

REPORT DOCUMENTATION PAGE					<i>Form Approved</i> OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY) 17-04-2020		2. REPORT TYPE Master of Military Studies (MMS) thesis			3. DATES COVERED (From - To) AY 2019-2020	
4. TITLE AND SUBTITLE Stepping Smartly: The Role of Healthy Feet in the Prevention of Musculoskeletal Injuries				5a. CONTRACT NUMBER N/A		
				5b. GRANT NUMBER N/A		
				5c. PROGRAM ELEMENT NUMBER N/A		
6. AUTHOR(S) Paxton, Hannah M. (Major)				5d. PROJECT NUMBER N/A		
				5e. TASK NUMBER N/A		
				5f. WORK UNIT NUMBER N/A		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) USMC Command and Staff College Marine Corps University 2076 South Street Quantico, VA 22134-5068					8. PERFORMING ORGANIZATION REPORT NUMBER N/A	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A					10. SPONSOR/MONITOR'S ACRONYM(S)	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S) N/A	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited.						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT The Marine Corps has historically sustained high levels of musculoskeletal injuries. A recent study reports that the preponderance of musculoskeletal injuries sustained are incurred in the lower extremities. This paper explores potential contributing factors to the incursion of musculoskeletal injuries, with particular emphasis on the role of the feet, demonstrating that foot strength is essential to musculoskeletal health. The Marine Corps has implemented programs which provide the framework for ensuring that foot strengthening techniques and general injury prevention knowledge are implemented across the force. The Sports Medicine Injury Prevention Program – which includes the implementation of the Athletic Trainer Cadre – the Force Fitness Instructor Program, the Optional Boot Program, and Professional Military Education programs, are avenues by which the Marine Corps can expand capabilities and options in support of injury prevention. While certainly the military life extracts a toll on the body and demands high levels of personal fitness, musculoskeletal injuries should not be viewed as simply a cost of doing business. The institution must continue its positive trajectory with respect to injury prevention, and can do so within the framework that is currently established.						
15. SUBJECT TERMS musculoskeletal injury prevention, barefoot training, force fitness instructor, athletic trainer cadre						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 40	19a. NAME OF RESPONSIBLE PERSON USMC Command and Staff College	
a. REPORT Unclass	b. ABSTRACT Unclass	c. THIS PAGE Unclass			19b. TELEPHONE NUMBER (Include area code) (703) 784-3330 (Admin Office)	

*United States Marine Corps
Command and Staff College
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, Virginia 22134-5068*

MASTER OF MILITARY STUDIES

TITLE:

Stepping Smartly: The Role of Healthy Feet in the Prevention of Musculoskeletal Injuries

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

AUTHOR:

Major Hannah M. Paxton, USMC

AY 2019-20

Mentor and Oral Defense Committee Member: _____

Approved: _____

Date: _____

Oral Defense Committee Member: _____

Approved: _____

Date: _____

Executive Summary

Title: Stepping Smartly: The Role of Healthy Feet in the Prevention of Musculoskeletal Injuries

Author: Major Hannah M. Paxton, United States Marine Corps

Thesis: By way of optimizing and empowering the Force Fitness Instructor Program and leveraging existing research with respect to appropriate footwear, the Marine Corps can lower musculoskeletal injury rates across the Fleet Marine Force, contributing to the retention of a fitter, healthier force and ultimately increased levels of combat readiness.

Discussion: The Marine Corps has historically sustained high levels of musculoskeletal injuries. A recent study reports that the preponderance of musculoskeletal injuries sustained are incurred in the lower extremities. This paper explores potential contributing factors to the incursion of musculoskeletal injuries, with particular emphasis on the role of the feet, demonstrating that foot strength is essential to musculoskeletal health. The Marine Corps has implemented programs which provide the framework for ensuring that foot strengthening techniques and general injury prevention knowledge are implemented across the force. The Sports Medicine Injury Prevention Program – which includes the implementation of the Athletic Trainer Cadre – the Force Fitness Instructor Program, the Optional Boot Program, and Professional Military Education programs, are avenues by which the Marine Corps can expand capabilities and options in support of injury prevention.

Conclusion: While certainly the military life extracts a toll on the body and demands high levels of personal fitness, musculoskeletal injuries should not be viewed as simply a cost of doing business. The institution must continue its positive trajectory with respect to injury prevention, and can do so within the framework that is currently established.

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Preface

As an avid runner, my earliest recollections of running date back to my early childhood. I remember vividly how I greatly disliked wearing shoes, and consequentially I was barefoot at every opportunity. As member of the Armed Forces for over seventeen years, the ability to meet standard run times has been a standing requirement for the entirety of my adult life. However, as with childhood, as an adult I fell in love with running when presented with opportunities to run barefoot on the beaches of Charleston, South Carolina. While I currently wear running shoes for the preponderance of my runs, I have witnessed friends, colleagues and junior Marines much younger than I experience musculoskeletal injuries presumably as a result of running. As a result, I became intrigued with the concept of barefoot running and its benefits to musculoskeletal health. Initial research on the benefits of barefoot running led me to explore the underlying concepts contributing to the benefits of barefoot activity, and ultimately to the concept of foot health and strength as a preventative measure for musculoskeletal injuries. As a result of my research, I have adapted the principles I have learned into my personal routine, and hope that the ideas in this paper present helpful solutions to lowering musculoskeletal injury rates within the Marine Corps.

I would be at a loss if I did not thank those who inspired and encouraged me through the process of completing this project. Colonel Stephen Armes, Director of the Marine Corps Force Fitness Division, planted the seed for the topic of this paper and provided information that informed valuable research. I would also like to thank Dr. Jonathan Phillips, my mentor, for guiding me through the project, providing constructive feedback and guidance. Finally, I thank my wife, Fab, who provided valuable insight, support and encouragement when I needed it most.

Introduction

In July 2019, General Berger published his Commandant's Planning Guidance, in which he stated that "everything starts and ends with the individual Marine" and that among recruiting, education and training, and instilling accountability, a principle emphasis of the Marine Corps must be "equipping; and treating [Marines] with dignity, care, and concern."¹ While often statements such as these are interpreted and directed to take place at the small unit level – which is of utmost importance – the Marine Corps must constantly identify ways in which it can solidify its framework of training, equipping, and caring for Marines at the institutional level. One such avenue by which the Marine Corps has grown in leaps and bounds is that of programs dedicated to the prevention and care of musculoskeletal injuries. While "old-school" Marines grew up with a mentality of "Pain is weakness leaving the body," current initiatives within the Marine Corps are reshaping this outdated precedent.² The Marine Corps must maintain its momentum within the realm of physical fitness and injury prevention and recovery by the implementation and maintenance of programs that effectively enhance injury prevention, gaining buy-in from all levels of the chain of command. By way of optimizing and empowering the Force Fitness Instructor Program and leveraging existing research with respect to appropriate footwear, the Marine Corps can lower musculoskeletal injury rates across the Fleet Marine Force, contributing to the retention of a fitter, healthier force, and ultimately increased levels of combat readiness.

Problem

Musculoskeletal injuries (MSKIs) are the most common injuries and cause for lost training days within the military. A study conducted in 2003 by Walter Reed and San Diego State

physicians identified that Army and Marine Corps entry level training (ELT) sites sustained injury rates of 20% to 40%.³ The study further identified that “it has been estimated that stress fractures alone among 22,000 Marine Corps trainees in one year resulted in 53,000 lost training days and cost more than \$16.5 million.”⁴ While the Marine Corps has witnessed a decrease in injury rates at ELT concurrent with the expansion of the Sports Medicine Injury Prevention (SMIP) program in 2003, the prevalence of MSKIs persists in the active duty force. In 2016, musculoskeletal injuries were reportedly the “single largest impediment to operational readiness in the military,” with over 600,000 servicemembers sustaining an MSKI annually.⁵ The Navy and Marine Corps Public Health Center reported that over 39,000 acute MSKIs were sustained by active duty United States Marine Corps (USMC) servicemembers in fiscal year 2018.⁶ Beyond acute injuries, over 136,000 chronic MSKIs were reported.⁷ Figures 1 and 2 identify the allocation of injuries by body region and nature of injury for both acute and chronic injuries, respectively. To summarize the data in Figures 1 and 2, the most prevalent acute and chronic injuries sustained across the active duty USMC force in 2018 were musculoskeletal injuries to the lower extremities.

Nature of Injury	Body Region						Total N (%)
	Lower Extremities N (%)	Upper Extremities N (%)	Head and Neck N (%)	Other N (%)	Torso N (%)	Spine and Back N (%)	
Musculoskeletal (MSK)							
Sprain/Joint Damage	11,071 (14.4%)	3,277 (4.3%)	96 (0.1%)	27 (<0.1%)	469 (0.6%)	949 (1.2%)	15,889 (20.7%)
Strain/Tear	3,481 (4.5%)	2,764 (3.6%)	879 (1.1%)	10 (<0.1%)	858 (1.1%)	1,248 (1.6%)	9,240 (12.0%)
Fracture	2,846 (3.7%)	3,049 (4.0%)	715 (0.9%)	--- ---	570 (0.7%)	262 (0.3%)	7,442 (9.7%)
MSK Tissue Damage, Other	2,660 (3.5%)	2,067 (2.7%)	13 (<0.1%)	69 (<0.1%)	33 (<0.1%)	27 (<0.1%)	4,869 (6.3%)
Dislocation	431 (0.6%)	1,258 (1.6%)	19 (<0.1%)	--- ---	27 (<0.1%)	23 (<0.1%)	1,758 (2.3%)
Amputation	11 (<0.1%)	33 (0.1%)	1 (<0.1%)	--- ---	1 (<0.1%)	--- ---	46 (0.1%)

Figure 1. Number of Acute Injuries among Active Duty Marine Corps Service Members by Body Region and Nature of Injury, FY 2018.⁸

Nature of Injury	Body Region						Total N (%)
	Lower Extremities	Spine and Back	Upper Extremities	Head and Neck	Other	Torso	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	
Musculoskeletal (MSK)							
MSK Tissue Damage, Other	61,219 (40.2%)	39,800 (26.1%)	27,792 (18.2%)	---	4,160 (2.7%)	---	132,971 (87.3%)
Fracture	1,721 (1.1%)	12 (<0.1%)	13 (<0.1%)	---	45 (<0.1%)	76 (<0.1%)	1,867 (1.2%)
Sprain/Joint Damage	689 (0.5%)	1 (<0.1%)	207 (0.1%)	---	118 (0.1%)	---	1,015 (0.7%)
Strain/Tear	4 (<0.1%)	---	990 (0.6%)	---	1 (<0.1%)	---	995 (0.7%)

Figure 2. Number of Chronic Injuries among Active Duty Marine Corps Service Members by Body Region and Nature of Injury, FY 2018.⁹

Contributing Factors

The most commonly reported contributing factor to MSKIs in the military environment is that of overuse. Both ELT and the sustained physical demands of a Marine Corps career extract a toll from those whose bodies are not fully prepared to withstand the demands of training. Physical fitness sessions have historically been led at the small unit level by a young non-commissioned officer or lieutenant with limited to no training in the field of human physiology and biomechanics.¹⁰ This has led to an unbalanced training regimen that ignores critical components such as agility, flexibility and balance.

Exacerbating the problem of overuse is the daily Marine Corps combat utility uniform. The combat boot, while effective as protection for loadbearing activities, rugged terrain, and the combat environment, also contributes to a reduction in the strength of the foot and ankle when worn as primary footwear. Dr. Gerard Hartmann, Physical Therapist to over 60 Olympic medal winners and Director of Hartmann International Sports Injury Clinic¹¹, asserted that “the deconditioned musculature of the foot is the greatest imbalance resulting in injury that I see in my practice”¹² and that “mankind, by relying on footwear to control and protect the foot, has allowed the foot to become weak and deconditioned.”¹³ To illustrate his point, he compares the restrictive properties and implication of prolonged use of a cervical collar to that of restrictive

footwear. “If a cervical collar is worn for a long period of time the muscles become redundant and weaken.” This leads to a larger problem “because the weight of the head does not change yet the muscles are weaker and the muscles that are functioning have a greater job in holding up the weight of the head...if a biological structure is supported it will weaken.”¹⁴ If indeed the restrictions of the boot contribute to the weakening of the foot and ankle, using the logic of Dr. Hartmann, the prolonged wear of combat boots with foot and ankle supporting properties likely leads to the incursion of MSKIs.

Dr. Hartmann is not alone in his assessment of the restrictive properties of modern-day footwear; furthermore, the impact of footwear on musculoskeletal health is not limited to the combat boot. Perhaps the earliest notable work on the topic is that of Dr. Phil Hoffman, whose study published by the American Journal of Orthopedic Surgery in 1905 compared the strength and structure of the human foot wearing traditional shoes to those of populations who are traditionally barefoot or “minimally shod.”¹⁵ The conclusions drawn from Dr. Hoffman’s study indicate that modern footwear detracts from the natural function of the foot, claiming that “the lasts over which the footwear of civilization is shaped are rarely modeled in the spirit of truth that would make them conform to the contour of a normal foot.”¹⁶ The impact is such that the natural shape of the foot conforms to that of the footwear worn – similar to the historical Chinese practice of foot binding.¹⁷ Figure 3, which contains foot impressions of children who had previously never worn shoes compared to impressions after a few weeks of shoe wearing, illustrates this point.

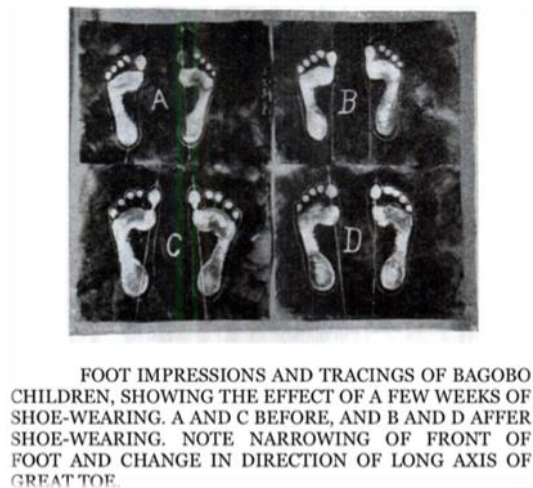


Figure 3. Illustration of the change in foot shape due to wearing restrictive shoes.¹⁸

Dr. Hoffman’s research suggests that “shoes, as they are usually worn, not only deform but interfere with the functions of the foot by restricting the movements of its many small joints.”¹⁹ Specifically, the preponderance of footwear restricts the lateral extension of the toes; this is observable when comparing the feet width of infants, who have never worn shoes, to adults whose foot shape has not only changed due to footwear, but whose ability to laterally separate the toes has also been diminished.²⁰ Compounding this issue, the preponderance of shoes – specifically athletic shoes – are built with toe spring: that is “the elevation of the toe-box above the supporting surface.”²¹ The impact of toe spring is such that the tendons in the feet are not recruited as designed,²² meaning that the toes are unable to fulfill their function of grasping the ground to assist with step propulsion.²³

Not only does modern day footwear impact the shape of the foot and functionality of the toes, contributing to the deconditioning of the foot, but elevated heels common to most footwear result in an alteration to weight distribution on the foot, shifting the human body’s natural biomechanics.²⁴ An additional element of Dr. Hoffman’s observation was that of the arch height of the minimally shod. While the previous school of thought maintained that arch height

indicated strength, Dr. Hoffman's study suggested that this was not the case. Conversely, his study demonstrated correlations between arch strength and foot strength uninhibited by the restrictions that are present in modern day footwear.²⁵

Dr. William Rossi, Doctor of Podiatry, argues that modern footwear makes normal gait impossible – with gait being the most complex motor function of the human body.²⁶ While high heels are the primary recipient of his criticism, Dr. Rossi demonstrates that the presence of any heel, or elevated heel, is cause for an alteration of natural biomechanics.²⁷ Specifically, the shoe's elevated heel causes a shortening of both the Achilles tendon and the calf muscles – both vital to proper gait and step propulsion. In order to compensate for the tendon and muscle shortening, “a small army of anatomical reinforcements must come to the rescue;” that anatomical rescue is by way of borrowed power from the knees, thighs, hips, and trunk.²⁸ This ultimately affects body weight distribution on the foot; because of the body's altered biomechanics as a result of the elevated heel, body weight shifts to the forefoot, altering the natural gait pattern.²⁹

Finally, restrictive, bulky footwear detracts from the functionality of the peripheral nervous system. Proprioception, defined as “the neural process by which the body takes in sensory input from the surrounding environment and integrates that information to produce a motor response,” is a key component of injury prevention.³⁰ When constantly housed in shoes, the Ruffini End Organs – nerve organs surrounding the ankle joints and critical to maintaining proprioception – are not well-stimulated.³¹ While not practical to overhaul Marine Corps uniform footwear in its entirety, the impacts of footwear – both uniform and civilian attire – should be cause for consideration when formulating prevention and recovery solutions to musculoskeletal injury sustainment.

Marine Corps Way Forward

Since 2003, the Marine Corps has witnessed a decrease in injury rates sustained at ELT sites concurrent with the implementation of the Sports Medicine Injury Prevention (SMIP) program. The SMIP Program’s mission is “to reduce attrition and lost work-days associated with musculoskeletal injuries (MSKI) in order to increase operational readiness of individual Marines and units.”³² Originating in 2003 as a pilot program, the SMIP was implemented in response to attrition due to “risk” entailed during the “physical transformation” at entry level training.³³ The main effort by which the Marine Corps would achieve the SMIP program mission is that of certified athletic trainer cadre (ATC) serving at entry level training sites.³⁴ The value of the ATC was recognized such that the program grew from eight athletic trainers (ATs) at the program’s inception in 2003 to twenty-eight in 2017.³⁵ Figure 4 depicts the distribution of ATs across entry level training sites from 2003 to 2017.

ELT Site	2003	2008	2009	2014	2017
Officer Candidates School (Quantico)	1	1	1	1	2
The Basic School (Quantico)	1	2	2	4	6
Marine Corps Recruit Depot (San Diego)	1	7	7	7	6
Marine Corps Recruit Depot (Parris Island)	3	5	5	5	7
School of Infantry-East (Camp Lejeune)	1	2	4	4	4
School of Infantry-West (Camp Pendleton)	1	2	2	3	3
Marine Aviation Support Training Group-21 (Pensacola)	0	0	2	0	0
Marine Corps Detachment Ft. Leonard Wood Missouri	0	0	2	0	0
Marine Corps Combat Service Support School (Camp Lejeune)	0	0	2	0	0
Force Fitness Readiness Center (Quantico)	0	0	0	0	1
Cumulative Total by Period	8	19	27	24	28

Figure 4. Growth of ATC across ELT sites.³⁶

Supporting the expansion of the ATC program was the data indicating the success of ATC implementation. An assessment of the effectiveness of the SMIP program in its pilot year indicated that recruit training platoons experienced an assignment rate to the Medical Rehabilitation Platoon (MRP) of 11% at Marine Corps Recruit Depot (MCRD) San Diego and that of 8.2% at MCRD Parris Island. Relative to MCRD San Diego, MCRD Parris Island experienced a greater reduction in assignment rates to the Medical Rehabilitation Platoon (MRPs) as a result of embedding the ATCs within the recruit training battalions. MCRD San Diego followed suit in 2008; as a result, the referral rate, which had once spiked upwards of 16% per platoon, reduced to between 3-4% by 2013 – similar to MCRD Parris Island. This reduced MRP referral rate indicates lower rates of sustained musculoskeletal injuries, and furthermore fewer lost training days.³⁷ Thus, the ATCs have proven their worth as advisors and injury prevention specialists, embedded and accessible not only to those in the training pipeline but also to the decision-makers – Recruit Training Battalion leadership.³⁸

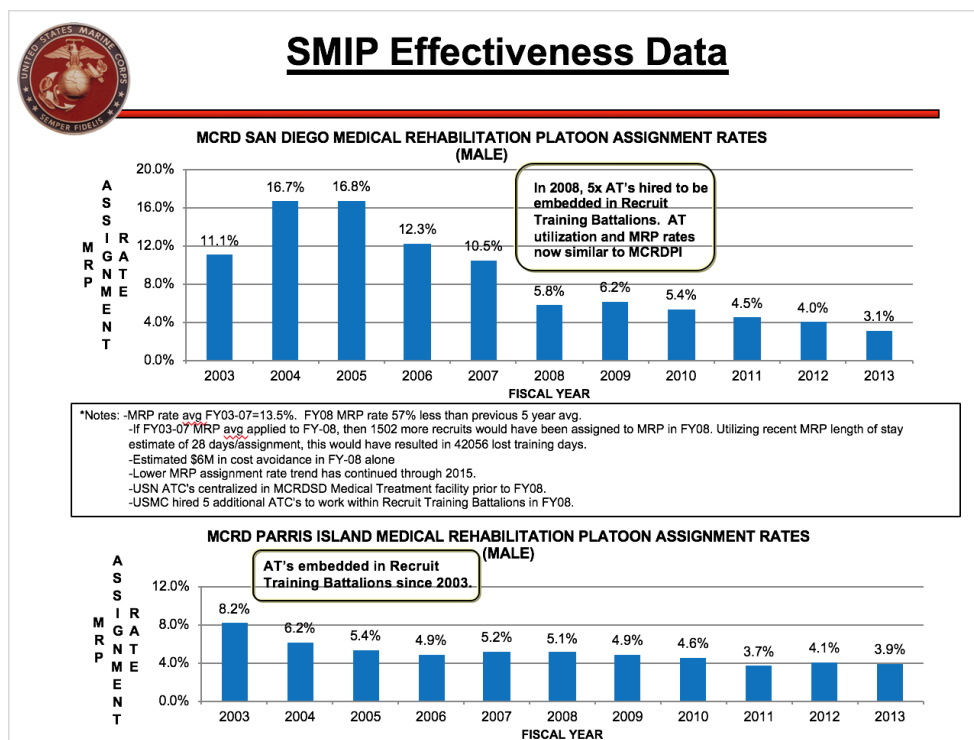


Figure 5. Medical Rehabilitation Platoon assignment rates prior to and after ATC implementation.³⁹

The entry level training implementation of the SMIP was a tremendous first step in countering the mindset prevalent in the Marine Corps that pain is a reflection of weakness, and that to gain strength one's mind and body must be resilient enough to ignore pain. This mindset no doubt contributed to MSKIs resulting from overuse.

Given the recognized benefits that the ATCs brought to entry level training, Marine Corps leadership saw fit to extend that capability to support the operating forces.⁴⁰

OPNAVINST/MCO 6400.2, signed in early 2017, set the conditions for which this would occur.⁴¹ In the two years following, the operating forces have received ATCs in all three Marine Expeditionary Forces (MEFs) at major installations in Hawaii, Japan, California, and North Carolina, with the intent that the quantity of ATCs in the operational forces to continue to expand.⁴² The ATC's role is that of "education, injury prevention, initial evaluation, treatment, and return to readiness."⁴³

The benefits of ATCs at entry level training are clearly identifiable. If the value gained from entry level training is any indication, the accessibility of ATCs in the fleet is a positive trajectory for Marines who have suffered or are prone to musculoskeletal injuries.

Concurrent with the expansion of the SMIP Program has been the development of the Marine Corps Physical Fitness Program (MCPFP). In 2016, then Commandant General Neller published white letter 2-16, which communicated the expectations of the Marine Corps Physical Fitness Program (MCPFP), aimed at “preventing and/or mitigating injuries.” “The centerpiece of the MCPFP and key to its success,” the white letter dictates, “is the creation of a cadre of Force Fitness Instructors (FFI) who will be assigned throughout the operating forces down to the company level.”⁴⁴

Marine Corps Order 1500.62 was published in December 2018, providing guidance to the force on the employment of the Force Fitness Instructor Program (FFIP).⁴⁵ “The intent of [the program] is to maximize physical fitness by integrating evidence-based systematic Physical Training (PT), injury prevention, and nutrition.”⁴⁶ An adherence to the FFI program will bridge the gap between injury prevention and sustainment. Or, to borrow a term from the Marine Corps Combat Hunter Program, the FFI’s responsibilities are aimed to get “left of bang”⁴⁷ with respect to musculoskeletal injuries. When employed in accordance with published guidance, the FFIs will develop “comprehensive physical training plans... that balance physical fitness, injury prevention, and overall health.”⁴⁸ By way of attending the six-week FFI course in Quantico, the FFIs are trained as “subject matter experts in developing fitness training plans that are holistic, progressive, and optimize physical performance tailored to unit missions and individual needs.”⁴⁹

Ultimately, the FFIs exist to decrease the risk of injury due to physical training, and to develop a holistically fit Marine who is prepared to withstand the physiological demands of

his/her military occupational specialty and mission essential tasks – or as the program guidance states, to “improve the overall health, physical fitness, and combat readiness of individual Marines and units.”⁵⁰

Beyond the SMIP and FFI Programs, the Marine Corps has historically and continues to perform research surrounding how best to equip the force with the appropriate combat clothing and equipment. Marine Corps System Command (MARCORSYSCOM) has, over the past four decades, evolved, performed testing, and expanded the Marine Corps boot program in an effort to identify means by which the boot program can contribute to the prevention of injuries.⁵¹ In 2018, a study was conducted at Marine Corps Recruit Depot Parris Island to determine whether a lighter weight boot would effect a decrease in the lower extremity injury (LEI) rate compared to the traditional sea bag issue boots – the Marine Corps Combat Boot (MCCB).⁵² The test involved over 700 recruits across eight platoons, including both males and females. While ultimately deemed insignificant, the lighter weight boots did incur up to a 2.7% decrease in the rate of LEI, as demonstrated in Figure 6.

Boot Assessed	Total number of LEI	Total number of recruits	% LEI
MCCB (control)	35	252	13.89%
Danner Reckoning	26	233	11.16%
Rocky Tropical	28	239	11.72%
Total	89	724	12.29%

Figure 6. Lower Extremity Injuries by boot assessed.⁵³

From this report, it has been determined that the minimal decrease in LEI when lighter boots were worn is inconsequential, and cannot be extrapolated to the total force.⁵⁴ Additional criteria need be considered when determining the salient boot characteristics that would contribute to a decrease in lower extremity MSKIs. Factors not considered in this study were those such as heel to toe drop measurements, or stack height, such as would advocates of minimalist footwear

recommend. While the benefits of minimalist footwear have been studied by leading podiatrists, limited research has been conducted to determine the impact of minimalist or zero-drop footwear on load bearing activities. With limited resources and no medical staff organic to the Marine Corps, this effort is a competing priority with other initiatives being conducted by the Navy and Army.⁵⁵

A secondary conclusion drawn from this study was that of the recruits' preference for a lighter boot in terms of comfort. The test boots, which were 60-70% lighter than the MCCB⁵⁶, gained significant positive results with respect to comfort when compared to the MCCB.⁵⁷ Consistent with the recruits' preference for a lighter boot, long-distance backpacking enthusiasts have trended toward lighter footwear over recent years. Furthermore, footwear preferences have trended in favor of light trail shoes over the previously traditional hiking boots. Thru-hiker surveys conducted by *The Trek* report a consistent positive trajectory in the preference for trail running shoes over hiking boots among Appalachian Trail thru-hikers since 2015, as depicted in figure 7.⁵⁸ In both 2018 and 2019, the survey reported the most popular shoe as one known for its wide toe-box and zero heel-to-toe drop measurement.^{59,60}

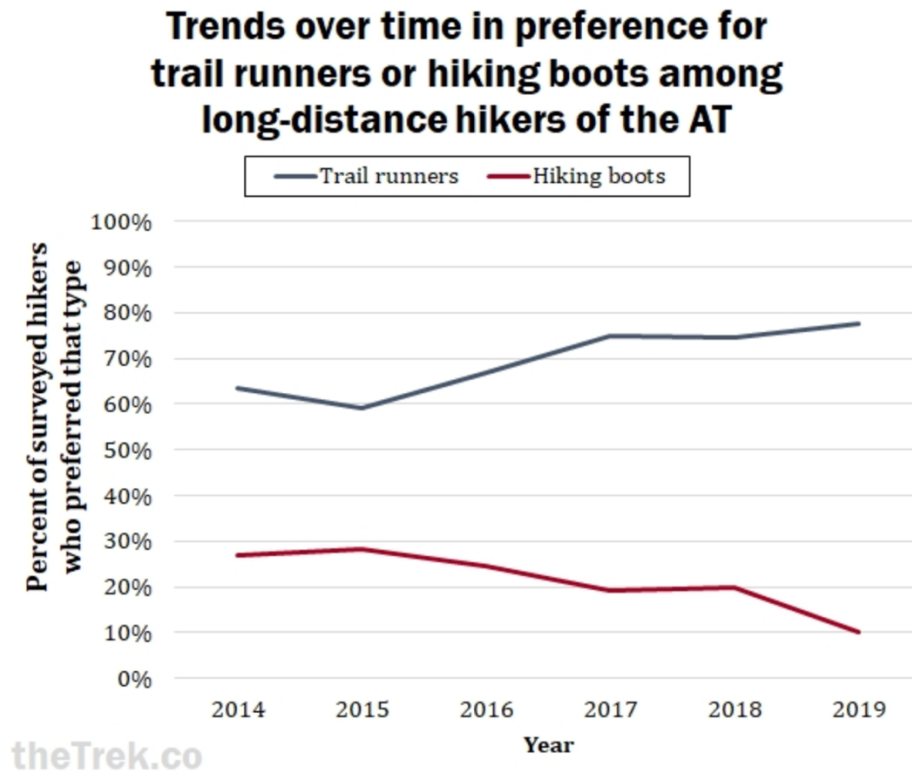


Figure 7. Trends in preference for trail runners or hiking boots among long-distance hikers of the Appalachian Trail (AT).⁶¹

The backpacking industry is also trending toward ultra-light equipment sets; the average base weight of a thru-hiker's pack load is fifteen to twenty pounds.⁶² While this base weight – that of the equipment set – does not account for the weight of nutrition and hydration, the combat load of a Marine rifleman easily exceeds the average base weight of an AT thru-hiker. Admittedly, additional research should be done on the topic of footwear in order to identify appropriate attributes such as attenuation and shock absorption with respect to the prevention of MSKIs during load bearing activities.⁶³ However, given the trends in footwear preferences among successful long-distance backpackers, the impacts of lighter and more flexible footwear on load bearing activities are worthy of the Marine Corps' consideration.

Recommendation: Expand the Way Forward

With the expansion of the SMIP, implementation of the FFI program, and ongoing footwear testing, the Marine Corps has taken great strides toward changing its culture and implementing mechanisms to prevent the incurrence of MSKIs. A solid framework has been established from which ongoing efforts can be implemented and sustained. The Marine Corps should maximize the efficacy of this framework to reduce lower extremity MSKIs by way of four recommendations. These recommendations, which are as follows, will be discussed in detail as they relate to lower extremity injuries in the following paragraphs. 1) Empower and employ the FFI as designed across the Fleet Marine Force (FMF). 2) Expand the knowledge base beyond the ATC and FFI. 3) Expand the optional boot program. 4) Sustain positive programs.

Empower and employ the FFI.

Beyond the individual Marine, the FFI is the leader closest to the ground with the ability to influence the prevention of MSKIs. However, since the inception of the FFI Program, the FFIs have not been optimized across the force in such a manner that the Commandant envisioned in his white letter.⁶⁴ While it is not possible to completely eliminate the risk of injuries, each FFI should be empowered by his/her Commander to create, implement, and sustain a sound physical fitness training program for his/her respective unit. By implementing mitigating training techniques, the FFI will be the catalyst for change with respect to injury prevention in his/her unit.

Given the contributing factors discussed previously regarding the deconditioned musculature of the foot due to restrictive footwear, the FFI program of instruction should incorporate training techniques that mitigate these effects. Those who have contributed to the research on the effects of traditional footwear offer that the solution is to address the underlying problem, which is that of structurally deconditioned feet.⁶⁵

Dr. Hoffman, whose study was cited previously as foundational research regarding the topic of footwear contributing to foot deformation, concluded that the minimally shod participants in his study “all had good strong feet.”⁶⁶ Contrast this with Dr. Hartman’s analysis of the primary cause for injuries amongst his patients – that of a weak foot, it is clear that strengthening of the foot is a necessary component of a well-balanced physical fitness training plan. Dr. Hartmann advocates strengthening exercises that are appropriate for a range of athletes⁶⁷ – and indeed, Marines should consider themselves athletes due to imposed physical fitness demands. Among the recommended exercises are those that promote flexibility, proprioception, strength, and dynamic strength.⁶⁸ Dr. Mark Cucuzella, physician and creator of the U.S. Air Force Efficient Running Program likewise proposes a goal of developing “strength, coordination, and support for the muscles of the feet.”⁶⁹

Dating back to 2010, a study conducted by the Secretary of Defense-chartered Military Training Task Force identified six scientifically validated strategies for the prevention of injuries. Second only to overtraining was the recommendation that “multiaxial (many planes of motion), neuromuscular (coordinated muscular movement), proprioceptive (body position sense), and agility (nonlinear movement) exercises be included as a regular component of military physical training programs.”⁷⁰ The study asserts that “aside from the neurophysiological learning that takes place to assist athletes and military service members in moving their bodies in

smoother, more coordinated fashion,”⁷¹ evidence suggests that these exercises will produce lower injury rates as they will contribute to a more well balanced training program.

Proprioception – an enabler of balance – has been studied specifically regarding its relation to injury prevention. Because better balance is positively associated with better athletic performance and negatively associated with lower extremity injuries,⁷² proprioceptive training techniques are imperative to a well-balanced training regimen. Specifically, due to the nature of most exercise activity, ankle proprioception is a key component to injury prevention.⁷³ Proprioceptive training activities range from simple activities requiring no equipment, such as balancing on one leg with eyes closed, to balance activities incorporating items such as wobble boards, ankle disks,⁷⁴ or with a medicine ball. When feasible, proprioceptive training should be conducted while barefoot, to take advantage of stimulating the 200,000 sensory receptors in the feet.⁷⁵ By doing so, foot to ground connection is enhanced, and proprioception, kinesthetic awareness, and intrinsic strength are improved.⁷⁶

Given their evidence-based results, proprioceptive training techniques should be incorporated into Marine Corps fitness training regimens. While they sound seemingly simple, and may not be attractive to the Marine Corps warrior culture, the value of proprioceptive training techniques should not be dismissed. Ultimately, benefits gained from these techniques produce balance and strength, which assist with negating the effects of traditional footwear, and will lead to a reduction in MSKIs and increased levels of readiness.

Similar to conducting proprioceptive training techniques while barefoot, barefoot running stimulates the sensory nerve endings in the feet, allowing the foot to better communicate sensory data to the brain and improving overall sensory awareness. Beyond barefoot proprioception training, however, barefoot running can be useful to assist with training the body to conform to

proper running biomechanics. Expanding on the tenets of Dr. Hoffman's study on the minimally shod is the work of former war correspondent Chris McDougall who documents the running accomplishments of the Tarahumara in his book, *Born to Run*.⁷⁷ While the popularity of this book inspired what some claim as a barefoot running fad, there are principles to be gained from the study of barefoot running that can influence injury prevention.⁷⁸ Dr. Dan Lieberman, Department Chair for Human Evolutionary Biology at Harvard University⁷⁹, is quoted as saying "How one runs probably is more important than what is on one's feet, but what is on one's feet may affect how one runs."⁸⁰ Dr. Lieberman advocates that barefoot running encourages a positive shift in biomechanics – particularly with respect to the foot strike when running. In essence, barefoot running acts as a free coach, retraining the body to adapt to the appropriate running biomechanics, and to run more gently and lightly, which results in less stress on the body.⁸¹

While beneficial, however, barefoot running is not necessary to the instruction of proper biomechanical running form. And most, if not all proponents of barefoot running would advocate for a graduated approach, rather than an abrupt change from motion control shoes to minimalist shoes or pure barefoot running. Force Fitness Instructors should be trained on the value of barefoot running, and consider implementing short barefoot training sessions into their training plans. Most importantly, however, the FFIs should be instructed on the appropriate running biomechanics, and how to convey those proper biomechanics to their Marines.

The recommendations included in this section are only a portion of the training that is or should be provided to the Force Fitness Instructor, and are by no means an exhaustive list of recommendations to prevent MSKIs. However, armed with these techniques in addition to the range of physical fitness and injury prevention training received via the FFI course, the FFI truly

is an indispensable asset to a unit's physical training and injury prevention program. Only by empowering and holding the FFIs accountable to their responsibilities, will the FMF realize the optimal results of the program. Given the injury rates consistently sustained across the Marine Corps, the FFI Program is a worthy investment; the FFIs must be empowered by their Commanders via their time, attention, and tasking priorities.

Expand the optional boot program.

The impact of the FFI can be further extended through an expansion of the optional boot program testing and fielding. The current minimum boot requirement can be satisfied by twelve style numbers across five manufacturers, with the optional boot program offering four additional options.⁸² While seemingly a wide variety of options, in reality, the preponderance of the boots conform to similar last styles, sole thickness and overall rigidity. With good reason, Marine Corps Systems Command focuses on salient characteristics required for protection and durability in a combat environment when testing and fielding boot options.⁸³ However, even so, the Marine Corps is somewhat at the mercy of existing market solutions with respect to available boot options.⁸⁴ With respect to the salient attributes for military boots, recommendations date back to the 1912 work by Dr. Edward Munson of the United States Army Medical Corps, who designed a shoe last that “permits the foot to assume a shape and relation approximately like that of the same foot when unconfined.”⁸⁵ Dr. Munson argues in favor of many of the aspects in today's boots – such as with respect to durability and protection of the foot.⁸⁶ Arguably, today's available footwear has exaggerated the properties necessary for a viable combat boot.

Modern research has demonstrated the negative effects of the properties of footwear such as are contained in the current Marine Corps combat boots. Consequently, it is possible that the prolonged wear of the combat boot results in an increased likelihood of MSKIs. While further research is required to determine the appropriate footwear for load bearing activities, it is not unreasonable for the Marine Corps to consider implementing an additional boot option for garrison wear – one that would lessen the impacts of the current authorized boots. (Lest one would argue that the Marine Corps should train as it fights as a justification to sustain the current boot inventory, it is worth mentioning that the Marine Corps maintains an inventory of garrison dress uniforms which are not suitable for the combat environment.)

In order to combat the negative effects of the combat boot, the Marine Corps should test and authorize a garrison boot with attributes such as the following:

- 1) A minimal heel to toe drop, to negate the effects of the elevated heel raise⁸⁷
- 2) A widened toe box, to allow the toes to expand laterally and fulfill their role in step propulsion;
- 3) A flexible sole, to allow the foot to contract and flex naturally⁸⁸
- 4) A thinner stack height (sole thickness), to allow stimulation of the sensory receptors in the foot⁸⁹

Summarized by Dr. Rossi, “a shoe, ideally, should be an anatomical and functional replica of the foot. And this can be considered a biomechanical law: The less a shoe does TO a foot, the better FOR the foot.”⁹⁰ With a shoe that does less to a foot, the efforts of the FFI can be extended beyond fitness training and throughout daily garrison activities.*

* Within the field of podiatry, alternate opinions exist with respect to the benefits gained from technological advancements in shoes, such as motion control and cushioning. However, research indicates that no evidence-based studies exist which would validate the benefits of the properties of traditional running shoes.

Expand the knowledge base.

In order to fully realize the benefit of the FFI in injury prevention, the knowledge base that will be contained within the FFI cadre must expand. Given the alarming injury rates reported in 2018, health, fitness and injury prevention should be a topic in which leadership of all levels is well-versed. Marine Corps education programs focus on warfighting and leadership, but seldom give credence to educating the force on how to achieve total fitness of an individual Marine. All Marines are expected to maintain a high state of physical fitness, but receive little to no formal training on basic anatomy, kinesiology, biomechanics, or physiology. While many Marine Corps units dictate an annual training requirement for nutrition, the requirement is often implemented in ineffective ways, such as via MarineNet course. If total fitness is indeed a topic of concern, discussions regarding this topic should permeate leadership discussions at all levels. Once again, the Marine Corps maintains a framework by which this can be accomplished. One avenue is the formal schools program; professional military education (PME) should include modules on physical fitness, with a focus on creating and sustaining a well-balanced training plan. With the expansion of the athletic trainer cadre to fleet units, their expertise should be leveraged to incorporate injury prevention topics in local PME ranging from Corporal's Course to Advanced Course for enlisted Marines, and at the Basic School for officers.

Another avenue by which the knowledge base regarding fitness and injury prevention can be expanded is that of the Commandant's Professional Reading List (CPRL). The current CPRL does not contain a single book on the topic of wellness, fitness, or nutrition.⁹¹ Conversely, titles on history, leadership, innovation, and teamwork elicit a common readership amongst military members due to their inclusion on the CPRL, the benefits of which are commonly understood

and discussed principles and values. The same should be the case for fitness, nutrition, and an understanding of the human body; a captivating read on these topics would no doubt initiate common discussion and change Marines' attitude toward total fitness. Rarely does one overhear Marines discussing principles gained from taking a MarineNet course on nutrition; however, "Message to Garcia" is such a commonly known read that when a Marine simply utters the title, the recipient understands the gist or intent of the comment.

The following recent titles on the topic of fitness, nutrition, and an understanding of human athletic performance capabilities – which were referenced during research and contributed in part to the inspiration for this paper – are recommended for inclusion on the CPRL.

1. *Run for Your Life: How to Run, Walk, and Move Without Pain or Injury* by Mark Cucuzzella. (New York: Vintage Books, 2018.)
2. *Endure: Mind, Body, and the Curiously Elastic Limits of Human Performance*. Alex Hutchinson. (New York: HarperCollins Publishers, 2018.)
3. *Natural Born Heroes: Mastering the Lost Secrets of Strength and Endurance*. Christopher McDougall. (New York: Vintage Books, 2015.)

Sustain Positive Programs.

No doubt, gains have been realized with respect to the SMIP. With the expansion of ATCs to operational units, it is expected that the Corps will continue to see positive results. Fortunately, the ATC program is currently funded across the Fiscal Year 2020 Future Years Defense Program (FY20 FYDP).⁹² In order to maintain its relevance, however, the program must be monitored for quantifiable positive results; if those results manifest themselves as expected, the program must be sustained. The Marine Corps cannot afford to take backward strides with respect to injury

prevention and recovery, particularly in an era when talent retention is a problem. While the FFIs are designated as the main effort in the physical fitness program, the ATC is designated as the primary supporting effort to ensure their success, particularly with respect to injury prevention.⁹³ Beyond their use as a resource for FFIs and Commanders, they provide the force with accessible, on-scene, expert care with respect to musculoskeletal injury treatment and prevention – an asset that has not been available prior to the implementation of this program. Because of their accessibility, the ATs are able to decrease injury wait times by up to 50%.⁹⁴

Conclusion

The Marine Corps has implemented programs that are expected to realize marked improvement with respect to the prevention of MSKIs. While this thesis offers solutions within the framework of existing programs, with respect to the use of appropriate footwear and the employment of the FFIs, further research is required to determine the optimal boot for load bearing activities. The SMIP, FFI, and optional boot programs are efforts to steer the Marine Corps in a positive trajectory, not only with respect to injury prevention, but also with respect to a change in culture, and ultimately toward increased levels of combat readiness. These are steps in the right direction. However, they are only effective if they are employed. Existing guidance establishes the framework for successful implementation and sustainment of these programs. It is imperative that injury prevention efforts do not stop with the publishing of an order, the hiring of a contractor, or the implementation of one or two optional boots. The Marine Corps must maintain its positive trajectory, leverage existing research, and continue to step smartly toward musculoskeletal injury prevention, and ultimately an increased level of combat readiness.

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