The tribe is known for their 24, 36, and 72 hour endurance runs over the mountainous terrain in central Mexico.

Where barefoot and shod populations co-exist, as in Haiti, injury rates of the lower extremity are substantially higher in the shod population. Steve Robbins and Adel Hanah from Concordia University in Montreal, Quebec, examine why pockets of unshod populations report minimal numbers of lower extremity injuries. The authors reviewed reports of barefoot runners competing internationally, a West German sports trainer using barefoot running techniques without incidents of injury, reports from Haiti of high number of lower extremity injuries in the shod population, and reports from other countries in the West Indies and Europe where populations report few lower extremity injuries.[38]

The authors hypothesize that protective footwear blocks the sensory feedback of the plantar surface. Shoes prevent the necessary protective adaptations needed for weight-bearing activity.[39] Shoes are designed to reduce impact along the plantar surface to reduce pressure and this design does not allow the runner's body to engage the natural mechanics to diminish impact. The authors identify that shoes have diminished sensory feedback without reducing impact forces.[40]

This first section of chapter four examined factors to determine if there is an association between shod or unshod running injuries. Injury rates among runners has steadily risen since the 1980s. Lower extremity injury rates among soldiers in Basic Combat Training have risen from15 percent to 29 percent despite the introduction of cushioned running shoe during physical fitness and running. The rearfoot strike generates up to three times a runners' body weight in impact forces, or five times the force of forefoot strikes. These impact forces generate stress on the human body that leads to many of the running overuse injuries. Advocates of shod running believe the human foot is fragile and the body is not made for running. However, evolutionary scientists have proven that this is not true and that the human body has the mechanisms to run long distances without the need for shoes. Shod running has a higher risk of injury because running shoes enable rearfoot striking that generates higher impact forces than unshod running.

Does the design of conventional running shoes prevent injuries?

Shoe Design

Footwear has been around for a long time. Sandals began appearing in Egypt about the first millennium BC and were worn by soldiers and in the king's court. Footgear was both functional and symbolic for the Greeks. The Mongols of the 14th century introduced a block heel to help grip the stirrup plate as they rode about the Middle East on horseback. The French Court of Louis XIV took the Mongolian block heel and transformed it into one of today's modern fashions-the stiletto heel. The shoe company, Addidas, was formed in 1936 by Adi Dassler, and Puma was founded in 1948 by his brother Rudolf Dassler. Olympic competitors such as Jesse Owens began wearing Addidas running shoes starting in 1936. Other companies such as Nike, Reebok, and ASICS entered the shoe markets in the 1970s.[41]

Running shoes have become increasingly complex over the years. Modern running shoes are designed by computers, require high-tech production systems, and use the latest in cushioning materials and fabrics. Addidas engineers even designed a shoe, the Addidas 1, that has sensors, a tiny computer and a compression system to adjust the heel pad cushioning with each stride. The shoe took three years to design and was first sold in 2005.[42] Product reviews of the Addidas 1 show that it gives a comfortable run, but there has been no research to show if this shoe can reduce injuries. Examples of shoe design technology include breathable materials, visible cushioning, internal air bladders, varying sole density, customizable foot beds, and mid-sole tuning.

In 2009, Benno Nigg from the University of Calgary examined the biomechanical differences between barefoot running and barefoot shoes. As barefoot running and

minimalist shoes have gained popularity, several running shoe manufacturers have produced shoes that attempt to mimic the barefoot condition. Two factors that Benno looked at were oxygen consumption and running injuries. Runners that wore traditional running shoes had a four to five percent higher oxygen consumption rate than barefoot runners. Some of the reasons that are attributed to this difference is the acceleration of the additional shoe mass, additional work needed to deform the shoe sole, effort needed to rotate the shoe sole on the ground, energy absorption in the shoe, and energy lost due to joint stiffness.[43] The lower oxygen consumption factors will be explored in more detail later when running efficiency is discussed.

Nigg makes the assumption that barefoot runners have a lower injury rate based on the literature review he conducted. His concerns about these studies are that countries that are less developed have a higher unshod population and fewer reported lower extremity injuries because fewer people seek medical assistance. Another point that Benno points out is that runners with shoes in unshod societies cover more miles and have more injuries. So, as part of Nigg's paper, he questions the validity of low injury rates in unshod societies.[44]

Next, Nigg's paper looks at different barefoot shoe designs. These shoes are developed and produced to give runners the advantages of running unshod. The five products he used in the study are The Feet You Wear by Addidas, the Nike Free, the Nike VIVO Barefoot shoe, Earth Footwear Kalso, and the MBT Masai Barefoot Technology. Addidas's The Feet You Wear are constructed to mimic the human foot with a narrow heel and wide forefoot area.[45]

The Nike Free was developed to mimic barefoot running kinematics with a wide soft heel and a flexible forefoot sole shoe design. Runners explained that running in the Nike Free allow for a flat foot fall versus heel striking. The flexible forefoot construction allows for an increased area to distribute the pressure and forces the foot to be more active than in a conventional shoe. The overall results showed a seven percent decrease in joint motion while running and a 20 percent increase in flexor joint strength. After a ten month test period, runners in the Nike Free had 29 percent less lower extremity injuries than the control group.[46]

The next shoe that Nigg used in his paper was the Earth Footwear Kalso. The Kalso features a negative heel position where the toes are 3.7 percent higher than the heel. This shoe looks similar to the Nike Free and Earth Footwear claims that the shoe enhances breathing and endurance.

The MBT Masai is the final shoe that was used in Nigg's study. This shoes primary function is as a training tool and mimics the feeling of barefoot movement. It is designed with a rounded sole that forces the wearer to utilize the smaller muscles of the foot to maintain balance. One three month study showed that the MBT reduced arthritis joint pain by 25 percent and another showed a reduction of lower back pain by 44 percent.[47]

Nigg concludes that although shoes can mimic a specific barefoot condition, it is not the same. Each shoe captures a specific barefoot aspect but cannot replicate all of the conditions experienced by barefoot runners even though each shoe provides some benefit individually. Thus the name and concept of barefoot shoes is more of a marketing strategy.[48]

There is no cushion for the heel and some models have a thicker midsole to prevent bruising from rugged terrain. Although there is not a significant study of how well FiveFingers perform, there have been many articles published about authors taking them for road tests. Brian Colleran is one of these authors. His initial trial with the VFF was a failure and he tossed them into a closet.[49] Then he reviewed an article highlighting that shoes may be causing running injuries. So he retried the FiveFingers with a different approach. His initial trial was a 30 mile hike where he alternated between his boots and the FiveFingers. He began working with the new shoes in short runs and hikes and worked up to a 16 mile trek through Yosemite. Colleran found that using his old hiking shoes was very uncomfortable.[50]

The Army Physical Fitness Institute examined the Vibram FiveFingers in October, 2010. The examination briefly looks at the growing popularity of the Vibram FiveFingers in the civilian and military populations. Based on information from Chris McDougal, Dr. Lieberman, and the Vibram web site, the article states that runners transitioning to this shoe need to be cautious. Running in Vibram FiveFingers changes a runner's biomechanics, the intrinsic, and extrinsic muscles of the foot need time to strengthen. These muscles are engaged more in VFFs than in tradition running shoes. Transition time and training duration could take a significant amount of time. The APFRI article concluded that the shoes may not be safe for runners in the Army.[51]

Do Running Shoes Prevent Injuries?

Nike founders Phil Knight and Bill Bowerman originally designed their first waffle shoe to help runners grip the new tracks made of urethane. There is no mention of injury prevention in their motivation for creating their first shoes. Today, shoe

manufacturers advertise two concepts for shoes: performance improvement and injury prevention.

The relationship between arch type and running mechanics has been studied several times. Dr. Butler's article in the *American Journal of Sports Medicine* observed this interaction using 40 runners while wearing a motion control shoe and a cushioned trainer shoe. The purpose of the study was to evaluate the affects on running shoe arch support design while running in stability and motion control running shoes. He found that the cushioned shoes reduce shock better than the motion control running shoes and the motion control shoe controls rear foot motion better than the cushioned shoes. Also, he found that both types of shoes supported the arch equally and that shoes designed to prevent arch type injuries are not effective. The conclusion he made was that runners should utilize shoes based on running mechanics and not arch type.[52]

Another consideration for runners is the wear of orthotic devices. Foot orthotic devices are used to correct alignment in runners that have excessive pronation. Overpronation is a problem because it does not allow the foot and ankle to stabilize the body properly and shock is not absorbed properly.[53] A study was conducted and printed in *The Journal of Orthopedic and Sports Physical Therapy* that used 29 volunteer runners to run barefoot, in shoes, and in shoes with orthotic devices. This examination of foot orthotic devices concluded that orthotic devices have questionable effectiveness at improving pronation. Another point of interest is that the article author explains that foot pronation is a normal function of the foot and abnormal running gaits should be further studied.

The U.S. Army, Air Force, and Marine Corps conducted studies on whether or not prescribing shoes based on foot shape impacted injury rates. The services examined basic trainee's foot types to determine which type of running footwear is best suited for the trainee.[54] The premise for The Army's study is based on evidence from other investigations concluding that ill fitted and old shoes may result in higher injury rates.[55] Dr. Knapik, from the U.S. Army Public Health Command, focused on the fact the Army prescribed running shoes based on foot shape to basic trainees and there had not been adequately studied to validate injury prevention. The study included 2,689 males and 1,263 females conducting Basic Combat Training at Fort Jackson, South Carolina. Trainees' feet were examined and running shoes were prescribed based on arch type.[56]

Knapik's study also incorporated a post wide effort at Fort Drum, New York, to decrease injuries among soldiers. What he found was that only eleven percent followed the shoe prescription advice at Fort Drum.[57] The basic training study was a more controlled environment and allowed Knapik to avoid this variance affecting the results. He concluded that prescribing running shoes based on plantar shape did not effectively prevent injuries among Basic Combat Training recruits.[58]

A follow up study in 2010 by Lieutenant Colonel Deydre Teyhen examined soldier compliance with the recommended running shoe selection. She found that 35 percent of soldiers at Fort Sam Houston wore shoes that are not correctly sized.[59] The study concluded that soldiers are not properly educated about running shoe fitting and proper education could prevent future injuries.[60]

Shoes Affect on Running Form

Running gait is the way humans move our limbs to gain locomotion. Walking and running gaits differ by the amount of time the feet remain in contact with the ground. Walking gaits have a long ground contact time while running gaits have shorter ground contact time. Running gait is broken down into two phases: stance phase and swing phase. The stance phase is when the foot makes contact with the ground and the swing phase is when the foot enters the air. While walking, one foot is always in contact with the ground. Running differs from the walking gait because at some point neither foot is in contact with the ground.[61] A study in 2011 by Caleb Wegener found that shoes impact children's gait while walking and running. Children ages ranged from 1.6 to 15 years and walking shoes, athletic shoes, and Oxford style footwear were compared to the children's barefoot condition.[62] While walking shod, the study found that children walked faster using a slower leg swing with a longer stride. Wegener concludes that the longer stride length is caused by the perception of protection and the decreased cadence is due to the increased mass of the shod foot.[63] The study found shoes affected children's gait by allowing rear foot strike. Shod running caused slower leg swing speed, decrease in impact transmission, and less ankle and foot flexibility. The children in this study also took longer strides that decreased the frequency of midfoot and forefoot striking while walking and running.[64]

In 45 years, Gordon Pirie participated in three Olympic Games, set five official world records and ran 216,000 miles by 1981 when he was 50 years old.[65] Gordon's success as a runner was based on his focus on form and dedication to training. He does express concern over how running shoes have become too bulky and do not promote

good form or injury prevention. One common injury area that he discusses is the Achilles Tendon. A cause for the injury is an Achilles protector that shoe makers' emplace for support. Unfortunately, when a runner's foot is pointed down, the protector causes discomfort for runners. Pirie's recommendation is to cut out the protector with a knife and toss it.[66]

Another problem that Pirie identifies in running shoes is that the human heel is shaped differently than running shoe heel areas. The human heel is narrow but many shoes design the heel space wider and he recommends using medical padding to fill in the gaps to prevent blistering and other injuries.[67]

Pirie explains that the foot is designed to flex and roll when it impacts with the ground. Yet, shoe manufacturers design shoes that limit foot motion and reaction with the ground. The problem is that this promotes a heel-to-toe impact and roll while shod running. The best running shoe is something like a heavy duty ballet shoe with a simple protective layer at the sole and the forefoot are is made of material that can sustain forefoot landing.[68]

The Tarahumara runners use gladiator style sandals. Although the book, *Born To Run*, seems to have spurred a barefoot running revolution, the Tarahumara tribes rarely run barefoot. The sandals they used are considered a minimalist type shoe. These sandals are called huarache sandals. Typically, this footwear is an old strip of tire laced together and fitted for the individual. They weight about 4 ounces per pair with a 4mm rubber sole. Several companies offer these sandals and other websites give directions on how to build the sandals yourself.

The second section of chapter 4 examined if running shoes prevent injuries. The research shows that running shoes do not prevent running injuries even though there has been many advances in the materials used to produce the running shoes. Also, selecting running shoes based on foot shape has been proven to not prevent injuries. Shoe manufacturers have begun to make shoes that mimic the barefoot condition but these shoes do not provide the same benefits as unshod running. Running shoes have been found to alter a runner's gait and mechanics. This result is caused by the cushioned heel that allows rearfoot striking. It has been found that running shoes do not prevent injuries because they enable running with a rearfoot strike.

Does running unshod change a runners mechanics and form?

Is running shod or unshod more efficient?

Oxygen consumption in runners is a way to determine how well a runner's body is transporting oxygen during exercise. The University of Nebraska conducted a study comparing oxygen consumption between shod and unshod runners. The study observed runners in the shod and unshod condition and measured the results in terms of VO2, or the maximum volume of oxygen consumption during aerobic activity. Subjects ran for six minute intervals at a 70 percent effort on a treadmill and on a track. The results were that shod runners consumer three percent more oxygen than unshod runners. Also, it was found that running unshod was more efficient than running shod.[69]

Divert has conducted several studies that compare shod and unshod running. In 2005, he published a study that concluded that unshod running led to reduced impact forces that created mechanical stress on the body while running.[70] Later, he published another study that examined if the higher oxygen consumption of shod runners was due

to the mass of running shoes. He compared unshod with five various shod conditions that weighed from 50g to 350g. A shoe weighing 50g translates to 1.75oz while a 350g shoe weighs 12oz. In comparison, a pair of Nike Free 2 weighs in at 8.2oz and a pair of Air Max+ 2012 weighs 12oz.[71] One finding is that the 50g water socks led to an absence of rearfoot to forefoot ground impact technique during the study and this footwear simulates the barefoot condition .[72] The study also found that the runner's oxygen consumption was higher while running shod and this was induced by shoe mass.[73]

Impact

The major contributor to injury is stress that impact forces place on the body. Dr. Lieberman from Harvard University conducted a study that showed a marked difference in impact between shod and unshod runners. Runners impact the ground by rearfoot striking, midfoot striking, or forefoot striking. 75 percent of shod runners impact the ground with a rearfoot strike, but sprinters typically strike the ground with a forefoot strike even though they run shod.[74] The premise of his study is how human beings ran prior to the invention of the modern cushioned running shoe that enables rearfoot strike landings while running.[75] He concluded that shod runners with a rearfoot strike impacted the ground with three times the body mass weight of unshod runners. Repetitive rearfoot striking generates high-impact collisions that generate stress injuries over a 30 year running career.[76]

Another Harvard University study examined endurance runners and injury rates in December 2011. The study examined the foot strike of 52 collegiate cross country runners. Rear foot striking runners made up 59 percent of the group and fore foot striking runners made up 16 percent of the group. The rest of the study group varied their foot

strike. The study found that runners that used a rear foot strike had 2.7 times greater frequency of a severe running injury.[77]

Leg stiffness during running was examined by Mark Bishop from East Carolina University in 2006. Bishop examined the effect of footwear on leg stiffness while running shod and unshod. Humans utilize leg flexibility as a part of the complex lower extremity musculoskeletal system. This system operates as the foot impacts the ground and joint motion lowers the body's center of mass and absorbs this energy as the "spring" collapses. The energy generation is returned as the runner's limbs extend like a recoiling spring.[78] Bishop's study found that footwear changes lower extremity stiffness and flexibility while running. Subjects needed to maintain greater limb stiffness while wearing cushioned running shoes to maintain limb stiffness. He also found that there was little difference between high and lost cost shoes.[79]

Another factor that causes injuries is joint stiffness. Rigid joints reduce the flexibility needed in the lower extremities to allow the body to deal with impact. Ankle stiffness during running is caused by rear foot-striking because of the foot impacting with the ground just under the ankle and rear of the foot. This impact does not allow the ankle to flex as it should. Rear-foot striking runners impact on the heel and the entire body pivots forward on the heel while the body continues to fall above the knee.[80] This is know as the common heel to toe foot movement of heel striking runners. Less joint flexibility and a of lack of plantar flexion does not allow an effective return of energy. Conversely, runners that used a forefoot strike had lower ankle stiffness rates or more movement and flexibility. The higher flex rate is generated because the fore-foot landing allows the ankle to lower the heel and engage the arch. At impact, the fore-foot stops but

the leg and knee continue to fall as the ankle flexes. By engaging the arch and other tendons, energy is used more effectively to convert rotational energy into kinematic energy.[81] Ankle stiffness and repetitive rear-foot striking can lead to a higher risk of lower extremity injuries.

In March 2011, Joseph Hamill from the University of Massachusetts examined the affect of footwear with different midsole thicknesses on impact forces. His study focused on research suggesting that a thick midsole in running shoes generates a large impact force by attempting to create a stable surface.[82] Hamill verifies Lieberman's conclusions that impact characteristics between shod and run shod runners are different. Foot fall patterns change to rear foot during shod running and forefoot during barefoot running. The evaluated leg stiffness and impact forces during the shod and unshod condition. Leg stiffness was found at the knee and ankle joints during the unshod condition. He concluded that greater leg stiffness in the barefoot condition prevent the heel from impacting the ground.[83] Reducing stride length was found to reduce impact characteristics and shock attenuation. The reduced stride explains why impact characteristics are less and greater attenuation are found in the barefoot condition.[84]

A recent study conducted at Harvard University examined injuries reported by Harvards distance running squads over a four year period. The running team tracked mileage and injuries to determine how a runner's feet impacts the ground affects a runner's risk of injury.[85] There were a total of 52 runners from the Harvard team that participated, and 69 percent of them were rearfoot strikers while 31 percent were fore-foot strikers. The study did not control the types of shoes that the runners wore. Some wore well-cushioned shoes and others wore racing flats. Some got hurt while others did

not. Daoud's study found that two-thirds of the group became injured enough to miss several days of training and rearfoot strikers had a twofold greater risk of becoming injured.[86]

Is there a correct Running Form?

Most runners use a rearfoot strike and have never determined what form they run with. Out of 100 recreational runners who run 10km or marathons, 63 percent did not know what form they used, they just run.[87] Poor form cannot be fixed by muscling through a run or by wearing certain shoes. Add poor form with improper shoe selection and this is a combination for injury. Poor form becomes evident with short or long distances. This is what puzzled Gordon Pirie for years as he trained injured runners, work with the founder of Addidas, and published running principles that are erroneous.[88]

Pirie has won Olympic medals, ran almost a quarter million miles, and was injury free. He was a form focused trainer that believed the simplest and lightest shoe was the best choice for running. Pirie's technique uses a forefoot strike with a flexed knee and a quiet, soft landing. The foot lands directly below the body and the runner does not lean at the waist or ankles. He also focused on arm swing and picking up the feet.[89] Once good form is achieved arm swing is proportional to a runners leg power and speed. Arms need to be kept close to the body versus flying outward and upsetting the bodies mechanics. Pirie attests that his lack of injuries and success is due to focusing on running form.[90]

Chi Running promotes a midfoot strike. The running style, created by Danny Dreyer, focuses on a forward lean that uses gravity to provide forward propulsion and discourages a rearfoot strike. Chi Running advocates report a significant improvement in runners who apply the running style. A survey of runners using Chi Running style

disclosed that 91 percent of those surveyed have changed their running mechanics from rearfoot strike to midfoot strike.[91]

The Chi Running method focuses on making running "effortless and injury free." Chi runners learn to lean from the ankles and maintain a straight line through the entire body. Chi Running teaches runners to tilt their body at the ankle to place their center of mass ahead of the foot strike. The result is relaxed legs that used for support between strides versus using muscles to propel the body forward.[92]

Nicholas Romanov created the Pose Running Method while he was training athletes in Russia in the 1970s and 1980s. He observed that when the work load was increased in his athletes, they began to break down physically. Romanov proposed that all runners should have the same running form based on their movements being a series of poses. The intent is that the more precise the pose, the more efficient the athlete. His pose running technique is designed to prevent undue strain on the joints. The pose style is distinguished by runners landing on the midfoot with flexed limbs and uses the hamstring muscles to withdraw the foot from the ground. The emphasis is placed on lifting the foot toward the buttock after foot impact.[93]

Ramonov's pose style focuses on form and utilizes various drills and exercises to strengthen the lower extremeties before running with this technique. The focus on form training is important because he has identified that many running trainers focus on developing aerobic capacity instead of running foundations. Pose Running style is similar to Danny Dryer's Chi Running by using a short stride and mid-foot landing. This is because longer strides with a low cadence is easier on the cardio system, but harder on the body's mechanics.[94]

The Pose Running Method uses gravity to give the runner forward momentum. By leaning at the ankle, runners can increase speed by leaning further forward or slowing down by leaning back. Runners avoid pushing off with the toes and maintain foot landing below the runner's center of mass and maintains a straight line from the ankle, to the hip, through the shoulders, and to the head. Strides are kept short, knees are bent and flexed, feet impact below the body and at the fore-foot, and the body maintains an S shape.[95]

A key difference between Chi Running and Pose Running is the cadence and muscular demand. Chi Running places a greater emphasis on relaxing the body, core strength, and extending the stride. Pose running demands a high cadence due to the short stride length and gains this high cadence through muscular demand and control. Romanov highly recommends runners go through the pose training drills to gain the needed strength for pose running. Without this strength, runners risk sustaining injuries such as calf strains, lower back problems, and hip pain.[96]

The final section of chapter 4 examined whether or not running unshod changes a runners form and mechanics. Running shoes have been shown to enable rearfoot striking because of the thick sole that protects the heel during a long forward stride. After looking at comparisons of multiple shoes against the barefoot running condition, it was found that unshod running is more efficient that shod running. Finally, the research examined several running forms. It has been shown throughout the research that rearfoot striking while running increases the risk of injuries. The examined running forms promote a midfoot or forefoot strike while running. These foot strike patterns have been shown to generate less impact forces than rearfoot striking. Unshod running has been shown to change a runner's form by enabling a midfoot or forefoot strike. This change in form

allows for the body to utilize the lower extremities handle the impact forces from running.

In conclusion, chapter four examined the research to answer the primary and secondary research questions. The first secondary research question is there an association shod and unshod running injuries? Injury rates of Basic Training recruits have risen from 10-15 percent in 1974 to 30 percent today. Impact forces have been identified as the major cause of lower extremity injuries among runners. The first secondary research question answer is that shod running had a higher injury risk than unshod running.

The second secondary research question is does the design of running shoes prevent injuries? The research showed that shoe design does not prevent injuries. Advances in shoe technology have not reduced or prevented injuries since the 1980s. Shoe manufacturers have begun designing shoes that capture specific characteristics of the unshod running condition, but cannot mimic the condition completely. Also, the research has shown that shoes alter runner's gait that enables rearfoot striking. The second secondary research question answer is that running shoes are not designed to prevent injuries.

The third secondary research question is does running unshod change a runner's mechanics and form? It has been shown that shod running is less efficient and generates higher ground impact forces than unshod running. Rearfoot strike running has 2.7 times higher risk of lower extremity injuries than running with forefoot or midfoot strike. The research also examined several running styles that utilize different foot strikes. It was found that the Pose Running Method and Chi Running.

The primary research question is can unshod running reduce running injuries? The research has shown that despite increasing use and improvements to running shoes lower extremity injury rates among runners have not improved since the 1980s and that injury rates have actually gradually risen since then. Today, the injury rate among runners is 70-75 percent of all runners become injured every year. Army studies have shown that past lower extremity injury rates among runners was 10-15 percent in 1974 and is currently about 30 percent. This thesis has shown that shoes do not cause injuries and it has also been found that shoes do not prevent injury. Cushioned running shoes alter the runner's gait and enable rearfoot striking that is not present in unshod running. This rearfoot striking is the main cause of lower extremity injuries among runners. Generated impact forces are higher among rearfoot striking shod runners because the rearfoot strike does not allow the body to attenuate the shock naturally.

Through the research process, it was found that unshod running uses forefoot and midfoot striking that allows the body to deal with ground impact forces. Barefoot runners utilize a forefoot strike while Pose and Chi runners use a midfoot strike. The answer to the primary research question is that unshod running can reduce running injuries because unshod runners use a forefoot strike. But, shod runners can reduce injuries by adapting a forefoot or midfoot strike while running. Both Pose and Chi running styles enable a midfoot strike while promoting injury prevention.

Comparison

Injury Rates is the first criterion to be applied to the information presented in chapter four. This criterion is weighted two times higher than the other criteria because this thesis examines injury reduction. As discussed, injury rates among runners have not

improved since 1982 even though footwear has made great advances. When comparing shod versus unshod running, lower injury rates are preferred. Shod runners generate higher impact forces than unshod runners. Shod running is awarded a (-1) for criteria and unshod is awarded (+1). Based on the criterion's weight, shod running earns -2 while unshod running earns 2.

Running Form is the next criterion applied and is also weighted twice as high as the other criteria. Less injurious running form has been shown as a fore or mid foot strike. This foot fall can be achieved in the shod and unshod condition using various running styles. Shod runners can learn a fore or mid foot strike like what is used in Chi Running or Pose Running. Fore or mid foot landing is preferred over rear foot landing. Shod running's disadvantage is that it allows runners to revert back to a rear foot strike and this fact is dependent on a runner's discipline and experience. Shod running earns a (0) because runners can run shod with proper form, but can revert back to rearfoot striking. With a weight of two, shod running earn (0). Unshod running is awarded (+1) because it promotes a fore or midfoot strike and does not allow runners to revert to a rearfoot strike due to lack of cushioning. Unshod running earns a 2.

The third criterion is impact forces. Impact forces create additional stress on the body and cause overuse injuries. The research has shown that shod running generates higher impact forces than unshod running. Shod running is awarded (-1) because shod running generates three to five times a runners body weight in impact force. Unshod running is awarded a (+1) because unshod running generates .58 times the runners body weight in impact forces.

The fourth criterion, shoe design, found that running shoe designs do not prevent injuries. Additional cushion in the running shoe sole has been seen to increase impact forces while running shod and heel striking. The various running styles presented in chapter 4 promote a fore or mid foot strike that can be achieved in conventional running shoes. Running shod using a fore foot landing should reduce impact forces that cause injuries. This criterion is weighted equally to impact forces and running efficiency. Shod and unshod running earn (0)0 because although cushioned running shoes enable rearfoot striking, runners are able to change their foot strike to a forefoot or midfoot strike.

Running efficiency is the last criterion to be applied. This criterion weighs unshod societies and evolution factors against injuries. Shod running receives a (0)0 because shod runners have not run with a low injury rate for a significant amount of time. Unshod receives a (+) 1 because review of previous studies has shown unshod societies tend to have lower injury rates of the lower extremities and because shod running has existed only since the 1970s. Table 2 summarizes the criteria application and results.

Unshod running scores 6 and shod running scores -3 using the five criteria to assess the research gathered in this meta-study. Based on these scores, unshod running can reduce injuries, and as discussed, it primarily does so through fore and midfoot running form that it promotes.

Table 2. Chapter 4 Criteria Application		
Shod	Criteria	Unshod
(-) -2	Injury Rates(x2)	(+) 2
(0) 0	Running Form(x2)	(+) 2
(-) -1	Impact Forces	(+) 1
(0)0	Running Shoe Design	(0) 0
(0)0	Running Efficiency	(+) 1
-3	TOTAL	6

Source: Created by author.

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[72]Ibid., 516.

[73]Ibid., 517.

[74]Lieberman, “Foot strike patterns and collision forces in habitually barefoot versus shod runners,” 531.

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[80]Lieberman, “Foot strike patterns and collision forces in habitually barefoot versus shod runners,” 533.

[81]Ibid., 533.

[82]Joseph Hamill, “Impact characteristics in shod and barefoot running,” *Footwear Science* 3, no. 1 (March 1, 2011): 33.

[83]Ibid., 38.

[84]Ibid., 39.

[85]Daoud, “Foot strike and injury rates in endurance runners: A retrospective study,” 1.

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CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It is all about form!

Despite increase technology in footwear, lower extremity injuries caused by running continue to rise. Approximately 75 percent of the 36 million runners in the U.S. are heel strikers and over 27 million of this number are injured annually because of running. Running remains a popular sport and recreational activity even with a high injury rate, and enthusiasts power through the pain of plantar fasciitis and other injuries. Research conducted at Basic Combat Training shows that 30 percent of initial entry soldiers are injured due to running, and lower extremity injuries account for 10.6 million of the 25 million limited duty days annually reported to the Army. Running will remain a part of The Army's physical training program because it is a part of the culture. But, leaders should recognize its hazards and how to best mitigate them to improve their units' readiness.

People have worn footwear for thousands of years to include such activities as marathons, but today's cushioned running shoe has only been around since the 1970s. Running shoes help protect the feet, but as shown in this research, they may also cause many injuries as well. There is no conclusive research that proves running shoes prevent injuries. The problem with cushioned running shoe is that it alters a runner's gait and promotes heel striking. This heel striking generates higher impact forces that creates higher stress levels that the ankles, knees, hips, and back are not best designed to handle.

The increased stress of striking the ground with the heel 1000 times a mile causes many overuse training injuries.

The Army is not ignorant of wide spread running injuries and has tried to reduce injuries among soldiers through the years. Transitioning from combat boots to running shoes in the 1980s was the first attempt to prevent injuries. Later, the Army tried to reduce injuries by matching soldier's foot shape with a specific shoe type. But, running injuries continue to plague service members and some soldiers have found better ways to run utilizing footwear such as Vibram FiveFingers. The Army issued the All Army Activities Message 239/2011 that bans the wear of footwear that has separate compartments for the toes. This includes Vibram FiveFingers and Fila Skele-toes. But, the message does not exclude soldiers from wearing minimalist shoes, such as Merrell's Trail Glove, New Balance's Minimus, that perform almost identically to Vibram FiveFingers.

Understanding how we run

Gordon Pirie mentions that poor running form is evident in a runner whether they run a 5km race or a marathon. The best way to prevent injury is to learn correct technique. Pirie explains this when he talks about running on sand. The forefoot makes the strongest imprint while the heel only make a soft indentation. Danny Dreyer also makes the same comparison and explains that runners should avoid making craters when they run. Dr. Lieberman's study shows that heel striking while running creates high impact forces that translate into more stress on the body. This stress is what leads to lower extremity injuries and overuse injuries.

This thesis examined four running forms that use a fore or mid footstrike. Gordon Pirie and barefoot advocates utilize a forefoot strike while Pose Running and Chi Running use a mid-foot strike. Each of the running forms differ slightly in some ways, but they all generate lower impact forces than rear foot striking and have a lower injury rate. The research indicates that unshod running produces less impact stress than shod running.

The Army's Physical Readiness Training manual, Training Circular 3-22.20 explains the importance of posture and good form during exercise and while not exercising. It also explains the importance of developing the body's core muscles while lifting, pulling, jumping, and lunging. The exercises used to develop these have specific form positions. The TC recognizes that running form is important and discusses some of the positions and actions of the body while running. The TC does not give any details about how the legs and feet should function while running. Nor does the TC give any details about how the feet should land or strike the ground. The manual does point out that the feet need to remain pointed forward and that fatigue can cause the feet and legs to rotate outward. Based on the research conducted in this thesis, here are four recommendations for The Army.

Recommendations

The first recommendation is that The Army should conduct research on the affects of running using the Pose Running Method. The research should focus on lower extremity injury reduction and compare this form to rearfoot strike running. The Pose Running Method heavily utilizes muscles for running locomotion and requires a strength training regimen. Chapters 9 and 10 of TC 3-22.20 build muscle strength and endurance

through conditioning drills. The Pose Running Method would fit into The Army's current training philosophy. Pose Running Method uses a midfoot strike and could reduce running injuries. Pose instructors are already at some military installations. According to Posetech.com, Fort Leonard Wood , MO has 21 Pose Running Method instructors and all of them are military.[1] In 2010, Dr. Romonov visited Schoffield Barracks in Hawaii and instructed soldiers on the Pose Running Method.[2]

The second recommendation is that The Army should formalize a running training program within the Physical Readiness Training Program. In TC 3-22.20, exercises are explicitly written out. The Power Jump under conditioning drills, has four steps and four execution checkpoints with pictures. Another conditioning drill, the V-Up, also has four steps, checkpoints, and pictures that are used to guide soldiers in the proper execution of the exercise. But, the TC and the Physical Readiness Training Program both recognize that soldiers' running form will vary and that forcing soldiers to conform to one running form could be harmful. To mitigate further injuries, soldiers need to be trained from initial entry and through their careers. This also includes training leaders, Non-Commissioned Officers, and Commissioned Officers on how to use the Pose Running form and how to build a running program in their units.

This leader education needs to focus on how soldiers run when they enter the service and why heel striking is harmful. Then, the training should educate leaders on running using a midfoot strike. First, land softly on the fore or mid foot to avoid heel striking and allow the legs to flex. Next, pick up the feet. Avoid skidding or shuffling because this causes the braking sensation that heel striking has. Ensure the feet land beneath the hips or center of mass and maintain an upright posture. Avoid slumping at the

shoulders or leaning at the waist because will cause the form to fall apart and the feet will start skidding or striding beyond the hips. Lastly, maintain a short stride with a high cadence and as little contact with the ground as possible.

As a part of the second recommendation, Training Circular 3-20.22 should be updated. The training circular spends a significant amount of time describing the proper position and posture for many of the exercises used for training. However, running form and mechanics are not discussed within the Training Circular. The physical training manual should at least have a section or appendix dedicated to proper running form, or form could be built into Chapter 10 of the manual. This new information should describe how a runner's feet strike the ground and that rearfoot striking should be avoided. If the Army adopts the Pose Running Method, the running technique could be explained in this area of the training circular.

The third recommendation is for soldiers that want to wear Vibram FiveFingers while running in the Army Physical Fitness Uniform. Soldiers should research unshod running and transition slowly to a minimalist shoe. The body needs time to change mechanics after running in running shoes with elevated heels and moving to unshod running too fast can cause injuries such as stress fractures. Those soldiers that are Vibram FiveFinger advocates should consider some of the other minimalist shoes on the market that can perform just as well. Minimalist running shoes such as the Merrell Trail Glove and the New Balance Minimus are examples of minimalist shoes that are authorized for wear in the APFU. The important thing to remember is that the other minimalist footwear will allow you to maintain proper form.

A final recommendation that is not in the scope of this research is that The Army should research the effect of rearfoot strike running while in combat boots. Many boot manufacturers have produced combat boots that look and feel like running shoes. If a runner generates three times their body weight in impact forces under normal circumstances, what are the impact forces being generated by soldiers while wearing body armor and carrying their weapon with ammunition? Does the risk of lower extremity injuries increase as a soldier runs 50 yards while carrying his combat load and running with a rearfoot strike?

TC 3-22.20 explains that The Army will not utilize a prescribed running form because it could cause more harm to the soldier. The research has established that there is a lower extremity injury rate among soldiers of about 30 percent. This percentage has remained consistent since the 1980s. Modular brigades are manned with about 3,500 depending on the type of brigade. Applying a 30 percent injury rate would yield 1,050 injuries per year caused from running for a typical brigade. Looking at a unit such as the 10th Mountain Division that has four combat brigades, this unit could see up to 4,200 running related injuries a year. When looking at readiness, this has a tremendous effect because soldiers miss training days because of medical appointments or become non-deployable due to profiles.

Thus, simply changes in running form, a relatively no cost solution for The Army, could save thousands of hours of medical procedure visits, millions of dollars in medical costs, and thousands of hours in lost physical training per every Army division and modular and training brigades.

[1]http://www.posetech.com/mil/army/running/instructors/pose-running-instructors.html.

[2]Amber Robinson, “Joint Services learn “Pose Running” method from the master,” http://www.army.mil/article/47349/Joint_Services_learn__quot_ Pose_Running.html. (accessed April 11, 2012).

GLOSSARY

Achilles tendinitis- is tendonitis of the Achilles tendon, generally caused by overuse of the affected limb and is more common among athletes training in under less than ideal conditions.

Frontfoot Strike-Utilizes the front 33 percent of the foot when it lands while running. Typical landing point is the ball or pad of the foot.

ITBFS- Iliotibial band friction syndrome is a common injury to the thigh, generally associated with running, cycling, hiking or weight-lifting (especially squats).

Kinematics-is the branch of classical mechanics that describes the motion of points, bodies (objects) and systems of bodies (groups of objects) without consideration of the forces that cause it. Running kinematic variables include velocity, distance, stride length, and direction.

Kinetics-Ancient Greek: κίνησις "kinesis", *movement* or *to move*, refers to the study of motion and its causes. Kinetics is concerned with the relationship between the motion of bodies and its causes, namely forces and torques. In mechanics, the Kinetics is deduced from Kinematics by the introduction of the concept of mass.

Meniscal injuries- Each knee joint has two crescent-shaped cartilage menisci. These lie on the medial (inside) and lateral (outside) of the upper surface of the tibia (shin) bone. They are essential components of the knee, acting as shock absorbers as well as allowing for the proper interaction and weight distribution between the tibia and the femur (thigh bone). As a result, injury to either meniscus can lead to critical impairment of the knee itself.

Midfoot Strike-A foot strike that utilizes the mid 33 percent of the foot between the ball of the foot and the heel.

Patellar tendinitis- Also known as jumper's knee, is a relatively common cause of pain in the inferior patellar region in athletes. It is common with frequent jumping and studies have shown it may be associated with stiff ankle movement and ankle sprains.

Patellar tendinopathy- It is an overuse injury from repetitive overloading of the extensor mechanism of the knee. The micro tears exceed the body’s healing mechanism unless the activity is stopped. It can also be caused by drug use. The injury occurs to athletes in many sports.

PFPS- Patellofemoral pain syndrome is a syndrome characterized by pain or discomfort seemingly originating from the contact of the posterior surface of the patella (back of the kneecap) with the femur (thigh bone).

Plantar fasciitis- is an inflammation of the fibrous tissue (plantar fascia) along the bottom of your foot that connects your heel bone to your toes. Plantar fasciitis can cause intense heel pain.

Pronation-Rotational movement of the of the foot at the ankle joint. Pronation will cause the sole of the foot to face more laterally than when standing in the anatomical position. Pronation is the opposite of supination.

Rearfoot Strike-Also called “heel strike”. Occurs when runners land on the heel.

Supination- Supination in the foot occurs when a person appears "bow-legged" with their weight supported primarily on the anterior of their feet. Supination is the opposite of pronation

Tibial stress syndrome-Also known as shin splints is a common injury that affects athletes who engage in running sports or basic activities such as cross country, football, or hiking. MTSS injuries affect the connective muscle tissue surrounding the tibia (bone located near the lower leg). This injury is brought on by exerting too much pressure on the lower leg muscles or excessive impact on the muscle.

VO2-VO_2 max is expressed either as an absolute rate in liters of oxygen per minute (l/min) or as a relative rate in milliliters of oxygen per kilogram of bodyweight per minute (ml/kg/min). The latter expression is often used to compare the performance of endurance sports athletes.

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