NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

AC/323(HFM-283)TP/1107

www.sto.nato.int

STO TECHNICAL REPORT **TR-HFM-283**

Reducing Musculo-Skeletal Injuries

(Réduction des lésions musculo-squelettiques)

Final report of Task Group RTG-283.

Published August 2023

Distribution and Availability on Back Cover

NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

AC/323(HFM-283)TP/1107

www.sto.nato.int

STO TECHNICAL REPORT **TR-HFM-283**

Reducing Musculo-Skeletal Injuries

(Réduction des lésions musculo-squelettiques)

Final report of Task Group RTG-283.

The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

The content of this publication has been reproduced directly from material supplied by STO or the authors.

Published August 2023

Copyright © STO/NATO 2023
All Rights Reserved

ISBN 978-92-837-2424-7

Single copies of this publication or of a part of it may be made for individual use only by those organisations or individuals in NATO Nations defined by the limitation notice printed on the front cover. The approval of the STO Information Management Systems Branch is required for more than one copy to be made or an extract included in another publication. Requests to do so should be sent to the address on the back cover.

Table of Contents

List of Figures

List of Tables

HFM-283 Membership List

CO-CHAIRS

Dr. Thomas KARAKOLIS
Defence Research and Development Canada
CANADA
Email: thomas.karakolis@ecn.forces.gc.ca

Mr. Graham WHITE
Dstl
UNITED KINGDOM
Email: gwhite1@mail.dstl.gov.uk

MEMBERS

Prof. Julie GREEVES
Army Personnel Research Capability Organization
UNITED KINGDOM
Email: julie.greeves143@mod.uk

Dr. Vedran HADŽIĆ
University of Ljubljana,
SLOVENIA
Email: vedran.hadzic@fsp.uni-lj.si

Dr. Rachel IZARD
British Army
UNITED KINGDOM
Email: Rachel.izard715@mod.gov.uk

Dr. Karen R. KELLY
Naval Health Research Center
UNITED STATES
Email: karen.r.kelly8.civ@health.mil

Dr. Susan P. PROCTOR (Retd.)
USARIEM
UNITED STATES
Email: *unavailable*

LtCol (MC) Ass.-Prof. Dr. Stefan SAMMITO
Bundeswehr Joint Medical Service
GERMANY
Email: stefansammito@bundeswehr.org

Ms. Beatriz SANZ-BUSTILLO AGUIRRE
Deputy Secretariat for Defence
SPAIN
Email: bsanagu@mde.es

Dr. Ainars STEPENS
Riga Stradins University
LATVIA
Email: ainars.stepens@rsu.lv

LTC Dr. Damien VAN TIGGELEN
Belgian Defence
BELGIUM
Email: damien.vantiggelen@gmail.com

LTC Prof. Wesselius O. ZIMMERMANN
TGTF
NETHERLANDS
Email: wo.zimmermann@mindef.nl

PANEL/GROUP MENTOR

Col Prof. Dr. Kai KEHE
Bundeswehr Medical Academy
GERMANY
Email: kaikehe@bundeswehr.org

Reducing Musculo-Skeletal Injuries

(STO-TR-HFM-283)

Executive Summary

The high prevalence (20 to 40 %) of Musculo-Skeletal Injuries (MSkIs) places considerable burden on soldiers throughout their military career, impacts operational readiness, and remains a concern to the NATO military community. The frequency and quality of injury reporting by clinicians and patients varies within and between partner nations: reported data tend to focus on more severe injuries that lead to medical discharge or downgrading. Better data on the incidence and causes of MSkI are required to determine the effectiveness of preventative measures.

The purpose of Research Task Group (RTG) HFM-283 “Reducing Musculo-Skeletal Injuries” was to analyze published and defence-controlled scientific literature on the prevalence, risk factors, and interventions for MSkI in military populations to form recommendations on preventative strategies to Commanders.

Across the participating NATO Nations, differences in methods of data collection, including coding of injuries, prevented detailed comparisons in injury rates between Nations. To conduct effective clinical trials on MSkI prevention measures across Nations, injury-type (e.g., overuse, acute) and causes need to be recorded using a standard coding system.

The risk factors for MSkI were prioritized by the expert panel members, based on the literature review and in-depth analysis of the scientific evidence; a new model was developed, categorizing the risk factors for injury as 1st, 2nd, or 3rd order of importance. This model includes the established concepts of modifiable, non-modifiable and extrinsic, intrinsic risk factors. This model can guide the planning and implementation of intervention strategies.

This report makes recommendations to reduce MSkI, by considering military training throughout the service member lifecycle as a dynamic system, a learning environment composed of three continuously interacting and changing subsystems: the organism (service member), the environment, and the tasks. To address these interacting components, active collaboration between leadership, policy makers, military instructors, healthcare providers, scientists, and researchers are key to contribute to a reduction in training injuries in the Armed Forces.

Recommendations for a successful MSkI preventative program include:

- Prevention strategies based on a multidisciplinary approach;
- Leadership (at all levels of the organization);
- Education of personnel;
- Trainers and leaders;
- Surveillance;
- Adequate resources for program evaluation; and
- Research.

Prioritization of preventative measures should take into account the following five elements: importance of the problem, likely effectiveness of the prevention strategy, feasibility of establishing the measure, timeliness of the implementation, and potential for evaluation of its effectiveness.

Réduction des lésions musculo-squelettiques

(STO-TR-HFM-283)

Synthèse

La prévalence élevée (20 à 40 %) des lésions musculo-squelettiques (LMS) pèse considérablement sur les soldats tout au long de leur carrière militaire, se répercute sur la préparation opérationnelle et demeure une préoccupation de la communauté militaire de l'OTAN. La fréquence et la qualité des signalements de blessures par les cliniciens et les patients varient dans chaque pays partenaire et d'un pays à l'autre : les données rapportées ont tendance à se concentrer sur les blessures graves qui entraînent un renvoi pour raisons médicales ou une dégradation. De meilleures données sur l'incidence et les causes de LMS sont nécessaires pour déterminer l'efficacité des mesures préventives.

L'objectif du groupe de recherche (RTG) HFM-283 « Réduction des lésions musculo-squelettiques » était d'analyser la littérature scientifique publiée et contrôlée par la défense sur la prévalence, les facteurs de risque et les interventions pour LMS dans les populations militaires, afin de formuler des recommandations sur les stratégies préventives, à destination des commandants.

Au sein des pays de l'OTAN participants, les différentes méthodes de collecte des données, notamment de codification des blessures, ont empêché la comparaison détaillée des taux de blessures entre les pays. Pour mener des essais cliniques efficaces sur les mesures de prévention des LMS dans les pays, il faut enregistrer le type de blessure (par exemple, blessure aiguë ou de fatigue) et les causes à l'aide d'un système de codification standard.

Les membres du groupe de spécialistes ont hiérarchisé les facteurs de risque des LMS à partir d'une revue de la littérature et d'une analyse approfondie des preuves scientifiques ; un nouveau modèle a été établi, classant les facteurs de risque de blessure selon leur ordre d'importance (1er, 2e ou 3e). Ce modèle inclut les concepts établis de facteurs de risque modifiables, non modifiables, extrinsèques et intrinsèques. Il peut guider la planification et la mise en œuvre des stratégies d'intervention.

Le présent rapport émet des recommandations pour réduire les LMS, en considérant l'entraînement militaire tout au long du cycle de vie des militaires en service comme un système dynamique, un environnement d'apprentissage composé de trois sous-systèmes qui interagissent et évoluent en continu : l'organisme (militaire en service), l'environnement et les tâches. Face à ces interactions, une collaboration active entre les dirigeants, les décideurs politiques, les instructeurs militaires, les soignants, les scientifiques et les chercheurs est essentielle pour contribuer à la réduction des blessures liées à l'entraînement dans les forces armées.

- Les recommandations en vue d'un programme réussi de prévention des LMS incluent :
- des stratégies de prévention basées sur une approche pluridisciplinaire ;
- le leadership (à tous les niveaux de l'organisation) ;
- l'éducation du personnel ;
- des formateurs et des dirigeants ;
- la surveillance; et
- des ressources adaptées à l'évaluation du programme et des recherches.

La hiérarchisation des mesures de prévention doit tenir compte des cinq éléments suivants : importance du problème, efficacité probable de la stratégie de prévention, possibilité de mise en place de la mesure, mise en œuvre en temps opportun et potentiel d’évaluation de l’efficacité.

Chapter 1 – INTRODUCTION

G. White, V. Hadžić, J.P. Greeves, T. Karakolis, K.R. Kelly, S. Proctor, S. Sammito, B. Sanz-Bustillo-Aguirre, A. Stepens, D. Van Tiggelen, and W.O. Zimmermann

The purpose of this report is to publish the results of the activities carried out by the NATO-HFM RTG 283 between 2017 and 2021 on reducing musculo-skeletal injuries.

1.1 BACKGROUND

Military training by design is physically demanding and many military roles (occupations) have increased physical demands as compared to others (e.g., infantry vs. cook). In physically demanding roles, a force that is fitter than the enemy has an advantage. However, physical training carries a risk of Musculo-Skeletal Injury (MSkI).

Musculo-skeletal injuries can affect all military personnel but are a particular hazard for new recruits. MSkIs can range from: muscle pain resulting in days lost during training through to stress fractures resulting in medical down-grading or medical discharge. Specific definitions regarding MSkIs are provided in the Glossary. The NATO military community recognizes MSkIs as a significant problem. Since MSkIs account for over half of all medical discharges, they reduce both training and operational effectiveness and increase the demands placed on associated medical care provision. Published reports show that 20 – 59 % of recruits are affected by MSkI with about 8% of recruits being discharged from service due to MSkI. Generic interventions have been found to be ineffective when it comes to reducing or preventing clinical conditions (see Chapter 4 – Interventions).

The frequency and quality of injury reporting varies within, and between, partner nations (see Chapter 2 – Prevalence). The data that are generally reported quantify the incidence and prevalence of MSkI to military personnel and focus on the more severe injuries that result in either medical discharge or medical down-grading. Whilst efforts have been made to reduce injury rates based on this relatively coarse data, a better understanding of the prevalence (Chapter 2 – Prevalence), causes of MSkI (Chapter 3 – Risk Factors), and effectiveness of existing preventative measures (Chapter 4 – Interventions) is necessary to decrease the number of personnel unfit for task and mission.

The purpose of this report is to:

- Collate peer reviewed, and non-peer reviewed, defence reports;
- Provide guidance to military commanders to enable them to make informed decisions on measures to introduce to reduce MSkI; and
- Identify data that must be captured to determine if the intervention has been effective.

1.2 OBJECTIVES

The objective of this RTG was to focus on primary preventative measures to reduce MSkI by:

1) Promoting the sharing information among participating nations;
2) Identifying the causes and associated risk factors for MSkI;

3) Identifying existing and novel strategies/technologies which may reduce the rate of MSkIs; and
4) Linking to other on-going STO-activities.

1.3 APPROACH

The approach taken by the group is reflected in the structure of the report.

Chapter 1. Impact of MSkIs in the military.

Chapter 2. Prevalence and site of injury, by nation. The collation of these data revealed that the collection of data is not consistent across nations, and some nations do not have electronic medical record systems.

Chapter 3. Risk factors for MSkI: A Literature Review. The number of participants in referenced studies ranged from tens to hundreds of thousands. Often studies had conflicting findings. The panel members reached a consensus on the strength of the evidence for each salient risk factor. For classification purposes, the panel considered the size of the study, the research method, and the study's findings, and then applied their professional experience in military MSkI. A graphical model was developed to assist commanders to make decisions on where to target resources to reduce MSkIs. Some risk factors are modifiable (e.g., smoking) whilst others are not (e.g., sex).

Chapter 4. Interventions for MSkI. In support of the findings, case studies of successful and unsuccessful or inconclusive interventions from each participating nation are presented. Each nation reports its current approach to reducing MSkI.

Chapter 5. Evidence-based recommendations. These recommendations are for consideration by military commanders and practitioners charged with decreasing the impact of MSkI on the readiness of their personnel and decreasing the rate of discharge of new recruits from initial training. These recommendations provide guidance on the principles to be considered when developing new intervention measures to address a nation's MSkI issue. Note: each new situation is unique and requires a novel approach. This chapter also provides recommendations to scientists and other researchers charged with understanding the underlying mechanisms that cause MSkIs, and effectiveness of interventions designed to prevent MSkIs.

The Glossary in Annex A contains a table of terms and their definitions for MSkI used by participating nations. This Glossary will enhance NATO's military readiness by improving the understanding of how MSkI reduction can be an important tool to reduce injury and optimize physical performance of both men and women across a diverse range of military settings.

Chapter 2 – PREVALENCE OF MUSCULO-SKELETAL INJURIES

S.P. Proctor, J.P. Greeves, V. Hadžić, K.R. Kelly, S. Sammito, B. Sanz-Bustillo-Aguirre, A. Stepens, D. Van Tiggelen, G. White, and W.O. Zimmermann

2.1 SUMMARY

The goal of this chapter is to address the following key points:

- NATO members states contributing to the Research Task Group (HFM-RTG-283) report differing capabilities and methods for determining the prevalence of Musculo-Skeletal Injuries (MSkIs) among their respective Armed Forces populations.
- Efforts to optimize MSkI monitoring and surveillance strategies will improve the ability to determine successful risk reduction strategies.

2.1.1 Outline of the Chapter

Part 1 – Overview of MSkI rates among NATO member states contributing to HFM-RTG-283 with short summaries from the following nations Armed Forces: Belgium, Germany, Latvia, Netherlands, Slovenia, Spain, United Kingdom, and the United States.

Part 2 – Summary and discussion of the findings related to available injury data and injury rates among the nations represented.

Part 3 – Recommendations for improving the standardization of data recording systems to determine MSkI rates, to lay a foundation for measuring the success of intervention, and prevention strategies.

2.2 PART 1 – OVERVIEW OF MSKI RATES OF NATO NATIONS

This section will present, by NATO Nation, an overview of the military population demographics and military service structure, along with MSkI rates from either primary data and/or scientific publications literature, from 2005 or later. Where possible, injuries have been organized by regions of the body. Also, where available, the prevalence of MSkIs among the nation-specific military overall and recruit (during initial military training) populations are presented, along with subgroup comparisons for acute compared to overuse/repetitive injury, men compared to women, and from medical records compared to self-report.

2.2.1 Belgium

D. Van Tiggelen

The Belgian military (on average 25,000) is composed of four branches: i) Army (n = 12,000), ii) Air Force (n = 10,000), iii) Navy (n = 1,500), and iv) Medical Branch (n = 1,500). Approximately 10% of the military personnel are women. The average age of volunteers entering the Belgian military is 19 years. The average age of the military overall is 34 years.

The physical tests required for enlistment are:

- One-minute sit-up (maximal scores: women = 29, men = 39);
- One-minute push-up (maximal scores: women = 20 reps*, men = 25 reps; *women perform knees on the ground push-ups); and
- Running test on treadmill (at incline 2%), with speed increasing every 30 sec by 0.3 km/h up to 14.4 km/h for men, and 12.6 km/h for women.

Running performance accounts for 80% of the points, push-ups and sit-ups each account for 10%. Recruits who want to join the Commandos are required to perform an additional 16 pull-ups regardless of sex.

Recruit training consists of a three-month basic training period. For non-commissioned officers, the training is four months. For officers, initial training is 6 weeks. Additionally, officers are required to complete 5 years continuous training at the Royal Military Academy.

The Belgian military have an electronic medical record system; however, the system is not designed to be used to determine population or group-level injury rates. Most service members use the civilian health/medical system for care, and none of the data/records captured by civilian health/medical system is reported within the military system.

Table 2-1 presents the Belgian military injury rates determined from self-reported data collected as part of a research study among a subset of Army recruits (n = 251) during Basic Military Training (BMT) between 2010 – 2017. Previous data (2004 – 2008) found the rates of injuries were 41% in female recruits, and 25% in male [1], [2].

Table 2-1: Belgian Army Recruits 2010 – 2017, Self-Report of n = 251.

<table>
<tr><th colspan="3">MSkI Category</th><th># Injuries</th><th>Rate</th></tr>
<tr><td rowspan="10">Extremities</td><td rowspan="4">Upper Quarter Injury (UQI)</td><td>Shoulder/upper arm</td><td rowspan="4">2</td><td>0.8%</td></tr>
<tr><td>Forearm/elbow</td><td></td></tr>
<tr><td>Wrist/hand/fingers</td><td></td></tr>
<tr><td>Other, unspecified</td><td></td></tr>
<tr><td rowspan="6">Lower Quarter Injury (LQI)</td><td>Hip</td><td>11</td><td>4.4%</td></tr>
<tr><td>Upper leg/thigh</td><td></td><td></td></tr>
<tr><td>Knee</td><td>37</td><td>14.7%</td></tr>
<tr><td>Lower leg/ankle</td><td>24</td><td>9.6%</td></tr>
<tr><td>Foot or toes</td><td>17</td><td>6.8%</td></tr>
<tr><td>Other, unspecified</td><td></td><td></td></tr>
<tr><td rowspan="4">Torso</td><td rowspan="4">Torso</td><td>Chest (thorax area)</td><td></td><td></td></tr>
<tr><td>Abdomen</td><td></td><td></td></tr>
<tr><td>Pelvis and urogenital</td><td></td><td></td></tr>
<tr><td>Trunk</td><td></td><td></td></tr>
</table>

MSkI Category			# Injuries	Rate
		Back and buttocks		
Spine and Back	**Spinal Cord and Vertical Column Injury (SCI, VCI) (combined)**	*Cervical SCI and VCI*	1 (Cervical) 1 Lumbar	0.8%
		Thoracic/dorsal SCI and VCI		
		Lumbar SCI and VCI		
		Sacrum coccyx SCI and VCI		
		Other spine and back		
Other	**Multisite/Polytrauma Injury**			
	Total		93	37.1%

2.2.2 Germany

S. Sammito

The German military (on average 180,000) is composed of several branches: i) Army (n = ~62,000), ii) Air Force (n = ~27,500), iii) Navy (n = ~16,000), iv) Joint Support and Enabling Service (n = ~27,500), v) Central Medical Service (n = ~20,000), vi) Cyber and Information Domain Service (n = ~13,000), vii) and other included Ministry of Defence personnel (n = ~14,000). Approximately 12% of the military personnel is female.

The physical tests required for enlistment is a modified Basic Fitness Test (BFT) [3]. The elements of this test are:

- An 11 x 10 m sprint test (max. 60 sec);
- A flexed-arm hang (min. 5 sec); and
- An ergometer bicycle test of 3,000 m max. 6:30 min.

In addition, a medical screening is done to exclude candidates with chronic diseases. Recruit training consists of a 3-month basic training period.

For active soldiers, the non-modified BFT [4] must be completed each year. The BFT consists of:

- An 11 x 10 m sprint test (max. 60 sec);
- A flexed-arm hang (min. 5 sec); and
- A 1000 m run (max. 6 min 30 secs).

In addition, every soldier has to confirm every year the requirement for safety control of their personal weapon including shooting, knowledge of first aid and personal CBRN-measurements, and they have to march 6 km carrying a 15 kg load minimum (max. 60 min) [5].

The German military does not have an electronic medical record system to track injury rates. Injuries are reported in written medical records; however, there is no formalized coding system to provide systematic injury summaries.

Table 2-2 presents a description of German military injury rates determined from analysis of the written medical data in three studies:

- **Study 1** [6]: male recruits; 1 training company, IV/2008 – III/2009; analysis of military medical record data.
- **Study 2** [7] male and female Active Duty, 21st tank brigade (3000+ soldiers), 01/2008 – 01/2009; analysis of military medical record data.
- **Study 3** [7]: male recruits, 2 training companies, IV/2012 – III/2014, analysis of military medical record data.

Study 1: Overall MSkI rate: 2.27 injuries / 1,000 h field training.

Study 2: Overall MSkI rate: 1.50 injuries / 1,000 h sport training.

Study 3: Overall MSkI rate: 1.09 injuries / 1,000 general military training and 4.17 injuries / 1,000 h sport training.

Table 2-2: German Military Rates.

MSkI Category			Study 1 Rate Training Study N = 394, Only Males	Study 2 Rate Active Duty Study, 21st Tank Brigade, Sport Training N = 3000	Study 3 Rate Training Study N = 774, Only Males
Extremities	**Upper Quarter Injury (UQI)**	*Shoulder/upper arm*	*7.9%*	*3.3%*	*13%*
		Forearm/elbow	*0.7%*	*1.8%*	
		Wrist/hand/fingers	*2.2%*	*10.0%*	
		Other, unspecified			
	Lower Quarter Injury (LQI)	*Hip*			*60%*
		Upper leg/thigh	*5.8%*	*11.9%*	
		Knee	*24.5%*	*24.9%*	
		Lower leg/ankle	*19.4%*	*32.7%*	
		Foot or toes	*15.8%*	*3.7%*	
		Other, unspecified			
Torso	**Torso**	*Chest (thorax area)*	*2.9%*	*6.7%*	*22 %*
		Abdomen			
		Pelvis and urogenital		*0.7%*	
		Trunk			
		Back and buttocks	*8.6%*		

MSkI Category			Study 1 Rate Training Study N = 394, Only Males	Study 2 Rate Active Duty Study, 21st Tank Brigade, Sport Training N = 3000	Study 3 Rate Training Study N = 774, Only Males
Spine and Back	**Spinal Cord and Vertical Column Injury (SCI, VCI) (combined)**	*Cervical SCI and VCI*	*0.7%*		
		Thoracic/dorsal SCI and VCI			
		Lumbar SCI and VCI			
		Sacrum coccyx SCI and VCI			
		Other spine and back			
Other	**Multisite/ Polytrauma Injury**		*10.1%*		
		Head	*1.4%*	*4.1%*	*4%*

2.2.3 Latvia

A. Stepens

The Latvian military (on average 13,350) is composed of five branches: i) Army (Land Forces n = 3,381) and National Guard (n = 8269); ii) Air Force (n = 434); iii) Navy (n = 474); iv) Logistic Command (n = 442); and v) Training and Doctrine Command (n = 352). Approximately 16% of the military personnel are women, which varies somewhat by branch with highest being in Logistic Command (29.2%) and lowest in the Navy (11.2%). Latvia has an all-volunteer force. The average age entering service is, 23.8 years. The average age of the military overall is 34.2 years (ranging between 33 – 38 years across the branches).

Both physical tests and medical screening are required for enlistment. The physical tests required for enlistment are:

- Two-minute sit-up (minimal scores: women = 31; men = 43);
- Two-minute push-up (minimal scores: women = 14; men = 33); and
- Fixed distance timed run (1.5 km for women, 3 km for men – minimal scores: women = 8:56 min; men = 14:29 min).

Recruits have to be able to pass all three tests. Medical screening consists of medical and psychological questionnaires, biometrics (height should not be lower than 150 cm and body mass not lower than 45 kg for both biological sexes). Depending on the pre-enlistment medical testing results, candidates are separated into six categories (1 to 6, where category 6 represents the best health status) and only those with category 5 and 6 are selected for enlistment (for some occupations, those in category 4 may be acceptable).

All selected recruits undergo the same 13-week basic training during the introductory course at the Infantry School, regardless of branch.

The Latvian military does not have an electronic medical record system. The National Army Medical Center collects monthly injury reports provided by the regional medical centers. These monthly injury reports mainly address acute MSkI; reports of overuse injuries are not easily extracted. Coding or categorizing of injuries can be conducted from written medical records; however, the coding system is not formalized. In 2017, overall, the MSkI medical report-based prevalence rate was 12.14% (men – 13.4%; women – 6.7%) (Table 2-3).

Table 2-3: Latvian Military Rates – Medical Report-Based Acute Injury Rates in 2017, for Land Forces.

MSKI Category			# Injuries	Denominator	Overall Rate %	Rate for Males (N = 2870)%	Rate for Females (N = 511)%
Extremities	**Upper Quarter Injury (UQI)**	*Shoulder/upper arm*	*26*		0.77	0.87	0.20
		Forearm/elbow	*27*		0.80	0.91	0.20
		Wrist/hand/fingers	*84*		2.48	2.79	0.78
		Other, unspecified	*0*				
	Lower Quarter Injury (LQI)	*Hip*	*0*				
		Upper leg/thigh	*18*		0.53	0.56	0.39
		Knee	*64*		1.89	1.88	1.96
		Lower leg/ankle	*85**	*3381*	2.51	2.79	0.98
		Foot or toes	*59*		1.75	1.74	1.76
		Other, unspecified	*1*		0.03	0.03	
Torso	**Torso**	***Chest (thorax area)***	*30*		0.89	1.01	0.20
		Abdomen	*2*		0.06	0.07	
		Pelvis and urogenital	*6*		0.18	0.17	0.20
		Trunk	*13*		0.38	0.45	
		Back and buttocks	*5*		0.15	0.17	
		Total Cases:	*420*		12.42	13.45	6.65

*2 cases on tibial stress fractures, 1 case on 5th metatarsal stress fracture identified.

In a study in which 227 Infantry Soldiers were surveyed in 2017 [8], the reported prevalence of acute and overuse injuries was 86.8% and the prevalence of overuse injuries was 43.1%. Among overuse injuries, the most prevalent were back and buttock (18.5%), whereas among acute injuries the most often reported were lower leg and ankle (18.1%).

2.2.4 Netherlands

W.O. Zimmermann

The Netherlands Armed Forces (~n = 30,000) is composed of four branches: i) Royal Netherlands Army (n = 17,450); ii) Royal Netherlands Air Force (n = 6,572); iii) Royal Netherlands Navy and Marines (n = 7,824);

and iv) Military Police (n = 5,931). In addition, a Reserve force (n = 8,500) is available for part-time duties. Approximately 10% of the military personnel are women.

On a yearly basis, up to 5000 recruits (age < 27 years; average age 21 years) start their military career. They all receive pre-enlistment field tests of fitness and a medical screening. They are officially employed from day one of training, and have job protection for two years, in case of sickness or injury. This means that recruits who become injured in basic training are not discharged. Instead, they receive care within the military health care services.

Pre-military training: many Dutch teenagers complete high school at the age of 16, but they are too young to join the military. As a result, the Netherlands has established more than 30 vocational schools that offer a two-year pre-military program geared towards preparing these youths for a military career.

For pre-enlistment, the following tests are required:

- Medical and psychological questionnaires (validated);
- Biometrics (including eyes and ears, pulmonary test);
- The physical activity readiness questionnaire (PAR-Q) [9]; and
- Functional physical tests (e.g., marching test, agility trail, lift and carry test, digging test, 12 minute run).

The result of the total package of pre-enlistment testing procedures for each candidate is then used to place the candidate in one of six categories/cluster of fitness, where cluster one represents the light military specialties and cluster six the most strenuous jobs (Special Forces). On base, training is not always separated into six fitness groups. Clusters 1 – 4 candidates may train in a single group. Special Forces in cluster 6 always have separate training regimens.

Military entry training is 4 months for all.

Unfortunately, the Netherlands Armed Forces do not have an adequate and widespread surveillance system for illness and injury of military personnel. The electronic patient records in primary, secondary and tertiary care are designed for patient care, not for epidemiological research. In primary care, disease codes from a national occupational medicine coding system are used. In secondary care (military hospital) ICD 10 codes are used.

Recently several studies have been undertaken to address the injury and drop out from basic military training and the armed forces in general. Here two studies are presented:

1) A recent study [10] combined information from medical records with information from personnel files (absenteeism) to produce the best approximation of incidence, duty days lost, and the financial burden of musculo-skeletal injuries. Information was obtained from more than 8000 subjects, across all four branches of our armed services, and across all ages (recruits and permanent staff) from 2014 – 2016. Study findings were that 23% of new medical consultations involved MSkI. Injuries of the back, knee and foot accounted for the majority of cases (see Table 2-4 to Table 2-8). Estimated costs for physician visits were 0.69 million euros, limited duty days accounted for 1.1 million euros productivity lost.
2) An analysis of drop out from elite military training in the years 2015 through 2017 [11] showed that drop out in Marine training was 53.9% and in elite infantry training 52.6%. Dropout due to MSkIs in these groups was 23% and 25% respectively. It was concluded that one out of four recruits in elite military training drops out due to MSkIs. To reduce dropout reducing MSkI must be addressed.

Table 2-4: The Netherlands Injury Rates – Entire Armed Forces.

Netherlands Armed Forces								
			ICPC2 L-Code	# Injuries	Denominator	Overall Rate %	Rate for Males (N = 7946) %	Rate for Females (N = 901) %
Torso	**Torso**	Chest (thorax)	04, 76.05, 81.02,	374	8847	4.23%	4.32%	3.44%
		Abdomen						
		Pelvis and urogenital	76.07	1		0.01%	0.01%	0%
		Trunk	05	21		0.24%	0.26%	0.11%
		Back and buttocks	02, 03, 86	1075		12.15%	12.16%	12.10%
		Neck	01	320		3.62%	3.40%	5.55%
Extremities	**Upper**	Shoulder and upper arm	08, 09, 80.01	688		7.78%	7.92%	6.55%
		Forearm and elbow	10, 72	134		1.51%	1.62%	0.55%
		Wrist, hand, and fingers	11, 12	650		7.35%	7.46%	6.33%
	Lower	Hip	13	115		1.30%	1.18%	2.33%
		Upper leg and thigh	14, 75	523		5.91%	6.02%	4.99%
		Knee	15, 76.08, 78, 96	990		11.19%	11.63%	7.33%
		Lower leg and ankle	16, 73, 77	655		7.40%	7.61%	5.55%
		Foot and toes	17, 99.08	845		9.55%	9.93%	6.88%
Other			81	143		1.62%	1.69%	1.00%

Table 2-5: The Netherlands Injury Rates – Royal Netherlands Army.

Royal Netherlands Army								
			ICPC2 L-Code	# Injuries	Denominator	Overall Rate %	Rate for Males (N = 2488) %	Rate for Females (N = 305) %
Torso	**Torso**	Chest (thorax)	04, 76.05, 81.02,	131	2793	4.69%	4.78%	7.21%
		Abdomen						
		Pelvis and urogenital	76.07	0		0%	0%	0%
		Trunk	05	6		0.21%	0.20%	0.33%
		Back and buttocks	02, 03, 86	398		14.25%	14.31%	13.77%
		Neck	01	111		3.97%	3.54%	7.54%
Extremities	**Upper**	Shoulder and upper arm	08, 09, 80.01	252		9.02%	9.24%	7.21%
		Forearm and elbow	10, 72	49		1.75%	1.85%	0.98%
		Wrist, hand, and fingers	11, 12	251		8.99%	9.20%	7.21%
	Lower	Hip	13	48		1.72%	1.53%	3.28%
		Upper leg and thigh	14, 75	231		8.27%	8.52%	6.23%
		Knee	15, 76.08, 78, 96	379		13.57%	13.95%	10.49%
		Lower leg and ankle	16, 73, 77	294		10.53%	10.89%	7.54%
		Foot and toes	17, 99.08	319		11.42%	11.78%	8.52%
Other			81	44		1.58%	1.61%	1.31%

Table 2-6: The Netherlands Injury Rates – Royal Netherlands Navy.

Royal Netherlands Navy								
			ICPC2 L-Code	# Injuries	Denominator	Overall Rate %	Rate for Males (N = 1953) %	Rate for Females (N = 150) %
Torso	**Torso**	Chest (thorax)	04, 76.05, 81.02,	68	2103	3.23%	3.38%	1.33%
		Abdomen						
		Pelvis and urogenital	76.07	1		0.05%	0.05%	0%
		Trunk	05	3		0.14%	0.15%	0%
		Back and buttocks	02, 03, 86	215		10.22%	10.50%	6.67%
		Neck	01	55		2.62%	2.61%	2.67%
Extremities	**Upper**	Shoulder and upper arm	08, 09, 80.01	217		10.32%	10.29%	10.67%
		Forearm and elbow	10, 72	29		1.38%	1.48%	0%
		Wrist, hand, and fingers	11, 12	129		6.13%	6.55%	0.67%
	Lower	Hip	13	25		1.19%	1.18%	1.33%
		Upper leg and thigh	14, 75	144		6.85%	6.93%	6.67%
		Knee	15, 76.08, 78, 96	289		13.74%	14.73%	2.67%
		Lower leg and ankle	16, 73, 77	188		8.94%	9.42%	2.67%
		Foot and toes	17, 99.08	259		12.32%	13.06%	2.67%
Other			81	30		1.43%	1.55%	0%

Table 2-7: The Netherlands Injury Rates – Royal Netherlands Air Force.

Royal Netherlands Air Force								
			ICPC2 L-Code	# Injuries	Denominator	Overall Rate %	Rate for Males (N = 1378) %	Rate for Females (N = 118) %
Torso	**Torso**	Chest (thorax)	04, 76.05, 81.02,	70	1496	4.68%	4.86%	2.54%
		Abdomen						
		Pelvis and urogenital	76.07	0		0	0%	0%
		Trunk	05	6		0.40%	0.44%	0%
		Back and buttocks	02, 03, 86	179		11.97%	11.97%	11.86%
		Neck	01	65		4.34%	4.57%	1.69%
Extremities	**Upper**	Shoulder and upper arm	08, 09, 80.01	135		9.02%	9.14%	7.63%
		Forearm and elbow	10, 72	29		1.94%	2.10%	0%
		Wrist, hand, and fingers	11, 12	127		8.49%	8.78%	5.08%
	Lower	Hip	13	21		1.40%	1.16%	4.23%
		Upper leg and thigh	14, 75	58		3.88%	3.85%	5.08%
		Knee	15, 76.08, 78, 96	118		7.89%	7.91%	7.63%
		Lower leg and ankle	16, 73, 77	61		4.08%	4.14%	3.39%
		Foot and toes	17, 99.08	115		7.69%	7.62%	8.47%
Other			81	41		2.74%	2.69%	3.39%

Table 2-8: The Netherlands Injury Rates – Netherlands Military Police.

Netherlands Military Police								
			ICPC2 L-code	**# Injuries**	**Denominator**	**Overall rate %**	**Rate for males (N = 2127) %**	**Rate for females (N = 328) %**
Torso	**Torso**	Chest (thorax)	04, 76.05, 81.02,	105	2455	4.28%	91	14
		Abdomen						
		Pelvis and urogenital	76.07	0		0%	0%	0%
		Trunk	05	6		0.24%	0.28%	0%
		Back and buttocks	02, 03, 86	283		11.53%	11.28%	13.11%
		Neck	01	89		3.63%	3.20%	6.40%
Extremities	**Upper**	Shoulder and upper arm	08, 09, 80.01	165		6.72%	6.96%	5.18%
		Forearm and elbow	10, 72	27		1.10%	1.18%	0.61%
		Wrist, hand, and fingers	11, 12	143		5.82%	5.41%	8.54%
	Lower	Hip	13	21		0.86%	0.80%	1.22%
		Upper leg and thigh	14, 75	90		3.67%	3.76%	3.05%
		Knee	15, 76.08, 78, 96	204		8.31%	8.60%	6.40%
		Lower leg and ankle	16, 73, 77	112		4.56%	4.37%	5.79%
		Foot and toes	17, 99.08	152		6.19%	6.11%	6.70%
Other			81	28		1.14%	1.27%	0.30%

2.2.5 Slovenia

V. Hadžić

The Slovenian Armed Forces (SAF) consists of 6678 permanent members and 811 members of the Voluntary Reserve structure (source: www.slovenskavojska.si), thus the Slovenian military has both a volunteer and draft force. Approximately 16.5% of the permanent composition are women, and most typically perform support functions (administration, staff, finance, law, etc.), though they may be deployed. The average age of persons entering service is 24 years, and the average age of the permanent military is 41 years.

For entry into the Slovenian Armed Forces (SAF), both psycho-physical capacity and medical readiness are evaluated. Each candidate must complete a selection process, which involves passing an Army physical fitness test (US APFT, with a score of 4 or 5) and completing a medical examination (which includes laboratory tests, clinical balance tests, heart and lung function tests, basic optometric testing for visual acuity, a doctor's and psychologist's examination, and dental status). Height should not be lower than 160 cm and body mass index should not exceed 30 for male and female Soldiers. With regard to "military fitness training" – every member of the SAF has a regular obligatory daily exercise (1 hour; usually in the morning) and APFT is performed once per year.

The Slovenian military does not have an electronic medical record system capable of tracking injury rates. Coding of injuries is done primarily by physicians and reported through the Republic of Slovenia ER-8 form for reporting occupational injuries and diseases (ICD10). The form has 45 items, which include details about the injuries (e.g., date of injury, injury body location, nature/cause of injury). Only injuries that cause the soldier to be absent from duty three or more working days are recorded. All data are confirmed by the treating physician and are used for medical insurance reimbursement.

In a recent study [12], the overall prevalence of MSkIs during the 10-year period 2006 – 2015 was 4.9%, with a lower percentage reported by females compared to males (3.1% compared to 5.4%, $p<.001$) [12]. The most frequent injured locations were ankle (23%) and knee (21%).

In a self-report study by members of the Slovenian Infantry forces, the overall reported prevalence of MSkI was 48.8% (65.8% in males, 27.7% in females), with the most common being knee injuries (26%) [12].

Table 2-9 presents the incidence rates of primarily acute injuries and more severe exacerbations of chronic injuries that require Soldiers to be absent from the duty 3 or more days. Table 2-9 shows the rates for the period 2006 – 2015, and denominator is the average number of members of SAF in the given time period. The records are overall including recruits and regular military.

Table 2-9: Slovenian Injury Rates (2006 – 2015).

MSkI Category			Rates	
			M	F
Extremities	**Upper Quarter Injury (UQI)**	*Shoulder/upper arm*	*4%*	*2%*
		Forearm/elbow	*1%*	*2%*
		Wrist/hand/fingers	*8%*	*10%*
		Other, unspecified	*10%*	*11%*
	Lower Quarter Injury (LQI)	*Hip*	*1%*	*<1%*
		Upper leg/thigh	*1%*	
		Knee	*21%*	*21%*
		Lower leg/ankle	*26%*	*24%*
		Foot or toes	*3%*	*4%*
		Other, unspecified	*12%*	*11%*
Torso	**Torso**	*Chest (thorax area)*	*1%*	*1%*
		Abdomen	*<1%*	*1%*
		Pelvis and urogenital	*<1%*	*<1%*
		Trunk	*1%*	*1%*
		Back and buttocks		
Spine and Back	**Spinal Cord and Vertical Column Injury (SCI, VCI) (combined)**	*Cervical SCI and VCI*	1%	1%
		Thoracic/dorsal SCI and VCI	<1%	1%
		Lumbar SCI and VCI	4%	4%
		Sacrum coccyx SCI and VCI		
		Other spine and back		
Other	**Multisite/Polytrauma Injury**		<1%	
Head			6%	4%

2.2.6 Spain

B. Sanz-Bustillo-Aguirre

The Spanish military (on average 121,000) is composed of four main branches: i) Army (n = 76,049); ii) Air Force (n = 20,654); iii) Navy (n = 20,901); and iv) Common Corps (n = 3,397) [13], [14]. Approximately 12.91% of the military personnel are women. The average age of persons volunteering to enter the Spanish military is 22.92 years; while the average age of the military overall is 37.79 years [13], [14].

Concerning the physical and psychological aptitude for enlistment, candidates are required to successfully complete several physical tests, psychological tests and medical examination [15], [16].

The physical tests for commissioned and non-commissioned officers comprise:

- Vertical jump test with joint feet (score: number of centimeters);
- Push-up test (score: number of repetitions);
- 50-metre running test (score: time in seconds);
- 1000-metre running test (score: time in minutes and seconds);
- 50-metre swimming test (score: time in minutes and seconds); and
- Agility circuit test (score: time in seconds).

Threshold scores in the different tests vary between genders and military corps and scales [15] (Table 2-10).

Table 2-10: Physical Tests Threshold Scores for Commissioned and Non-Commissioned Officers, Spain [15].

Physical Tests Threshold Scores: Commissioned and Non-Commissioned Officers (Spain)										
	Without Degree Prior to Enlistment				With Degree Prior to Enlistment					
Officers	General Corps		Medical Corps		General Corps and Quartermaster Corps-Commissioned		Engineers Corps and Common Corps-Commissioned		Non-Commissioned	
Physical Test	M	F	M	F	M	F	M	F	M	F
Vertical Jump (cm)	42	36	36	31	48	42	33	29	46	40
Push-Up (# Repetitions)	18	12	14	9	24	18	9	7	22	16
50-m Running (secs)	8”	8.8”	8.5”	9.5”	7.7”	8.5”	9”	9.9”	7.8”	8.6”
1000-m Running (mins secs)	3’55”	4’25”	4’15”	4’45”	3’40”	4’10”	4’30”	5’10”	3’55”	4’15”
50-m Swimming (mins secs)	1’	1’08”	1’11”	1’21”	56”	1’04”	1’22”	1’35”	58”	1’06”
Agility Circuit (secs)	14”	16”	15”	17”	14”	16”	16”	19”	14”	16”

Soldiers and Sailors undergo the following physical tests:

- Horizontal jump test with separated feet (score: number of centimeters);
- One-minute sit-up test (score: number of repetitions);
- One-minute push-up test (score: number of repetitions); and
- 20-metre round-trip running test with progressive increase of speed (score: number of completed paths).

The level of physical fitness is based on the scores achieved by each participant in the different tests, provided they reach the minimum thresholds established, which vary between genders [16] (Table 2-11).

Table 2-11: Physical Tests Threshold Scores for Soldiers and Sailors, Spain [16].

Physical Tests Threshold Scores: Soldiers and Sailors (Spain)								
Soldiers and Sailors	**Level A**		**Level B**		**Level C**		**Level D**	
Physical Test	M	F	M	F	M	F	M	F
Horizontal Jump (cm)	145	121	163	136	187	156	205	171
Sit-Up (# repetitions)	15	10	21	14	27	18	33	22
Push-Up (# repetitions)	5	3	8	5	10	6	13	8
Running (# paths)	5	3.5	5.5	4	6.5	5	7.5	6

During their professional career and on a regular basis, active military personnel have to undergo medical examination and physical assessment comprised of:

- Two-minute push-up test*;
- Three-minute sit-up test*; and
- 2000 or 6000-metre running test and agility-speed circuit test*.

* Minimum threshold scores in each test depend on age and gender [17].

Recruit basic training consists of an 8-week period, subsequently completed with the specific and optimization training at the corresponding military academy, altogether lasting, in general, 5 years.

The Spanish Armed Forces count with various electronic platforms to register health and occupational data. Additionally, the different military branches submit annual reports of the contingencies occurred within their setting. Although the military personnel also have access to civilian healthcare, if the health issue results in sick-leave and/or activity limitation, or the cause is related to the occupational setting, it is also recorded in the military system. These platforms are more oriented to personnel care than to epidemiological research.

Table 2-12 and Table 2-13 represent the number of injuries and their rates (% in each sample size) in the different body sites registered within the Spanish Army and Air Force during 2017 [18] and 2018 [19]. The information refers to the overall Active Duty military population, recruits included. Data reveal a clearly higher prevalence of injuries in upper and lower quarters in both military branches during 2018, as well as in the Army personnel in 2017. Considering all recorded injuries, males were affected in a higher proportion (>75%) compared to their female counterparts (<25%).

Table 2-12: Spanish Army Injury Rates – Reported per Body Site in 2017 (n = 76,694) and 2018 (n = 76,049).

MSkI Category	2017 (N = 76.694) Number of Injuries	Rate (%)	2018 (N = 76.049) Number of Injuries	Rate (%)
Body Region Not Specified	15	0.020	11	0.014
Head	87	0.113	75	0.099
Neck (includes cervical SCI and VCI)	181	0.236	159	0.209
Back (includes dorsolumbar SCI and VCI)	149	0.194	136	0.179
Torso (trunk and internal organs)	35	0.046	24	0.032
Upper Quarter Injury (UQI)	273	0.356	262	0.345
Lower Quarter Injuries (LQI)	271	0.353	245	0.322
Whole Body / Multisite	50	0.065	42	0.055
Other Site Not Mentioned Above	34	0.044	33	0.043
Total	1095	1.428	987	1.298
Female	197	0.257	240	0.316
Male	898	1.171	747	0.982

Table 2-13: Spanish Air Force – Injuries Reported per Body Site in 2017 (n = 20,657) and 2018 (n = 20,654).

MSkI Category	2017 (N = 20.657) Number of Injuries	Rate	2018 (N = 20.654) Number of Injuries	Rate
Body Region Not Specified	1	0.005	1	0.005
Head	9	0.044	38	0.184
Neck (includes cervical SCI and VCI)	41	0.198	43	0.208
Back (includes dorsolumbar SCI and VCI)	38	0.184	68	0.329
Torso (trunk and internal organs)	8	0.039	12	0.058
Upper Quarter Injury (UQI)	54	0.261	127	0.615
Lower Quarter Injury (LQI)	89	0.431	121	0.586
Whole Body / Multisite	6	0.029	16	0.077
Other Site Not Mentioned Above	3	0.015	7	0.034
Total	249	1.205	433	2.096
Female	52	0.252	65	0.315
Male	197	0.954	368	1.782

2.2.7 United Kingdom

J.P. Greeves

Medically reported Musculo-Skeletal Injuries (MSkI) in the United Kingdom (UK) Armed Forces are centrally documented on the Defence Medical Information Capability Programme (DMICP), implemented in 2007. DMICP has 2,364 read codes of MSkI disorders registered on its system. Inconsistencies in the selection of read codes, however, may skew the numbers for specific diagnoses. Moreover, disorders are not counted if the treating clinician does not use one of the specified codes or makes a free text entry. Despite these limitations, a central repository of MSkI disorders exist, and is used by Defence to understand temporal patterns in MSkI, and effect on retention and deployability. The causes of MSkI and situational risks, however, are not easily defined and not routinely recorded. Defence Statistics (Health) (DS(H)), under the authority of the Surgeon General, are responsible for accessing and analyzing DMIPC data; DS(H) also have the capability to link pseudo anonymized clinical data with job information contained in the military's human resource database.

Data on MSkI are also recorded by single Services (sS), at organizational and Unit level, for the Chain of Command and / or for use by Unit Health Committees. For example, Initial Military Training (IMT) units routinely monitor MSkIs, although, within and between sS methods of recording MSkIs and data analysis may not be standardized (nature of injury, population at risk). The IMT environment is popular for epidemiological research, with better control of confounding factors such as equipment, training load, nutrition, and sleep, indicated by a dominance of peer-reviewed research published on MSkI during IMT. This focus on IMT has resulted in a lack of published data on the trained strength, and injury risk in different groupings/populations (e.g., sex, trade) and *through career* in the UK Armed Forces is, therefore, not widely understood.

Bespoke questionnaires have been used to collate relevant data to address specific organizational or research questions when databases do not capture relevant information. In 2016, 12-month period prevalence of MSkI in service personnel operating in combat and non-combat arms was determined from a purposed designed questionnaire for the Interim Health Report, used to help inform a ministerial decision for full inclusion of women in the UK Armed Forces. These 'experimental' approaches are also helpful to identify demographic and lifestyle risk factors for injury.

This report presents baseline data on MSkI in the UK Armed Forces between 2015 and 2016 prior to the opening of ground close combat roles to women in i) Army trainees; ii) A cross-sectional sample of service personnel in the *trained strength*; and, iii) MSkIs resulting in medical discharge. Latest data (2019 – 2020), and data across the three Services, are presented where available.

Key Findings

Incidence of musculo-skeletal injuries in Army trainees during Initial Military Training (1 April 2015 to 31 March 2016):

- Around 50% of recruits suffered an injury during IMT (Table 2-14).
- Men in infantry training had a lower incidence of total musculo-skeletal injuries, but a higher incidence of stress fracture, compared with men in standard entry training (Table 2-14).
- The injuries sustained by men during IMT were predominantly lower limb. Men in infantry training had a higher incidence of upper limb injuries compared with men in standard entry training (Table 2-14).

- Women in standard entry training had a higher incidence of total musculo-skeletal injuries, but not stress fractures, compared with men (Table 2-15).
- Women in officer training had a higher incidence of stress fracture, but not musculo-skeletal injury, compared with men (Table 2-15).

12-month prevalence of musculo-skeletal injuries in Army personnel of the trained strength (January to March 2016, Table 2-16):

- Women reported more total, upper limb, lower limb, and hip musculo-skeletal injuries than men in the same career employment groups.
- Female sex was an independent predictor of hip injury, while slower 1.5 mile run time was associated with greater prevalence of total and lower limb musculo-skeletal injuries.
- There were no differences in the prevalence of musculo-skeletal injuries between men in combat and non-combat roles.
- A lower proportion of men were medically downgraded in combat than non-combat roles.

Rates of medical discharges by age group, gender, rank and training status, across the three Services (1 April 2019 and 31 March 202, Table 2-17):

- A total of 1,578 medical discharges occurred in 2019 – 2020, equivalent to approximately four UK regular armed forces personnel medically discharged every day.
- The groups at risk for medical discharge were women, other ranks, and untrained personnel. In each Service, the rate of medical discharge was higher for:

  a) **Army:** Women; other ranks; and untrained personnel.

  b) **RAF:** Women and other ranks.

  c) **Navy (all):** Other ranks; personnel aged 30 to 39 years; and Royal Marines.

  d) **Royal Navy only:** Personnel aged 35 to 39 years; women; other ranks; and trained Personnel.

  e) **Royal Marines:** Other ranks and untrained personnel.

UK regular Service Personnel medical discharges by principal ICD-10 cause code group (1 April to 31 March, 2015 – 2016 and 2019 – 2020, Table 2-17):

- The rate of medical discharge was lower for the Army and Naval Service in 2019 – 2020 compared with 2015 – 2016.
- The lower rate of medical discharge for the Army likely reflects the changes in boarding practices, retention policies, and / or changes to employment standards.
- Musculo-skeletal injuries were the principal cause of medical discharge in the three Services in 2019 – 2020, consistent since 2015 – 2016.
- The principal causes of MSkI are injuries to the back, knee, and ankle and foot.

Table 2-14: Musculo-Skeletal Injury Incidence (per 1000 Personnel) During Initial Military Training. Odds Ratio (OR) are shown for men undergoing 14 weeks of standard entry training compared with men undergoing 14 weeks of infantry training. Data are from 1 April 2015 to 31 March 2016.

	Standard Entry (n = 4229)		Infantry (n = 2683)			
	n	per 1000 Personnel	n	per 1000 Personnel	OR [95%CI]	P
Musculo-Skeletal Injury						
Upper Limb	173	41	69	26	**0.62 [0.47, 0.82]**	**<0.001**
Lower Limb	1,277	302	782	291	0.95 [0.86, 1.06]	0.354
Other	300	71	190	71	1.00 [0.83, 1.21]	1.000
Unspecified	14	3	7	3	0.79 [0.32, 1.95]	0.603
Total	1,764	417	1,048	391	**0.90 [0.81, 0.99]**	**0.028**
Stress Fracture						
Upper Limb	0	0	0	0	N/A	N/A
Lower Limb	19	4	29	11	**2.42 [1.35, 4.33]**	**0.002**
Other	~	~	~	~	3.16 [0.58, 17.24]	0.161
Unspecified	0	0	~	~	N/A	**0.012**
Total	21	5	37	14	**2.80 [1.64, 4.80]**	**<0.001**

Numbers fewer than 5 have been replaced with '~' in line with the Joint Services Publication 200 and Office for National Statistics Guidelines; the next lowest value has also been replaced with '~' to prevent identification of removed number.

OR, Odds Ratio.

Bold values are P < 0.05.

Table 2-15: UK Army Untrained[1] Musculo-Skeletal Injury Rates for Regular Recruits[2] and Officer Cadets[3]. Data are from 1 April 2015 to 31 March 2016.

	Standard Entry						Officer					
	Men (n = 4229)		Women (n = 626)				Men (n = 478)		Women (n = 70)			
	n	r	n	r	OR [95%CI]	P	n	r	n	r	OR [95%CI]	P
Musculo-skeletal Injury												
Upper Limb	173	41	~	~	1.31 [0.89, 1.91]	0.171	56	117	~	~	0.84 [0.37, 1.92]	0.674
Lower Limb	1,277	302	240	383	**1.44 [1.21, 1.71]**	**<0.001**	219	458	35	500	1.18 [0.72, 1.95]	0.512
Other	300	71	52	83	1.19 [0.87, 1.61]	0.275	~	~	9	129	0.83 [0.39, 1.76]	0.623
Unspecified	14	3	~	~	0.97 [0.22, 4.26]	0.962	~	~	~	~	0.21 [0.03, 1.95]	0.067
Total	1,764	417	327	522	**1.53 [1.29, 1.81]**	**<0.001**	330	690	53	757	1.40 [0.78, 2.50]	0.255
Stress Fracture												
Upper Limb	0	0	0	0	N/A	N/A	0	0	~	~	N/A	**0.001**
Lower Limb	19	4	~	~	0.71 [0.16, 3.06]	0.644	9	19	~	~	**4.89 [1.68, 14.18]**	**0.006**
Other	~	~	0	0	N/A	0.586	0	0	0	0	N/A	N/A
Unspecified	0	0	~	~	N/A	**0.009**	0	0	0	0	N/A	N/A
Total	21	5	~	~	0.96 [0.29, 3.25]	0.954	9	19	8	114	**6.72 [2.50, 18.07]**	**<0.001**

[1] **During Initial, or Phase 1, training**

[2] **14 weeks standard entrants**

[3] **44 weeks**

Numbers fewer than 5 have been replaced with '~' in line with the Joint Services Publication 200 and Office for National Statistics Guidelines; the next lowest value has also been replaced with '~' to prevent identification of removed number.

OR, Odds Ratio.

Bold values are P < 0.05.

Table 2-16: Musculo-Skeletal Injury Rates in Army Personnel of the Trained Strength[1]. Data reflect a 12-month period prevalence to February and March 2016.

Rates per 1,000 Personnel at risk	Combat Men (n = 375)	Non-Combat Men (n = 391)	Non-Combat Women (n = 118)
All MSkI	595	578	720*
Upper Limb	211	230	322*
Lower Limb	533	501	686*
Hip	72	64	178*

[1] **Passed out of Initial and Trade Training**

* **Significantly different from non-combat men ($P < 0.05$). Combat men and non-combat women were not statistically compared. Unadjusted data.**

Table 2-17: UK Regular Service Personnel Medical Discharges[1] by Age Group, Gender[1], Rank[1], Training Status[1] and Service[2] Between 1 April 2019 to 31 March 2020.

	Numbers and Rates per 1,000 Personnel at Risk					
	Army		RAF		Navy	
	n	*r*	n	*r*	n	*r*
Numbers of UK Service Personnel Medically Discharged	**1,043**	***12.7***	**169**	***5.2***	**366**	***11.2***
Age						
< 20	75	*12.5*	10	*8.5*	7	*4.5*
20 – 24	224	*13.6*	14	*2.8*	49	*7.9*
25 – 29	231	*12.7*	27	*4.3*	86	*12.1*
30 – 34	210	*13.2*	37	*6.1*	84	*14.0+*
35 – 39	159	*12.3*	33	*5.8*	78	*16.5+*
40 – 44	94	*12.3*	24	*6.3*	36	*12.4*
45 – 49	33	*9.9*	17	*6.5*	17	*7.5*
>50	17	*9.2*	7	*3.1*	9	*5.2*
Gender						
Male	915	*12.3*	115	*4.1*	320	*10.9*
Female	128	*16.8**	54	*11.2**	46	*14.6*
Rank						
Officer	34	*2.6*	18	*2.3*	25	*3.6*
Other Rank	1,009	*14.6**	151	*6.0**	341	*13.3**
Training Status						
Trained[3]	822	*11.2*	150	*5.0*	334	*11.6*
Untrained	221	*25.7**	19	*6.3*	32	*8.2*

	Numbers and Rates per 1,000 Personnel at Risk					
	Army		RAF		Navy	
	n	*r*	n	*r*	n	*r*
Service						
Royal Navy					242	*9.4*
Royal Marines					124	*18.4**

Source: DMICP, FMed 23 and JPA.

1 **As recorded on JPA system at the time of discharge.**

2 **Includes Royal Navy and Royal Marines.**

3 **Includes those trade trained, defined as those who have completed Phase 1 and Phase 2 training for Army.**

+ **Groups found to be at a significantly higher than average risk using a z-test for a single proportion at a 95% confidence level.**

Table 2-18: UK Regular Service Personnel Medical Discharges by Principal ICD-10 Cause Code Group, Numbers and Percentages[1], Between 1 April 2015 and 31 March 2016 versus 1 April 2019 and 31 March 2020.

	Numbers and Rates per 1,000 Personnel at Risk[1]											
	Army				**RAF**				**Navy[2]**			
	2015 – 2016[P]		*2019 – 2020[P]*		*2015 – 2016[P]*		*2019 – 2020*		*2015 – 2016[P]*		*2019 – 2020*	
	n	***r***	**n**	***r***	**n**	***r***	**n**	***r***	**n**	**r**	**n**	***r***
Cause of coded medical discharges (number and rate per 1000 personnel)	1695	20‰	851[3]	13‰	136	4.2‰	169	5.0‰	436	14‰	366	11‰
Musculo-skeletal disorders and injuries	1,016	60%	438	51%	66	49%	66	39%	253	58%	175	48%
Back pain	95	9%	69	16%	14	21%	11	17%	39	15%	40	23%
Knee	179	18%	76	17%	11	17%	12	18%	62	25%	32	18%
Ankle and foot	91	55%	38	9%	-	-	7	11%	29	11%	14	8%
Other[4]	561	*9%*	237	54%	41	*62%*	36	55%	113	*45%*	89	51%
Cold injury	90	9%	18	4%	-	-	-	-	10	4%	-	-

Source: DMICP, Fmed 23 and JPA

1 **Due to rounding percentages might not add up.**

2 **Includes Royal Navy and Royal Marines.**

3 **Total number of Army discharges was 1043, however, 192 personnel had no details on principal conditions for medical boarding.**

4 **Includes all other musculo-skeletal disorders and includes heat injuries.**

P **Indicates provisional data.**

2.2.8 United States of America

K.R. Kelly and S.P. Proctor

In 2018, the US military was comprised of over 1.3 million Active Duty (Army, Air Force, Navy, Marines) personnel and almost 800,000 in the Reserve forces (Army, Air Force, and Navy Reserves and Army and Air Force National Guard), with almost 50,000 in the US Coast Guard [20].

The 2018 distribution of Active Duty US military is Army (36.2%), Navy (24.9%), Air Force (24.7%) and Marine Corps (14.2%), with the age distribution (Figure 2-1) varying slightly between services. Overall, women represent on average 16% of Officers and 15% enlisted groups.

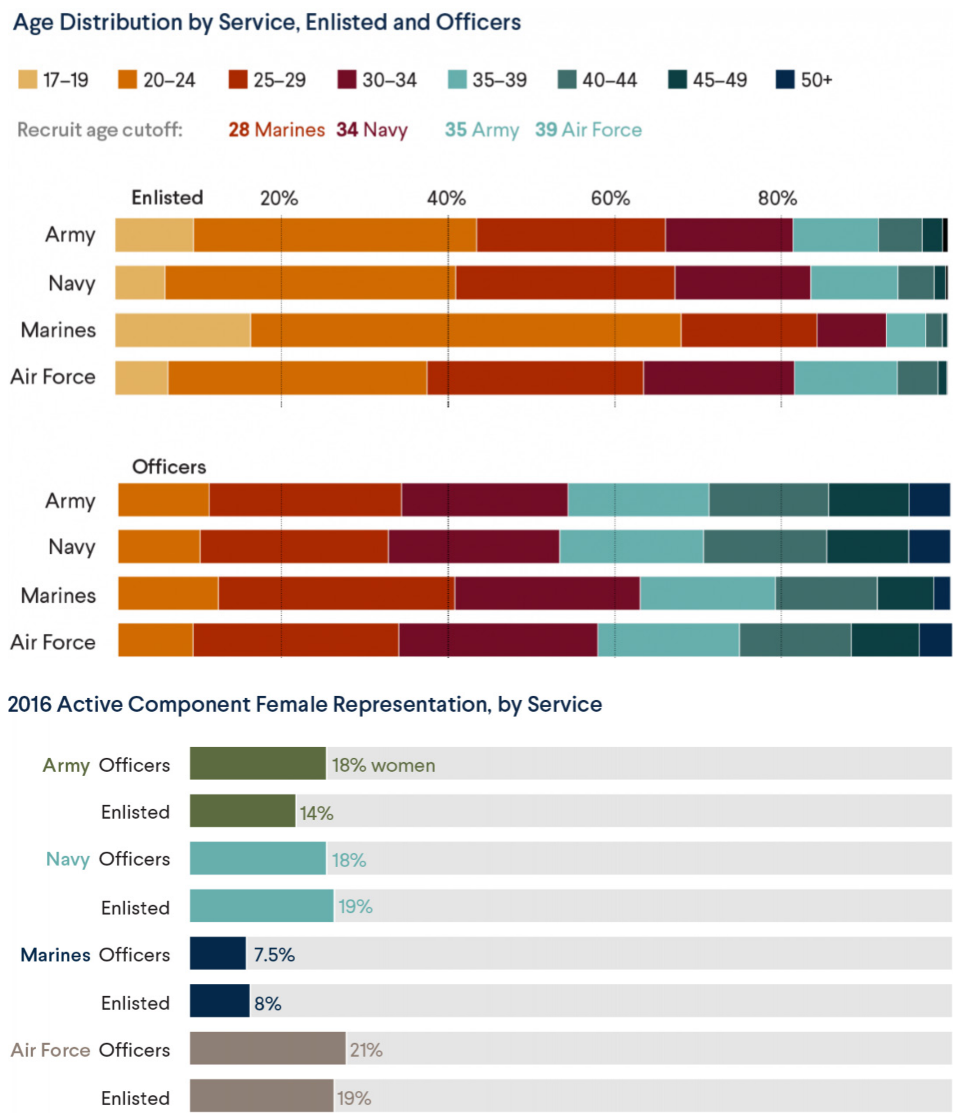

Figure 2-1: US Armed Forces Age Distribution.

2.2.9 US Army

S.P. Proctor

The US total Active Army Force included 560,500 in 2015, 496,136 in 2016, and 479,508 in 2017; ~15% female. The average age of those in the Active Duty Army is 29.1 years (FY17).

The US military does have electronic medical record systems, with several systems in play over the past 15 – 20 years. Overall, these electronic medical data systems consist of both in- and outpatient records and from both within DoD and outside DoD care providers, as these records are utilized for military medical insurance purposes. Diagnostic codes are determined following the International Classification of Diseases (ICD) system. The US Army utilized the ICD9 up through FY15 (until 30 Sep 2015). For the US Army, 2015 prevalence rates reported in Table 2-19 were obtained through the US Army Research Institute of Environmental Medicine's, Soldier Performance, Health, and Readiness (SPHERE) data repository (formerly known as the Total Army Injury and Health Outcome Database (TAIHOD)). The SPHERE is a comprehensive research data repository that links administrative data, medical encounter information, and performance metrics for all US Army personnel including Active Duty, National Guard, and Army Reserves (n>7 million) [21]. To categorize the MSkIs into regions or categories of interest, the Barell matrix system [22] was applied to code the respective injury ICD9 into body region categories. It is important to note that the Barell matrix only permits coding of acute injuries. Since then, the ICD10 coding system has been in place.

Table 2-19: US Acute Injury Rates for FY15- Army N = 560,500.

MSkI Category			Males N = 477854	Females N = 79,253	Overall Rate (%)	
Extremities	Upper Quarter Injury (UQI)	*Shoulder/upper arm*	3.92	3.43	3.85	9.56
		Forearm/elbow	0.69	0.74	0.70	
		Wrist/hand/fingers	4.23	3.98	4.24	
		Other, unspecified	0.75	0.89	0.77	
	Lower Quarter Injury (LQI)	*Hip*	1.75	2.60	1.87	15.24
		Upper leg/thigh	0.13	0.14	0.13	
		Knee	1.78	1.71	1.77	
		Lower leg/ankle	3.80	4.60	3.91	
		Foot or toes	2.17	3.3	2.34	
		Other, unspecified	4.97	6.74	5.22	
Torso	Torso	*Chest (thorax area)*	0.73	0.62	0.71	3.32
		Abdomen	0.12	0.16	0.13	
		Pelvis and urogenital	0.73	1.26	0.81	
		Trunk	1.12	1.30	1.14	
		Back and buttocks	0.50	0.66	0.53	

MSkI Category			Males N = 477854	Females N = 79,253	Overall Rate (%)	
Spine and Back	Spinal Cord and Vertical Column Injury (SCI, VCI) (combined)	*Cervical SCI and VCI*	0.89		0.99	2.94
		Thoracic/dorsal SCI and VCI	.41		0.44	
		Lumbar SCI&VCI	1.39		1.35	
		Sacrum coccyx SCI and VCI	0.094		0.12	
		Other spine and back	0.038		0.04	
Other	Multisite/ Polytrauma Injury		5.10		5.44	5.44
Head	(TBI, other head, face, eye, neck, unspecified)		5.59		5.54	5.54
	TOTALS (sum of counts/%)					42.02

Currently, there is no one systematic coding scheme in place for describing rates of acute and overuse injuries utilizing US military medical databases. More recent efforts are ongoing in the US to create, standardize and validate coding systems applied to ICD10-coded diagnoses and conditions and capture all injuries (MSkI as well as non-MSkI such as environmental injuries) and are inclusive acute traumatic and cumulative microtraumatic (or overuse) injuries [23], [24].

In an anonymous survey among Army Soldiers in a US Infantry Control Brigade (n-1,388 (1269 M; 74 F; 45 unknown)), a total of 3202 injuries were reported [25] as occurring in the past 12 months, with 49% (1,566) identified as not reported to medical providers. About equal proportions of these unreported injuries were acute (49%) compared to chronic (51%). Fear that the injury might affect one's military career and avoiding mandates physical restrictions were the most commonly reported reasons why the injuries were not reported. The most common unreported injuries were to the knee and back; these areas were also the most commonly reported injuries to a medical provider [26]. Among deployed Army populations, injuries to the lower back were the most often reported injury [27], [28].

2.2.10 US Navy/Marines

K.R. Kelly

The U.S. Navy currently has 383,542 Active Duty sailors (Jan 2019) with 2.0% of those being women while the US Marine has approximately 184,415 Active Duty (Jan 2018) with approximately 8.6% being women. Both the Navy and Marine Corps have 100,344 and 14,000 ready reservists. Additionally, the US Navy has 287 deployable battle force ships (destroyers, amphibious assault ships, aircraft carriers, submarines).

Musculo-skeletal injury rates were calculated from the Navy-Marine Corps CTR Expeditionary Medical Database and are expressed as number of acute injuries as well as the rate of injury per 1000 military personnel (Table 2-20, Table 2-21).

Table 2-20: US Navy Acute MSkI Rates Over Time.

	2012 n = 324,666	MKSI Rate per 1000 Persons	2014 n = 324,308	MKSI Rate per 1000 Persons	2016 n = 323,708	MKSI Rate per 1000 Persons
Upper Quarter Injury	20744	63.89	29673	91.5	29136	90.01
Lower Quarter Injury	31444	96.85	42777	131.9	42278	130.61
Torso	7183	22.12	5735	17.68	6458	19.95
Spine and Vertical Column Injury	11765	36.24	10318	31.82	10845	33.5

Table 2-21: US Marine Corp Acute MSkI.

MSkI Category			Males N = 477854	Females N = 79,253	Overall Rate (%)	
Extremities	Upper Quarter Injury (UQI)	*Shoulder/upper arm*	3.92	3.43	3.85	9.56
		Forearm/elbow	0.69	0.74	0.70	
		Wrist/hand/fingers	4.23	3.98	4.24	
		Other, unspecified	0.75	0.89	0.77	
	Lower Quarter Injury (LQI)	*Hip*	1.75	2.60	1.87	15.24
		Upper leg/thigh	0.13	0.14	0.13	
		Knee	1.78	1.71	1.77	
		Lower leg/ankle	3.80	4.60	3.91	
		Foot or toes	2.17	3.3	2.34	
		Other, unspecified	4.97	6.74	5.22	
Torso	Torso	*Chest (thorax area)*	0.73	0.62	0.71	3.32
		Abdomen	0.12	0.16	0.13	
		Pelvis and urogenital	0.73	1.26	0.81	
		Trunk	1.12	1.30	1.14	
		Back and buttocks	0.50	0.66	0.53	

MSkI Category			Males N = 477854	Females N = 79,253	Overall Rate (%)	
Spine and Back	Spinal Cord and Vertical Column Injury (SCI, VCI) (combined)	*Cervical SCI and VCI*	0.89		0.99	2.94
		Thoracic/dorsal SCI and VCI	.41		0.44	
		Lumbar SCI and VCI	1.39		1.35	
		Sacrum coccyx SCI and VCI	0.094		0.12	
		Other spine and back	0.038		0.04	
Other	Multisite/ Polytrauma Injury		5.10		5.44	5.44
Head	(TBI, other head, face, eye, neck, unspecified)		5.59		5.54	5.54
	TOTALS (sum of counts/%)					42.02

Musculo-Skeletal Injuries (MSkIs) are a leading source of personnel loss or the classification of "not fit for full duty" among warfighters. These losses are estimated to cost the US Marine Corps approximately 111 million and 356,000 lost duty days each year. An archival dataset of Marine recruits from 2011 – 2016 was reviewed and included 43,004 observations from 28,829 unique individuals [29]. Injuries were classified as mild, moderate, and severe and categorized into new overuse, preexisting overuse, and traumatic. Injury classification and categorization were stratified by event in which the injury occurred. The majority of injuries were due to overuse, and the most common types were sprains, strains, iliotibial band syndrome, and stress fractures, which constituted over 40% of all injuries. Conditioning hikes were the primary event leading to injury, with 31% of all injuries occurring during this training; running claimed 12%. Most injuries sustained during basic training comprised sprains and strains. Marines who remained uninjured during basic training outperformed those who reported at least one injury on fitness tests. These results point to enhanced conditioning as a potential entry point to target future intervention efforts. A recent report from the Center for Naval Analyses [30] found that greater fitness levels were associated with lower rates of injury in a large sample of both male and female Marines: 4.6% for the least fit, 3.6% for the moderately fit, and 2.4% for the fittest groups.

2.3 PART 2 – SUMMARY OF FINDINGS

In order to work to reduce MSkIs, an understanding of whether there are similar or different patterns of MSkI rates across the NATO nations is important in order to assist in identifying areas of focus to military medicine providers and operational leadership.

From the data presented at the beginning of this chapter, there are some similarities in MSkI rates across the NATO nations, in that they represent a large impact on proportion of the nations' military force and that the most common MSkIs tended to be those of the lower extremities. For some injury locations, MSkI rates are considerably different between men and women. However, overall, it was not possible to combine information and present an overall summary table outlining differences in MSkIs across the countries.

Table 2-22 presents an overview of the respective represented NATO nations, in terms of military size, average age, and percent women, along with details on how each nation records MSkIs within their military population.

Several specific reasons are determined for the inability to effectively identify and characterize the MSkI events and to compare rates of MSkIs across the NATO nations:

1) There is currently no consistent or standard injury coding system or common set of definitions applied among all nations.
2) Not all nations have military medical record systems that encompass all injury care (for care provided both inside and outside of military health system) to allow for complete capture of injuries.
3) Not all nations have military medical record systems that allow for injury-type (overuse, traumatic, chronic) or cause/mechanism of injury (what was Soldier doing when injured) that would be useful for targeting of prevention and/or intervention strategies.
4) If there are nation-level electronic medical record systems, these are not designed necessarily for research or surveillance purposes.
5) Reporting of self-reported rates of MSkIs tend to be conducted among military subgroups from the different nations and are thus not necessarily comparable.
6) Not all military personnel seek medical treatment for their injuries so it is not possible to track these through medical record systems.

Table 2-22: Summary.

	Military Characteristics			Medical Record Systems	
	N	% Female	Average Age (Years)	Electronic System (Yes/No)	Current Diagnosis Coding Systems
Belgium	25,000	10%	34	Yes, but system excludes civilian care which military use	ICD10 now/ converting to SNOWMED CT
Canada	95,000	15%	34	Yes	ICD
Germany	180,000	12%	NA	No, only paper records	-
Latvia	13,000	16%	NA	No	-
Netherlands	30,000	10%	Varies, 27 (Infantry)	Yes, but not designed for research, open text	ICPC-2
Slovenia	7,000	17%	41	No	ICD10
Spain	121,000	12.9%	38	Yes, but system excludes civilian care which military use	ICD10
United Kingdom	150,000	11%	31	Yes	ICD10
United States					
Army	560,000	15%	29	Yes	ICD10
Navy	383,000	2%	30	Yes	ICD10
Marines	184,500	9%	25	Yes	ICD10

2.4 PART 3 – RECOMMENDATIONS

It may be difficult for all NATO nations to establish a medical record system that would permit an internationally standardized systematic capture of MSkI rates for acute and overuse-type MSkIs. However, below are several recommendations or next steps to improve injury and rate data that can serve as metrics or benchmarks to determine if interventions are having an impact on reducing musculo-skeletal injuries.

Short term:

- Identify key common data elements or metrics critical to start to establish an internationally comparable system. In the Glossary of this report, the RTG has proposed a set of common definitions and data elements (such as, adopting a common diagnosis coding (such as ICD10)) and definitions for terms (such as for injury types – e.g., acute and overuse injuries, body regions or injury location categorizations).
- Provide study design requirements with which to benchmark improvements with interventions.
  - Identify baseline MSkI rates before the study starts or include control/comparison group in order to identify pertinent risk factors and determine whether interventions work, improving the ability that knowledge gained could be applied to other countries.
  - Identify possible common methods to report/record risk factors, context of injury details in a systematic manner (for example, a short checklist that the provider completes) to link into the medical records system.
- Examine effective ways to account and include MSkIs that may not be reported to medical providers (such as monitoring through weekly surveys)

Longer term:

- Strive to create standardized international surveillance MSkI tracking system

An effort of this scope will be difficult as it is costly and requires dedicated epidemiologists and data managers working with military health care providers to complete and validate. As the successes (and failures) of tested interventions and preventions strategies become known, having a common military MSkI recording and tracking system will only serve to improve efforts designed to reduce MSkIs.

2.5 REFERENCES

[1] Duvigneaud, N., Bernard, E., Stevens, V., Witvrouw, E., Van Tiggelen, D. (2008). Isokinetic assessment of patellofemoral pain syndrome: A prospective study in female recruits. Isokinetics and Exercise Science 16(4), 213-219. (Doi: 10.3233/IES-2008-0311) https://content.iospress.com/articles/isokinetics-and-exercise-science/ies00311

[2] Van Tiggelen, D., Cowan, S., Coorevits, P., Duvigneaud, N., Witvrouw, E. (2009). Delayed vastus medialis obliquus to vastus lateralis onset timing contributes to the development of patellofemoral pain in previously healthy men: A prospective study. American Journal of Sports Medicine 37(6), 1099-1105. https://insights.ovid.com/american-sports-medicine/ajsm/2009/06/000/delayed-vastus-medialis-obliquus-lateralis-onset/5/00000475

[3] Bundesamt für Personalwesen der Bundeswehr (13 June 2019). Bereichsvorschrift C1-1334/0-5000 Fitnesstest der Personalgewinnungsorganisation (BFT-PersG), BAPersBw II 1.1, 2.0.

[4] Kommando SKB (17 Feb 2020). Zentralvorschrift A1-224/0-1 Sport und Körperliche Leistungsfähigkeit, Kommando Streitkräftebasis, 1.2.

[5] Sammito, S. (2011). Risk of injury during combat training – Assessment of the relative rate of injuries during four successive basic training periods. Wehrmed Mschr 55(4), 90-93.

[6] Sammito, S. (2011). Sport injuries during duty sport – A risk assessment. Sportverletz Sportschaden 25(1), 50-55.

[7] Müller-Schilling, L., Gundlach, N., Böckelmann, I., Sammito, S. (2019). Physical fitness as a predisposing factor for injuries and excessive stress symptoms during basic military training. Int Arch Occup Environ Health. Aug 92(6), 837-841. Doi: 10.1007/s00420-019-01423-6. Epub 20 March 2019.

[8] Nesterovica, D., Vaivads, N., Stepens, A. (2020). Self-reported musculoskeletal acute and overuse injuries among Latvian infantry soldiers. Proceedings of the International Scientific Conference VI, 354-360. Doi: 10.17770/sie2020vol6.5094.

[9] Shephard, R.J. (1988). PAR-Q, Canadian home fitness test and exercise screening alternatives. Sports Medicine 5, 185-195. Doi: /10.2165/00007256-198805030-00005.

[10] Dijksma, I., Bekkers, M., Spek, B., Lucas, C., Stuiver, M. (2020). Epidemiology and financial burden of musculoskeletal injuries as the leading health problem in the military. Mil Med 2 Mar ;185(3-4), e480-e486. Doi: 10.1093/milmed/usz328. [Epub ahead of print].

[11] Dijksma, I., Zimmermann, W.O., Hertenberg, E.J., Lucas, C., Stuiver, M.M. (2022). One out of four recruits drops out from elite military training due to musculoskeletal injuries in the Netherlands Armed Forces. BMJ Mil Health Apr;168(2), 136-140. Doi: 10.1136/bmjmilitary-2020-001420. [Epub 2020 Mar 5].

[12] Kovcan, B., Vodicar, J., Šimenko, J., Videmšek, M., Pori, P., Vedran, H. (2019). Retrospective and cross-sectional analysis of physical training-related musculoskeletal injuries in Slovenian Armed Forces. Mil Med. 1 Jan 184(1-2), e195-e199. Doi: 10.1093/milmed/usy156. Erratum in: Mil Med. (2019) 1 Mar 184(3-4), 111.

[13] Ministerio de Defensa (2019). Estadísticas de Personal Militar de Carrera de las Fuerzas Armadas de las categorías de Oficial General, Oficial y Suboficial y de Personal Militar de Carrera del Cuerpo de la Guardia Civil, año 2018. Ministerio de Defensa, Secretaría General Técnica, Vicesecretaría General Técnica, Unidad de Estadística del Órgano Central, Plan Estadístico de la Defensa. NIPO: 083-15-072-9.

[14] Ministerio de Defensa (2019). Estadística de Personal Militar de Complemento, Militar de Tropa y Marinería y Reservista Voluntario, año 2018. Ministerio de Defensa, Secretaría General Técnica, Vicesecretaría General Técnica, Unidad de Estadística del Órgano Central, Plan Estadístico de la Defensa. NIPO: 083-15-073-4.

[15] Ministerio de Defensa (2019). Resolución 452/38130/2019, de 13 de mayo, de la Subsecretaría, por la que se convocan los procesos de selección para el ingreso en los centros docentes militares de formación, mediante la forma de ingreso directo, con y sin exigencia de titulación universitaria previa, para la incorporación como militar de carrera a las Escalas de Oficiales de los Cuerpos Generales, del Cuerpo de Infantería de Marina y del Cuerpo de la Guardia Civil. BOE-A-2019-7288.

[16] Ministerio de Defensa (2020). Resolución 452/38033/2020, de 13 de febrero, de la Subsecretaría, por la que se aprueba el proceso de selección para el ingreso en los centros docentes militares de formación para incorporarse a las escalas de tropa y marinería. BOE-A-2020-2301.

[17] Ministerio de Defensa (2014). Orden Ministerial 54/2014, de 11 de noviembre, por la que se establecen las pruebas físicas periódicas a realizar por el personal de las Fuerzas Armadas. BOD-2014-226-27637.

[18] Memoria de Actividades de los Servicios de Prevención de Riesgos Laborales, año 2017. Ministerio de Defensa, Subsecretaría de Defensa, Dirección General de Personal, Unidad de Coordinación de los Servicios de Prevención. 2018.

[19] Memoria de Actividades de los Servicios de Prevención de Riesgos Laborales, año 2018. Ministerio de Defensa, Subsecretaría de Defensa, Dirección General de Personal, Unidad de Coordinación de los Servicios de Prevención. 2019.

[20] Office of the Under Secretary of Defense, Personnel and Readiness (2020). Population Representation in the Military Services: Fiscal Year 2018 Summary Report. Accessed 3 May 2020. http://www.cna.org/research/pop-rep

[21] US Army Research Institute of Environmental Medicine. Soldier Performance, Health, and Readiness (SPHERE) Data repository (2019). https://www.usariem.army.mil/index.cfm/about/divisions/mpd/sphere

[22] Barell, V., Aharonson-Daniel, L., Fingerhut, F.A., Mackenzie, E.J., Ziv, A., Boyko, V., Abargel, A., Avitzour, M., Heruti, R. (2002). An introduction to the Barell body region by nature of injury diagnosis matrix. Injury Prevention 8:91-96.

[23] Hauschild, V.D., Schuh-Rennera, A., Lee, T., Richardson, M.D., Hauret, K., Jones, B.J. (2019). Using causal energy categories to report the distribution of injuries in an active population: An approach used by the U.S. Army. Journal of Science and Medicine in Sport 22, 997-1003.

[24] Roy, T.C., Richardson, M.D., Ritland, B.M., Cushing, R.E., Nyguyen, V.T. (2021). The occupational military neuromusculoskeletal injury matrix. Mil Med 1 July, 187(7-8), e889-e897. Doi: 10.1093/milmed/usab300. Online ahead of print.

[25] Smith, L.B., Westrick, R.B., Sauers, S.E., Cooper, A., Scofield, D., Claro, P., Warr, B. (2016). Underreporting of musculoskeletal injuries in the US Army: Findings from an Infantry Brigade Combat Team Survey Study. Sports Health 8(6), 507-5013.

[26] Sauers, S.E., Smith, L.B., Scofield, D.E., Cooper, A., Warr, B.J. (2016). Self-management of unreported musculoskeletal injuries in a US Army Brigade. Mil Med 181(9), 1075-1080.

[27] Rhon, D.I. (2010). A physical therapist experience, observation, and practice with an infantry brigade combat team in support of Operation Iraqi Freedom. Military Medicine 175(6), 442-447.

[28] Roy, T.C., Knapik, J.J., Ritland, B.M., Murphy, N., Sharp, M.A. (2012). Risk factors for musculoskeletal injuries for soldiers deployed to Afghanistan. Aviation, Space, and Environmental Medicine 83(11), 1060-1066.

[29] Jensen, A., Laird, M., Jameson, J.T., Kelly, K.R. (2019). Fitness and body composition as predictors of musculoskeletal injury risk (FITRISK). Mil Med 1 Mar, 184(Suppl 1), 511-520.

[30] Trost, R.P., Peterson, J., Shuford, R., Quester, A., Hiatt, C. (September 2014). Assessing how delayed entry program physical fitness is related to in-service attrition, injuries, and physical fitness. CAN Coporation Technical Report 2014 DRM-2014-U-007869-Final. Fort Belvoir, VA, Defense Technical Information Center. Accessed 9 April 2018. https://www.cna.org/cna_files/pdf/DRM-2014-U-007869-Final.pdf

Chapter 3 – RISK FACTORS FOR MUSCULO-SKELETAL INJURIES IN THE MILITARY

S. Sammito, V. Hadžić, T. Karakolis, K.R. Kelly, S.P. Proctor,
A. Stepens, G. White, and W.O. Zimmermann[1]

3.1 SUMMARY

Introduction: Musculo-Skeletal Injuries (MSkIs) are a leading cause of health care utilization, as well as limited duty and disability in the US military and other armed forces. MSkIs affect members of the military during initial training, operational training, and deployment and have a direct negative impact on overall troop readiness. Currently, a systematic overview of all risk factors for MSkIs in the military is not available.

Methods: A systematic literature search was carried out using the PubMed, Ovid/Medline, and Web of Science databases. Additionally, a reference list scan was performed (using the "snowball method"). Thereafter, an international, multidisciplinary expert panel scored the level of evidence per risk factor, and a classification of modifiable/non-modifiable was made.

Results: In total, 176 original papers and 3 meta-analyses were included in the review. A list of 57 reported potential risk factors was formed. For 21 risk factors, the level of evidence was considered moderate or strong. Based on this literature review and an in-depth analysis, the expert panel developed a model to display the most relevant risk factors identified, introducing the idea of the "order of importance" and including concepts that are modifiable/non-modifiable, as well as extrinsic/intrinsic risk factors.

Discussion: This is the first systematic review of studies on risk factors for MSkIs in the military that has attempted to be all-inclusive. A total of 57 different potential risk factors were identified, and a new, prioritizing injury model was developed. This model may help us to understand risk factors that can be addressed, and in which order they should be prioritized when planning intervention strategies within military groups.

3.2 INTRODUCTION

Musculo-Skeletal Injuries (MSkIs) are a leading cause of health care utilization, as well as limited duty and disability in the US military [1] and other armed forces [2], [3], [4], [5], [6]. MSkIs affect members of the military during initial training [7], operational training [8], and during deployment [9], and have a direct negative impact on overall troop readiness. MSkIs have been shown to make up 50% of disease and non-battle injury (DNBI) casualties, and 43% of DNBI casualties requiring evacuation. Additionally, many service members sustain MSkIs, which are treated conservatively in the theater during deployment, but eventually require surgery following a combat tour [10], [11]. The consequences of MSkIs are reduced individual fitness and health [12], and ultimately discharge from military duty [13], [14].

[1] The contents of this chapter have also been published as: Sammito, S., Hadžić, V., Karakolis, T., Kelly, K.R., Proctor, S.P., Stepens, A., White, G. and Zimmermann, W.O. (2021). Risk factors for musculo-skeletal injuries in the military – A systematic review of the literature from the last two decades and a new prioritizing injury model. Mil Med Res 8, 66. doi 10.1186/s40779-021-00357-w.

As such, the prevention of MSkIs is considered a main target area to increase the readiness, performance, and health of military personnel. Approaches include the identification of risk factors and purposeful intervention strategies to reduce MSkIs. In recent decades, hundreds of original studies have been published with the goal of identifying risk factors for MSkIs, including narrative and systematic reviews on specific risk factors [15] – [26]. However, an overall summary of the published data on risk factors for MSkIs in the military is not available. Further, for several risk factors, such as sex, there is an ongoing debate on whether there is a direct association with an increased risk of MSkIs, or whether the association is indirect via a confounding risk factor [27]. Finally, there is no model that clarifies the relative order of importance of the risk factors for MSkIs in the military.

Given the gaps in knowledge identified above and the fact that soldier readiness is of great importance to all allied militaries, the multidisciplinary NATO Science and Technology Organization (STO) Research Task Group (RTG) 283 on "Reducing Musculo-Skeletal Injuries" set out to perform a systematic review of risk factors for MSkIs in the military to address and discuss the facilitation of successful interventions.

3.3 METHODS

A systematic literature search considering the PRISMA guidelines [28] was initiated using the PubMed, Ovid/Medline, and Web of Science databases with the search terms "(military) AND ((injury) OR (trauma)) AND ((basic training) OR (physical training))" with all MeSH terms (see details on Additional file 1) on September 10, 2019. The principal criterion for inclusion was that the study reported on risk factors for MSkIs in a military population. The exclusion criteria were as follows: a language other than English; studies without a risk factor evaluation; and studies published before January 1st, 2000. Review articles (without a meta-analysis) were used to find the included original works (see below) but were not included as such in this review. Of the 1794 studies identified (after removing duplicates), 179 were selected for full-text analysis. After full-text analysis, 42 papers were excluded because they did not meet the inclusion criteria, and 19 studies were reviews and did not present new information. So far, a total of 118 original papers and 3 meta-analyses have been included.

Moreover, to present a complete overview, a reference list scan (using the "snowball method") [29] was performed on each of the 179 fully analyzed texts, including each of the 19 review articles. With this approach, an additional 283 studies were identified, of which 87 were excluded due to the publication date being before January 1st, 2000. The remaining 196 papers were also read in full to determine relevance. If two studies reported on exactly the same population, only the publication that provided the most details was included. As a result, an additional 58 studies were included in this review, bringing the total to 176 original papers and 3 meta-analyses (see Figure 3-1).

Once all the literature was identified, a list of all reported risk factors was created. Each original paper and meta-analysis was then assigned to a risk factor. If an original paper described multiple risk factors, it was assigned to every risk factor it reported.

In the results section, a general description of all the included publications is provided first, followed by specific descriptions per risk factor. Risk factors were sorted into different groups (in alphabetical order), lifestyle factors, medical factors, occupational factors, physiological factors, social factors, and training factors. For each risk factor, an accompanying table was included that summarizes each aspect of the supporting studies: lead author; year of publication; country of origin; characteristics of the population examined (branch and unit/type of military activity); study type (retrospective or prospective); sample size of the population studied; and whether or not the study concluded that the risk factor was correlated to MSkIs (yes or no). In a number of publications, more than one risk factor was evaluated.

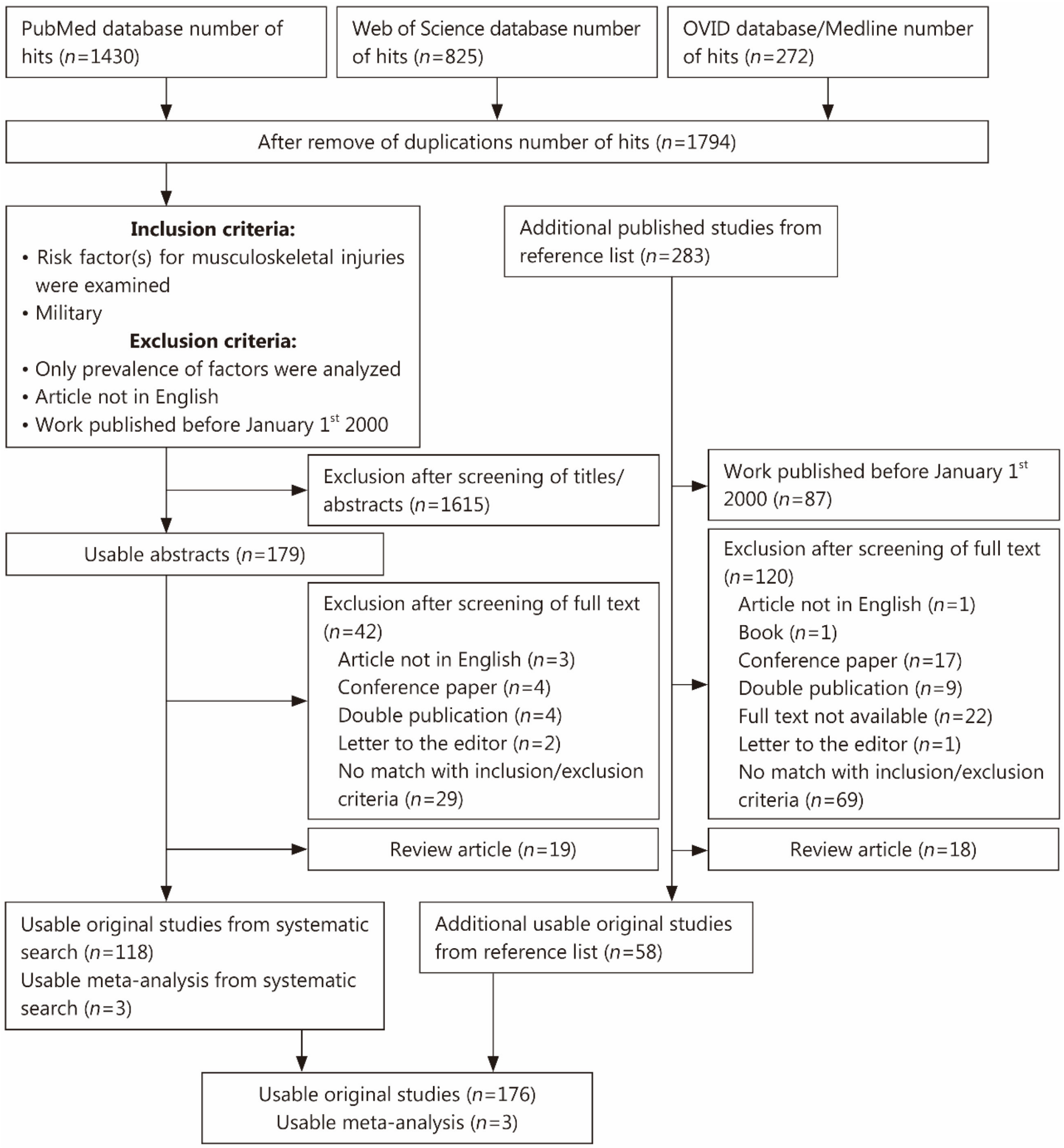

Figure 3-1: Flow-Chart of the Systematic Review.

Finally, the multidisciplinary expert panel (consisting of all coauthors of this review) classified the evidence supporting the association between a risk factor and MSkI into one of five categories: strong, moderate, weak, insufficient, or no evidence. For this classification, the expert panel took into account the results of the studies, as well as the number of participants and their professional experience in military MSkI injury prevention. In addition, the expert panel included a determination as to whether a risk factor would be considered modifiable or non-modifiable in the military context. A risk factor was defined as modifiable if a service member could influence it (e.g., to be a smoker) or if military authorities could influence it (e.g., by changing the training schedule or by providing other gear). Risk factors classified as non-modifiable are beyond personal control (e.g., the weather). Whether a risk factor is modifiable is a significant determinant for the application of intervention strategies. Based on the literature review and an in-depth analysis, the multidisciplinary expert panel developed a model to classify the different risk factors identified, introducing the concept of "order of importance" and including the notions of modifiable/non-modifiable and extrinsic/intrinsic risk factors.

3.4 RESULTS

Of the 176 original papers, 101 came from investigations in the US Armed Forces. Additional investigations were conducted in the armed forces of the UK (19 studies), Israel (18 studies), and Finland (14 studies). Australia and Switzerland produced 4 studies each, China and Greece had 3 studies each, Germany had 2 studies, and Belgium, Denmark, India, Iran, Malta, Poland, Slovenia, and Sweden were represented by 1 study each. A majority of the studies examined risk factors in the army (113 studies), whereas there were considerably fewer studies conducted in the marines (16 studies), the air force (7 studies), the navy (5 studies), and the special operations forces (2 studies). Seven studies explored risk factors, including multiple armed services branches; 4 studies were conducted only among recruits or participants in academy training, and 22 studies did not include descriptions of the particular service branch. More than half of the studies (n = 101) chose a prospective study design, and the remaining 75 papers evaluated data retrospectively. The study populations ranged from 20 subjects [30] to 5,580,875 analyzed person-years [31]. In two studies [32], [33], no information about the underlying size of the population was reported. Less than half of the studies (n = 79) scrutinized populations of less than 1000 participants, while 27 studies had a population greater than 10,000 participants. A number of retrospective studies involved populations with over 100,000 participants [31], [34] – [51]. A large minority of the studies included both male and female military personnel (n = 51). In 33 studies, only male members were included, whereas 17 studies focused exclusively on women in the military. In most of the studies (n = 75), no specific information was given about the sex of the included participants.

3.4.1 Lifestyle Factors

3.4.1.1 Alcohol Intake

Nine studies focused on higher alcohol intake as a risk factor for MSkIs (see Table 3-1). Five studies were conducted in the US Army, 2 within the British Army, and 1 in Finland and in Greece. The sizes of the study populations ranged from 64 to 4139 participants. Three of the 9 studies identified alcohol intake as a risk factor for MSkIs, and 6 did not show a significant association between alcohol intake and MSkIs.

Table 3-1: Summary of All Studies that Focused on Alcohol Intake as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	No
Chatzipapas [63]	2008	Greece	n/a	Active duty	R	64	No
Cosa-Lima [64]	2013	USA	Army	Sergeants Major Academy	R	149	No
Lappe [65]	2005	USA	Army	Recruits BCT	R	4,139 f	Yes (f)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	Yes (f)
Robinson [67]	2016	UK	Army	Recruits	P	1,810	No
Schneider [68]	2000	USA	Army	Airborne Division	R	1,214	Yes
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	No (m)
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **insufficient** scientific evidence for alcohol intake as a **modifiable** risk factor.

3.4.1.2 Calcium Intake (Low)

Four studies focused on low (daily) calcium intake as a risk factor for MSkIs (see Table 3-2). Three studies were conducted in the Israel Defense Force (IDF) and one in the Armed Forces of Greece. The sizes of the study populations ranged from 64 to 2,306 participants. Only the study with one of the smallest populations identified low daily calcium intake as a risk factor for MSkIs. The other three studies, including one with more than 2000 participants, did not find a significant association.

Table 3-2: Summary of All Studies that Focused on Low Calcium Intake as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Chatzipapas [63]	2008	Greece	n/a	Active duty	R	64	No
Givon [70]	2000	Israel	n/a		P	2,306 m	No (m)
Moran [71]	2012	Israel	Army	Recruits of elite combat unit	P	116	No
Moran [72]	2012	Israel	Army	Elite combat unit BCT	P	74	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, (m) = RF only for males

There is **insufficient** scientific evidence for low (daily) calcium intake as a **modifiable** risk factor.

3.4.1.3 Milk Consumption (Low)

Three studies focused on milk consumption as a risk factor for MSkIs (see Table 3-3). The research was conducted within the militaries of Israel, the USA, and the UK (1 study from each country). The sizes of the study populations ranged from 116 to 1082 participants. Only one study identified low milk consumption as a risk factor for MSkIs; the other two studies did not find a significant association.

Table 3-3: Summary of All Studies that Focused on Low Milk Consumption as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Cosman [73]	2013	USA	Army	Military Academy	P	755 m, 136 f	No
Moran [71]	2012	Israel	Army	Recruits of elite combat unit	P	116	No
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? P = prospective study, m = male, f = female, (m) = RF only for males

There is **insufficient** scientific evidence for low milk consumption as a **modifiable** risk factor.

3.4.1.4 Vegetable Consumption

Two studies focused on the amount of vegetables eaten (as measured via a self-report questionnaire) as a risk factor for MSkIs (see Table 3-4). The research was conducted within different branches of the UK military. The sizes of the study populations ranged from 1082 to 1810 participants. Neither study found a significant association between the amount of vegetable consumption and MSkIs.

Table 3-4: Summary of All Studies that Focused on Vegetable Consumption as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Robinson [67]	2016	UK	Army	Recruits	P	1,810	No
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? P = prospective study, m = male, (m) = RF only for males

There is **no** scientific evidence for the amount of vegetable consumption as a **modifiable** risk factor for MSkIs.

3.4.1.5 Vegetarian Diet

Only one study focused on a vegetarian diet as a risk factor for MSkIs (see Table 3-5). This study was conducted within the Indian Army. In this study, with 8,570 participants, a vegetarian diet was identified as a risk factor for stress fractures.

Table 3-5: Summary of All Studies that Focused on Vegetarian Diet as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Dash [74]	2012	India	Army	Recruits	P	8,570	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? P = prospective study

There is **weak** scientific evidence for a vegetarian diet as a **modifiable** risk factor.

3.4.1.6 (Reduced) Sleep Time

Two studies focused on little time for sleep as a risk factor for MSkIs (see Table 3-6). These studies were conducted within the Army of Switzerland and the Army of Slovenia. The sizes of the study populations ranged from 129 to 1676 participants. A larger study identified little time for sleep as a risk factor for MSkIs; however, this was not observed within the smaller study.

Table 3-6: Summary of All Studies that Focused on Sleep Time as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Kovcan [75]	2019	Slovenia	Army	Infantry, active duty	R	118 m, 11 f	No
Wyss [76]	2014	Switzerland	Army	Recruits BCT	P	1,676	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, m = male, f = female

There is **weak** scientific evidence for little time for sleep as a **modifiable** risk factor.

3.4.1.7 Smoking

Fifty-four studies focused on smoking as a risk factor for MSkIs (see Table 3-7). Most of the research was conducted within different branches of the US Armed Forces (32 studies); additional studies were conducted within the militaries of the UK (8 studies), Finland (5 studies), China, Israel, Switzerland (2 studies from each) and Greece, Malta, and Slovenia (1 study from each nation). The study populations ranged from 64 to 238,772 participants. Twenty-seven studies identified smoking as a risk factor for MSkIs, and 23 studies did not find a significant association between smoking and MSkI. One study found a significant increase in MSkIs related to a lower level of smoking, and one study found that former smoking habits were a significant risk factor for MSkIs. In one study, the association between smoking and increased risk for MSkIs was found only for males (not for females). A meta-analysis, which included 18 studies, found that smoking increases the risk for MSkIs, for males by 26% (a low level of smoking) up to 84% (a high level of smoking) and for females by 30% (low level of smoking) up to 56% (high level of smoking) [24]. For both sexes together, the increased risk ranges from 27% to 71%.

Table 3-7: Summary of All Studies that Focused on Smoking as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Altarac [77]	2000	USA	Army	Recruits	P	187 m, 915 f	Yes
Anderson [78]	2015	USA	Army	Light Infantry Brigade	R	2101	Yes
Anderson [79]	2017	USA	Army	Light Infantry	R	4,384 m, 363 f	No
Bedno [80]	2013	USA	Army	IET	P	8,456 m	Yes
Bedno [35]	2019	USA	Army	Recruits BCT	R	238,772	Yes
Brooks [81]	2019	USA	Army	Recruits BCT	R	1,460 m, 540 f	Yes
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	Yes
Chatzipapas [63]	2008	Greece	n/a	Active duty	R	64	No
Cosa-Lima [64]	2013	USA	Army	Sergeants Major Academy	R	149	No
Cosman [73]	2013	USA	Army	Military Academy	P	755 m, 136 f	Yes
Cowan [82]	2012	USA	Army	Trainees	P	1,568 f	No
Cowan [83]	2011	USA	Army	Recruits	P	7,323	Yes
Davey [84]	2015	UK	Marines		P	1,090 m	Yes
Fallowfield [85]	2018	UK	Air Force	Recruits	P	990 m, 203 f	Yes
Givon [70]	2000	Israel	n/a		P	2,306 m	Yes (less)
Grier [86]	2017	USA	Army	Infantry brigades	R	4,236 m	No
Grier [87]	2010	USA	multiple		R	24,177 m	Yes
Kelly [88]	2000	USA	Navy	Recruits BCT	R	86 f	No
Knapik [89]	2010	USA	Air Force	Recruits BCT	P	1,042 m, 375 f	Yes

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Knapik [90]	2013	USA	Army	Army military police training	P	1,838 m, 553 f	Yes[2]
Knapik [91]	2013	USA	Army	Brigade Combat Team[1]	P	805	No
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	Yes
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	No
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	Yes
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	Yes (m), No (f)
Korvala [57]	2010	Finland	n/a	Conscripts	P	192	No
Lappe [65]	2005	USA	Army	Recruits BCT	R	4,139 f	Yes
Kovcan [75]	2019	Slovenia	Army	Infantry, active duty	R	118 m, 11 f	Yes
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	Yes
Lauder [97]	2000	USA	Army	Active duty	P	230 f	No (f)
Munnoch [98]	2007	UK	Marines		P	1,115 m	Yes
Nagai [99]	2017	USA	Army	Airborne Division	P	275	Yes
Pihlajamäki [100]	2019	Finland	n/a		R	4,029 m	No
Psaila [101]	2017	Malta	n/a	Recruits BCT	P	114 m, 13 f	No
Rappole [102]	2017	USA	Army	Army Brigade	R	1,099	Yes
Reynolds [103]	2009	USA	Army	Infantry	P	181	Yes
Reynolds [104]	2002	USA	Army	Construction engineers and Combat artillery soldiers	P	313	No
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	Yes
Robinson [67]	2016	UK	Army	Recruits	P	1,810	No
Roos [105]	2015	Switzerland	Army	Recruits	P	651 m	Yes

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Ruohola [106]	2006	Finland	n/a	Recruits	P	756 m	No
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	No
Scheinowitz [107]	2017	Israel	Army	Recruits	P	350 f	No
Schneider [68]	2000	USA	Army	Airborne Division	R	1214	No
Sharma [108]	2019	UK	Army	Infantry recruits	P	562 m	Yes
Sharma [109]	2011	UK	Army	Infantry recruits	P	468 m	Yes
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	No (m)
Taanila [110]	2015	Finland	Army	Conscripts	P	1,411 m	Yes
Trone [111]	2014	USA	Marine Corp Air Force Army	Recruits BCT	R	900 m, 597 f	Yes
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	No
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No
Wunderlin [113]	2015	Switzerland	Army	Recruits	P	230 m	Yes
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females, [1]Deployment; [2]Former smoking

There is **strong** scientific evidence for smoking as a **modifiable** risk factor for MSkIs. Smoking is associated with a 27% to 71% increased risk of MSkIs.

3.4.2 Medical Factors

3.4.2.1 Current Illness

The term "current illness" was used to describe the situation where an injured person was ill (e.g., with influenza at the time the MSkI occurred). There was only one study on current illness as a risk factor for MSkIs (see Table 3-8). The study was conducted in 2010 in the US Armed Forces. With 24,177 male participants, this study found a significant association between current illness and an increased risk for MSkIs. It must be noted that the risk factor "current illness" may represent a bias. Soldiers with an identified current illness are generally removed from active duty and training. This means that current illness is a risk factor mostly based on retrospective self-report by the service member.

Table 3-8: Summary of All Studies that Focused on Current Illness as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Grier [87]	2010	USA	multiple		R	24,177 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? R = retrospective study, m = male, (m) = RF only for males

There is **weak** scientific evidence for current illness as a **non-modifiable** risk factor.

3.4.2.2 The Prescription of Hormonal Contraceptives

Four studies focused on the prescription of hormonal contraceptives as a risk factor for MSkIs (see Table 3-9). Most of the research was conducted within different branches of the US Armed Forces (3 studies). An additional study was conducted within the IDF. The sizes of the study populations ranged from 350 to 2962 participants. None of the four studies identified the prescription of hormonal contraceptives as a risk factor for MSkIs.

Table 3-9: Summary of All Studies that Focused on Prescription of Hormonal Contraceptives as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [95]	2008	USA	Army	Recruits BCT	P	920 f	No
Knapik [96]	2009	USA	Marines	Recruits BCT	P	571 f	No
Scheinowitz [107]	2017	Israel	Army	Recruits	P	350 f	No
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2962 f	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, f = female

There is **no** scientific evidence for the prescription of hormonal contraceptives as a **modifiable** risk factor for MSkIs.

3.4.2.3 The Prescription of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)

Only one study focused on the prescription of a NSAID as a risk factor for MSkIs (see Table 3-10). This study was conducted within the US Army. In this retrospective study, with 120,730 participants, the prescription of a NSAID was identified as a risk factor for MSkIs (specifically stress fractures). There may be a bias between NSAID use and increased risk for a stress fracture because with the medication, soldiers may have stayed in training longer and consequently were more likely to suffer a fracture. Therefore, this study also explored the relationship with a subset who were taking NSAIDs for non-pain or injury reasons and found a similar relationship with increased risk for MSkIs.

Table 3-10: Summary of All Studies that Focused on Prescription of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Hughes [50]	2019	USA	Army	Active duty	R	120,730	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? R = retrospective study

There is **weak** scientific evidence for prescription for a NSAID as a **modifiable** risk factor.

3.4.2.4 Previous MSkIs

Thirty studies focused on previous MSkIs as a risk factor for MSkIs (see Table 3-11). Most of the research was conducted within different branches of the US Armed Forces (18 studies); the remaining research was conducted within the militaries of the UK (3 studies), Israel and China (2 studies from each), Australia, Finland, Slovenia, Sweden, and Switzerland (1 study from each nation). The sizes of the study populations ranged from 53 to 83,323 participants. Nineteen of the 30 studies identified an earlier MSkI as a risk factor for MSkIs; 7 studies did not find a significant association. Two studies found a significant association only for one sex but not the other. The remaining two studies found that an earlier MSkI reduced the risk for MSkIs.

Table 3-11: Summary of All Studies that Focused on Previous MSkIs as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Cameron [115]	2013	USA	Army	Military Academy	P	630 m, 84 f	Yes
Cosman [73]	2013	USA	Army	Military Academy	P	755 m, 136 f	No
Evans [116]	2005	USA	Army		R	1,532	Yes
Finestone [117]	2011	Israel	Army	Elite infantry soldier	P	77 m	No (m)
Garnock [118]	2018	Australia	Navy	Recruits	P	95 m, 39 f	Yes
George [119]	2012	USA	Army	Combat medics	P	1230	Yes
Givon [70]	2000	Israel	n/a		P	2,306 m	Yes (m) (invers)
Hill [54]	2013	USA	Army	Active duty	R	83,323	Yes
Knapik [89]	2010	USA	Air Force	Recruits BCT	P	1,042 m, 375 f	No
Knapik [90]	2013	USA	Army	Army military police training	P	1,838 m, 553 f	Yes (m), No (f)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [120]	2013	USA	Army	Combat engineer enlisted trainees	P	1,633	Yes
Knapik [91]	2013	USA	Army	Brigade Combat Team[1]	P	805	No
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	Yes
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	No (m), Yes (f)
Kovcan [75]	2019	Slovenia	Army	Infantry, active duty	R	118 m, 11 f	Yes
Kucera [121]	2016	USA	Army	Cadets	P	9,811	Yes
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	No (f)
Lisman [122]	2013	USA	Marines	Officer candidate training	P	874	Yes
Monnier [123]	2019	Sweden	Marines	Training course	P	48 m, 5 f	Yes
Rice [124]	2017	UK	Marines	Recruits	P	147 m	Yes (m) (invers)
Robinson [67]	2016	UK	Army	Recruits	P	1,810	Yes
Roos [105]	2015	Switzerland	Army	Recruits	P	651 m	Yes (m)
Roy [125]	2014	USA	Army	Active duty	R	625 f	Yes (f)
Schneider [68]	2000	USA	Army	Airborne Division	R	1,214	Yes
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	No
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	No (f)
Taanila [127]	2010	Finland	n/a	Conscripts	P	944 m	Yes (m)
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	Yes (m)
Wilkinson [56]	2009	UK	Army	Infantry	P	660	Yes
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	Yes[2] (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females, [1]Deployment; [2]Only for fractures

There is **strong** scientific evidence for earlier MSkIs as a **non-modifiable** risk factor for MSkIs.

3.4.2.5 Prior Pregnancy

Only one study focused on prior pregnancy as a risk factor for MSkIs (see Table 3-12). This study was conducted within the US Army. In this study, with 920 female participants, prior pregnancy > 7 months prior was identified as a risk factor for MSkIs.

Table 3-12: Summary of All Studies that Focused on Prior Pregnancy as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [95]	2008	USA	Army	Recruits BCT	P	920 f	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, P = prospective study, f = female

There is **weak** scientific evidence for prior pregnancy as a **non-modifiable** risk factor.

3.4.2.6 Serum Iron/Serum Ferritin (Lower)

Two studies focused on serum iron/serum ferritin as a risk factor for MSkIs (see Table 3-13). Both studies were conducted within the IDF. The sizes of the study populations were 227 and 438 participants. Both studies identified low serum iron/serum ferritin as a risk factor for MSkIs.

Table 3-13: Summary of All Studies that Focused on Serum Iron/Serum Ferritin as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Merkel [128]	2008	Israel	Army	Infantry/ non-combatant (medics)	P	83 m, 355 f	Yes
Moran [129]	2008	Israel	Army	Recruits	P	227 f	Yes (f)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, P = prospective study, m = male, f = female, (f) = RF only for females

There is **weak** scientific evidence for low serum iron/serum ferritin as a **modifiable** risk factor.

3.4.2.7 Vitamin D Status [Low Level of 25(OH)D]

Four studies focused on vitamin D status as a risk factor for MSkIs (see Table 3-14). The studies were conducted within the militaries of the UK (2 studies), Israel, and the US (1 study from each country). The sizes of the populations of both UK studies [52], [53] were the same. The study populations ranged from 1,082 to 2,306 participants. Three studies identified low vitamin D status as a risk factor for MSkIs, while another study did not find a significant association. The two studies from the UK reported different outcomes. Davey et al. [52] compared to a group that did not [(64.2 ± 28.2) nmol/L for participants with stress fracture vs.

(78.6 ± 35.9) nmol/L for participants without a stress fracture, P = 0.004]. Alternatively, Sanchez-Santos et al. [53] presented the results as odds ratios with a cutoff value for a low level of vitamin D at 50 nmol/L. They found no difference in the likelihood of stress fractures between the groups above and below the vitamin D level cutoff (P = 0.077).

In a meta-analysis by Dao et al. [23], it was reported that the mean serum 25(OH)D level was lower in stress fracture cases than in controls at the time of entry into basic training. The mean serum 25(OH)D level was also lower in the stress fracture cases at the time of stress fracture diagnosis.

Table 3-14: Summary of All Studies that Focused on Vitamin D Status as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Burgi [130]	2011	USA	Navy	Recruits	P	2,300 f	Yes (f)
Davey [52]	2016	UK	Marines		P	1,082 m	Yes (m)
Givon [70]	2000	Israel	n/a		P	2,306 m	Yes (m)
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **moderate** scientific evidence for a low level of vitamin D status as a **modifiable** risk factor.

3.4.3 Occupational Factors

3.4.3.1 Branch

Three studies focused on membership in different branches as a risk factor for MSkIs (see Table 3-15). Two studies were conducted within the US Armed Forces and 1 within the Army of Finland. The sizes of the study populations ranged from 982 to 423,581 participants. All 3 studies identified membership to different branches as a risk factor for MSkIs.

Table 3-15: Summary of All Studies that Focused on Branch as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Cameron [44]	2010	USA	multiple	Active duty	R	423,581	Yes
Owens [131]	2009	USA	Army, Marines, Navy, Air Force	Active duty	R	19,730	Yes
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? R = retrospective study, P = prospective study, m = male, (m) = RF only for males

There is **strong** scientific evidence for branches as a **non-modifiable** risk factor for MSkI.

3.4.3.2 Length of Service

Eight studies focused on the length of service as a risk factor for MSkIs (see Table 3-16). Half of the research was conducted within different branches of the US Armed Forces (4 studies), and the remaining studies were conducted within the militaries of Finland (2 studies), Israel, and the UK (1 study from each country). The sizes of the study populations ranged from 195 to 152,095 participants. Five studies identified that military servicemen and servicewomen with a longer length of service have an increased risk for MSkIs; 3 studies did not find a significant association. Two of the largest studies only examined conscripts (Kuikka et al. [36] and Mattila et al. [38]), with a small range of lengths of service, and found conflicting results. Hill et al. [54] included a broad range of active duty personnel and showed a strong association for military servicemen and women with more than 10 years of service for an increased risk of MSkIs. Reynolds et al. [55] and Wilkinson et al. [56] detected no association, but had only a small range of lengths of service.

Table 3-16: Summary of All Studies that Focused on Length of Service as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Hill [54]	2013	USA	Army	Active duty	R	83,323	Yes
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	Yes
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	Yes
Mattila [38]	2007	Finland	Army	Conscripts	P	149,750 m, 2,345 f	No
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	No
Schermann [132]	2018	Israel	Army	Infantry unit vs. female unit working with dogs[1]	R	7,949	Yes
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	Yes
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? R = retrospective study, P = prospective study, m = male, f = female, [1]LOS examined in month of service

There is **moderate** scientific evidence for length of service as a **non-modifiable** risk factor.

3.4.3.3 Load Carriage

Six studies focused on load carriage as a risk factor for MSkIs (see Table 3-17). Most of the research was conducted in the US Armed Forces (5 studies); the remaining study was conducted within the IDF. The sizes of the study populations ranged from 263 to 1,423 participants. Five studies identified body-borne load as a risk factor for MSkIs, with 3 of the 5 studies reporting load via self-report. One study found no association between load carriage and the risk for MSkIs.

Table 3-17: Summary of All Studies that Focused on Load Carriage as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Constantini [133]	2010	Israel	Army	Border Police Infantry	P	1,423 f	Yes (f)
Knapik [91]	2013	USA	Army	Brigade Combat Team[1]	P	805	Yes
Konitzer [134]	2008	USA	n/a	Active duty[1]	R	863	Yes
Rappole [135]	2018	USA	Army	Active duty	R	368 f	No (f)
Roy [136]	2012	USA	Army	Brigade Combat Team[1]	P	246 m, 17 f	Yes
Roy [137]	2015	USA	Army	Brigade Combat Team[1]	R	536 m, 57 f	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (f) = RF only for females, [1]Deployment

There is **strong** scientific evidence for body-borne load as a **modifiable** risk factor for MSkI.

3.4.3.4 Military Occupational Specialty (MOS)

Seven studies focused on Military Occupational Specialties (MOS) as a risk factor for MSkIs (see Table 3-18). Most of the research was conducted within the US Armed Forces, 2 studies were from the IDF, and only 1 study was from the military of the UK. The sizes of the study populations ranged from 1,788 to 19,791 participants. All but one study (with light infantry) identified membership in different MOSs as a risk factor for MSkIs.

Table 3-18: Summary of All Studies that Focused on Military Occupational Specialty (MOS) as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Anderson [79]	2017	USA	Army	Light Infantry	R	4,384 m, 363 f	No
Darakjy [8]	2006	USA	Army	Active duty	P	4,101 m, 413 f	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Roy [138]	2011	USA	Army	Brigade Combat Team	P	3,066 patient encounters	Yes
Schermann [132]	2018	Israel	Army	Infantry unit vs. female unit working with dogs	R	7,949	Yes
Schwartz [138]	2018	Israel	Army	Combat units	R	19,791 m	Yes (m)
Sefton [140]	2016	USA	Army	Recruits IET	P	1,788 m	Yes (m)
Sharma [141]	2017	UK	Army	Recruits	P	5,708	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? IET = Initial Entry Training, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males

There is **strong** scientific evidence for MOS as a **non-modifiable** risk factor for MSkI.

3.4.3.5 Previous Deployment

Four studies focused on previous deployment as a risk factor for MSkIs (see Table 3-19). All 4 studies were conducted within different branches of the US Armed Forces. The sizes of the study populations ranged from 625 to 83,323 participants. Three of the 4 studies identified previous deployment as a risk factor for MSkI, and 1 study did not find a significant association.

Table 3-19: Summary of All Studies that Focused on Previous Deployment as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Hill [54]	2013	USA	Army	Active duty	R	83,323	Yes
Konitzer [134]	2008	USA	n/a	Active duty[1]	R	863	Yes
Roy [125]	2014	USA	Army	Active duty	R	625 f	Yes (f)
Skeehan [142]	2009	USA	Army, Marine, Navy	Active duty[1]	R	3,367	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? n/a = not available, R = retrospective study, f = female, (f) = RF only for females, [1]Deployment

There is **moderate** scientific evidence for previous deployment as a **non-modifiable** risk factor.

3.4.3.6 Status (Active vs. Reserve)

Three studies focused on status (active vs. reserve) as a risk factor for MSkIs (see Table 3-20). All 3 studies were conducted within the US Armed Forces. The sizes of the study populations ranged from 1,902 to 3,367 participants. All 3 studies identified status as a risk factor for MSkIs: 1 study only for women (when they are in the reserve instead of active duty), 1 for active personnel vs. reserve, and 1 for reserve vs. active personnel.

Table 3-20: Summary of All Studies that Focused on Status (Active vs. Reserve) as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	No (m) Yes (f)
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	Yes (invers)
Skeehan [142]	2009	USA	Army, Marine, Navy	Active duty[1]	R	3,367	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females, [1]Deployment

There is **no** scientific evidence for being part of the reserve (instead of active duty) as a **non-modifiable** risk factor for MSkIs.

3.4.4 Physiological Factors

3.4.4.1 Age

Sixty-five studies focused on age as a risk factor for MSkIs (see Table 3-21). Most of the research was conducted within different branches of the US Armed Forces, 8 within the military of the UK, and 7 within the military of Finland; the other studies were conducted within the militaries of China (3 studies), Israel (2 studies), Belgium, Greece, Iran, Poland, and Switzerland (1 study for each country). The study populations ranged from 44 to 5,580,875 participants. Thirty-three of the 65 studies identified older age as a risk factor for MSkIs (however, the definitions of older age differ across studies); 30 studies did not find a significant association between age and MSkIs, while 1 study found a significant rise in MSkIs for younger participants when compared to older participants. When only studies with a population of 1,400 or more participants were taken into account (this represents 31 of the 65 studies), 23 studies revealed a significant association between age and an increased risk for MSkIs compared to only 8 studies that did not find a significant association. When only studies that had 5,000 participants or more were considered, the relationship was 12 (significant association) vs. 1 (no association).

Table 3-21: Summary of All Studies that Focused on Age as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Anderson [78]	2015	USA	Army	Light Infantry Brigade	R	2,101	Yes
Anderson [79]	2017	USA	Army	Light Infantry	R	4,384 m, 363 f	Yes
Beck [143]	2000	USA	Marines		P	624 m, 693 f	No
Bedno [80]	2013	USA	Army	IET	P	8,456 m	Yes (m)
Cameron [44]	2010	USA	multiple	Active duty	R	423,581	Yes
Canham-Chervak [144]	2000	USA	Army	Recruits BCT	P	655 m, 498 f	No
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	No
Cosa-Lima [64]	2013	USA	Army	Sergeants Major Academy	R	149	No
Cowan [82]	2012	USA	Army	Trainees	P	1,568 f	No (f)
Cowan [83]	2011	USA	Army	Recruits	P	7,323	Yes
Craig [40]	2000	USA	Army	Airborne Division	R	242,949 aircraft exists	Yes (30 years+)
Davey [84]	2015	UK	Marines		P	1,090 m	No (m)
Dixon [145]	2019	UK	Marines	Recruits	P	1065	Yes (younger)
Grier [86]	2017	USA	Army	Infantry Brigade	R	4,236 m	Yes (m)
Grier [87]	2010	USA	multiple		R	24,177 m	Yes (m)
Havenetidis [146]	2011	Greece	n/a	Recruits	P	253	Yes
Henderson [147]	2000	USA	Army	Combat medic	P	439 m, 287 f	Yes
Hill [54]	2013	USA	Army	Active duty	R	83,323	Yes
Knapik [47]	2012	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes
Knapik [148]	2006	USA	Army	Recruits BCT	P	1,174 m, 898 f	Yes

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Knapik [90]	2013	USA	Army	Army military police training	P	1,838 m, 553 f	Yes
Knapik [149]	2007	USA	Army	Mechanics	R	518 m, 43 f	No
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	No
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	Yes
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	Yes
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	No
Korvala [57]	2010	Finland	n/a	Conscripts	P	192	Yes
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	Yes
Lappe [65]	2005	USA	Army	Recruits BCT	R	4,139 f	Yes (f)
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	Yes (f)
Lauder [97]	2000	USA	Army	Active duty	P	230 f	No (f)
Ma [150]	2016	China	n/a		R	2,479	No
Mahieu [151]	2006	Belgium	n/a	Recruits Royal Military Academy	P	69 m	No (m)
Mattila [38]	2007	Finland	Army	Conscripts	P	149,750 m, 2345 f	Yes
Moran [152]	2013	Israel	Army	Recruits	P	44	No
Munnoch [98]	2007	UK	Marines		P	1,115 m	Yes (m)
Nunns [153]	2016	UK	Marines	Recruits	P	160 m	No (m)
Nye [59]	2016	USA	Air Force	Recruits BCT	R	67,525	Yes
Owens [154]	2007	USA	n/a	Active duty	R	4,451	Yes

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Owens [131]	2009	USA	Army, Marines, Navy, Air Force	Active duty	R	19,730	Yes
Parr [155]	2015	USA	Army	Special Operations Forces	P	106	No
Pihlajamäki [99]	2019	Finland	n/a	Full duty	R	4,029 m	No (m)
Rabin [156]	2014	Israel	Army	Recruits	P	70 m	No (m)
Reynolds [103]	2009	USA	Army	Infantry	P	181	No
Reynolds [104]	2002	USA	Army	Construction engineers and Combat artillery soldiers	P	313	No
Roos [105]	2015	Switzerland	Army	Recruits	P	651 m	No (m)
Roy [136]	2012	USA	Army	Brigade Combat Team[1]	P	246 m, 17 f	No
Roy [125]	2014	USA	Army	Active duty	R	625 f	Yes (f)
Ruohola [106]	2006	Finland	n/a	Recruits	P	756 m	No (m)
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	Yes (m)
Schneider [68]	2000	USA	Army	Airborne Division	R	1,214	Yes
Sefton [140]	2016	USA	Army	Recruits IET	P	1,788 m	Yes (m)
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	No (f)
Sharma [108]	2019	UK	Army	Infantry recruits	P	562 m	No (m)
Sharma [109]	2011	UK	Army	Infantry recruits	P	468 m	No (m)
Skeehan [142]	2009	USA	Army, Marine, Navy	Active duty[1]	R	3,367	No
Sobhani [157]	2015	Iran	n/a	Recruits	R	181 m	No (m)
Sormaala [39]	2006	Finland	n/a	Recruits	R	118,149	No

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	Yes (m)
Trybulec [158]	2016	Poland	Army	Airborne Brigade	R	162 m, 3 f	Yes
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	No (m)
Waterman [31]	2016	USA	multiple	Active Duty	R	5,580,875	Yes
Wilkinson [56]	2009	UK	Army	Infantry	P	660	Yes
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, IET = Initial Entry Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females, [1]Deployment

There is **moderate** scientific evidence for age as a **non-modifiable** risk factor.

3.4.4.2 Ankle Dorsiflexion (Limited)

Only 2 studies focused on limited ankle dorsiflexion as a risk factor for MSkIs (see Table 3-22). One study was conducted within the IDF, and one in the armed forces of the UK. The sizes of the study populations were 20 and 70 participants, respectively. In both studies, limited ankle dorsiflexion was not significantly identified as a risk factor for MSkIs.

Table 3-22: Summary of All Studies that Focused on Ankle Dorsiflexion as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	N	RF?
Dixon [30]	2006	UK	Marines	Recruits	R	20	No
Rabin [156]	2014	Israel	Army	Recruits	P	70 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? R = retrospective study, P = prospective study, m = male, (m) = RF only for males

There is **no** scientific evidence for limited ankle dorsiflexion as a **non-modifiable** risk factor.

3.4.4.3 Balance (Low)

Two studies that focused on low balance as a risk factor for MSkIs (see Table 3-23). These studies were conducted within the special operations forces of the US military. In the larger study, poor balance (measured as single-leg balance with the eyes open, and the eyes closed on a force plate) was identified as a risk factor for MSkIs, whereas in the other studies, no association was identified.

Table 3-23: Summary of All Studies that Focused on Low Balance as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Heebner [159]	2017	USA	Army	Special Operation Forces	P	95	No
Sell [160]	2014	USA	Special Operation Forces		P	226	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? P = prospective study

There is **weak** scientific evidence for low balance as a **modifiable** risk factor.

3.4.4.4 BMI: In General

Fifty-two studies focused on BMI (in general) as a risk factor for MSkIs (see Table 3-24). BMI in general means that the studies have looked at BMI without categorization (such as obese, overweight, underweight categories). This makes it very difficult to compare different study outcomes. Most of the research was conducted within different branches of the US Armed Forces (24 studies); 9 studies within the military of the UK, 6 within the Finnish armed forces, and 5 within the IDF. The remaining studies were conducted in the militaries of Switzerland (3 studies), Greece (2 studies), Australia, Belgium, and Malta (1 study each). The sizes of the study populations ranged from 44 to 238,772 participants. Fourteen of the 52 studies identified BMI as a risk factor for MSkIs. Thirteen studies found that higher BMI was a risk factor; 1 study found that lower BMI was a risk factor. Thirty-five studies did not find a significant association between BMI and MSkIs, and 3 studies found that BMI is a risk factor for men, but not for women.

Table 3-24: Summary of All Studies that Focused on BMI (in General) as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Allsopp [161]	2003	UK	Navy	Recruits	R	1,287 m, 354 f	Yes
Beck [143]	2000	USA	Marines		P	624 m, 693 f	Yes (m), No (f)
Bedno [35]	2019	USA	Army	Recruits BCT	R	238,772	Yes (m), No (f)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Billings [162]	2004	USA	Air Force	Recruits BCT	R	2,006	Yes
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	Yes
Burgi [130]	2011	USA	Navy	Recruits	P	2,300 f	No (f)
Cosa-Lima [64]	2013	USA	Army	Sergeants Major Academy	R	149	No
Davey [84]	2015	UK	Marines		P	1,090 m	No (m)
Garnock [118]	2018	Australia	Navy	Recruits	P	95 m, 39 f	No
George [119]	2012	USA	Army	Combat medics	P	1,230	Yes
Havenetidis [164]	2017	Greece	Army	Officer recruits	P	268 m	No (m)
Havenetidis [146]	2011	Greece	n/a	Recruits	P	253	No
Jones [34]	2017	USA	Army	Recruits BCT	R	143,398 m, 41,727 f	Yes
Knapik [148]	2006	USA	Army	Recruits BCT	P	1,174 m, 898 f	No
Knapik [90]	2013	USA	Army	Army military police training	P	1,838 m, 553 f	Yes
Knapik [149]	2007	USA	Army	Mechanics	R	518 m, 43 f	Yes (m)
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	No
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	No
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	No
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	No
Kodesh [165]	2015	Israel	n/a	Combat Fitness Instructor Course	P	158 f	No
Korvala [57]	2010	Finland	n/a	Conscripts	P	192	Yes
Kupferer [166]	2014	USA	Air Force	Trainees	R	141	No
Lauder [97]	2000	USA	Army	Active duty	P	230 f	Yes (f)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Mahieu [151]	2006	Belgium	n/a	Recruits Royal Military Academy	P	69 m	No
Mattila [38]	2007	Finland	Army	Conscripts	P	149,750 m, 2,345 f	No
Moran [152]	2013	Israel	Army	Recruits	P	44	No
Moran [72]	2012	Israel	Army	Elite combat unit BCT	P	74	No (m)
Moran [129]	2008	Israel	Army	Recruits	P	227 f	Yes (f)
Munnoch [98]	2007	UK	Marines		P	1,115 m	No (m)
Nunns [153]	2016	UK	Marines	Recruits	P	160 m	Yes (m)
Nye [59]	2016	USA	Air Force	Recruits BCT	R	67,525	No
Parr [155]	2015	USA	Army	Special Operations Forces	P	106	No
Pihlajamäki [99]	2019	Finland	n/a	Full duty	R	4,029 m	No (m)
Psaila [101]	2017	Malta	n/a	Recruits BCT	P	114 m, 13 f	No
Rabin [156]	2014	Israel	Army	Recruits	P	70 m	No (m)
Rappole [102]	2017	USA	Army	Army Brigade	R	1,099	Yes
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	No
Rice [124]	2017	UK	Marines	Recruits	P	147 m	Yes (m, especially lower BMI)
Roos [105]	2015	Switzerland	Army	Recruits	P	651 m	No (m)
Ruohola [106]	2006	Finland	n/a	Recruits	P	756 m	No (m)
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	No
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	No (f)
Sharma [108]	2019	UK	Army	Infantry recruits	P	562 m	No (m)
Sharma [109]	2011	UK	Army	Infantry recruits	P	468 m	No (m)
Sillanpää [51]	2008	Finland	n/a	Conscripts	R	128,508 m	No (m)
Sormaala [39]	2006	Finland	n/a	Recruits	R	118,149	No
Waterman [167]	2010	USA	Military Academy		R	10,511 person years	Yes (m), No (F)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No
Wunderlin [113]	2015	Switzerland	Army	Recruits	P	230 m	Yes (m)
Wyss [76]	2014	Switzerland	Army	Recruits BCT	P	1,676	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **insufficient** scientific evidence for BMI in general as a **modifiable** risk factor.

3.4.4.5 BMI: Obesity (BMI ≥ 30 kg/m²)

Seventeen studies focused on obesity as a risk factor for MSkIs (see Table 3-25). Most of the research was conducted within different branches of the US Armed Forces (12 studies). Additional studies were conducted within the militaries of Finland (3 studies), China, and Germany (1 study for each country). The sizes of the study populations ranged from 410 to 387,536 participants. Sixteen studies identified obesity as a risk factor for MSkIs; only one study, with 1,568 participants, did not find a significant association.

Table 3-25: Summary of All Studies that Focused on Obesity as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Anderson [78]	2015	USA	Army	Light Infantry Brigade	R	2,101	Yes
AMSA [43]	2000	USA	Army	Active duty	R	387,536	Yes
Bedno [80]	2013	USA	Army	IET	P	8,456 m	Yes (m)
Billings [162]	2004	USA	Air Force	Recruits BCT	R	2,006	Yes
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	Yes
Cowan [82]	2012	USA	Army	Trainees	P	1,568 f	No (f)
Cowan [83]	2011	USA	Army	Recruits	P	7,323	Yes
Gundlach [168]	2012	Germany	Army	Active duty	P	410	Yes
Henderson [147]	2000	USA	Army	Combat medic	P	439 m, 287 f	Yes
Hruby [48]	2016	USA	Army		R	736,608	Yes
Jones [34]	2017	USA	Army	Recruits BCT	R	143,398 m, 41,727 f	Yes
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	Yes
Ma [150]	2016	China	n/a		R	2,479	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Packnett [41]	2011	USA	Army	Recruits BCT	R	217,468 m, 47,813 f	Yes
Rappole[102]	2017	USA	Army	Army Brigade	R	1,099	Yes
Taanila [127]	2010	Finland	n/a	Conscripts	P	944 m	Yes (m)
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, IET = Initial Entry Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **strong** scientific evidence for obesity (BMI ≥ 30 kg/m²) as a **modifiable** risk factor for MSkIs.

3.4.4.6 BMI: Overweight (BMI ≥ 25 and < 30 kg/m²)

Sixteen studies focused on being overweight as a risk factor for MSkIs (see Table 3-26). Most of the research was conducted within different branches of the US Armed Forces (10 studies); the remaining studies were conducted within the Finnish armed forces (4 studies) and within the militaries of China and Germany (1 study each). The sizes of the study populations ranged from 410 to 736,608 participants. Eleven studies identified being overweight as a risk factor for MSkIs; 4 studies did not find a significant association. One study found an association for men but not for women. It is important to acknowledge that these findings are based on BMI alone; none of the 16 studies analyzed the body composition of the included soldiers in detail (i.e., body fat or muscle mass).

Table 3-26: Summary of All Studies that Focused on Being Overweight as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Anderson [78]	2015	USA	Army	Light Infantry Brigade	R	2,101	Yes
Bedno [80]	2013	USA	Army	IET	P	8,456 m	No (m)
Billings [162]	2004	USA	Air Force	Recruits BCT	R	2,006	Yes
Canham-Chervak [62]	2006	USA	Army	Recruits BCT	P	1,156 m, 746 f	Yes
Cowan [82]	2012	USA	Army	Trainees	P	1,568 f	No (f)
Grier [86]	2017	USA	Army	Infantry Brigade	R	4,236 m	Yes (m)
Gundlach [168]	2012	Germany	Army	Active duty	P	410	Yes
Henderson [147]	2000	USA	Army	Combat medic	P	439 m, 287 f	Yes
Hruby [48]	2016	USA	Army		R	736,608	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [47]	2012	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes (m), No (f)
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	No
Ma [150]	2016	China	n/a		R	2,479	Yes
Mattila[37]	2007	Finland	n/a	Conscripts	R	133,943 m, 2,044 f	Yes
Rappole [102]	2017	USA	Army	Army Brigade	R	1,099 m	Yes (m)
Taanila [127]	2010	Finland	n/a	Conscripts	P	944 m	Yes (m)
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, IET = Initial Entry Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **strong** scientific evidence for being overweight (BMI ≥ 25 and < 30 kg/m²) as a **modifiable** risk factor for MSkI.

3.4.4.7 BMI: Underweight (BMI < 18.5 kg/m²)

Fifteen studies focused on being underweight as a risk factor for MSkIs (see Table 3-27). Most of the research was conducted within different branches of the US Armed Forces (10 studies); the remaining studies were conducted within the militaries of Finland (3 studies), China, and Israel (1 study each). The sizes of the study populations ranged from 135 to 736,608 participants. Twelve studies identified being underweight as a risk factor for MSkIs, and 3 studies did not find a significant association.

Table 3-27: Summary of All Studies that Focused on Being Underweight as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
AMSA [43]	2000	USA	Army	Active duty	R	387,536	Yes
Bedno [80]	2013	USA	Army	IET	P	8,456 m	Yes (m)
Billings [162]	2004	USA	Air Force	Recruits BCT	R	2,006	Yes
Cowan [82]	2012	USA	Army	Trainees	P	1,568 f	No (f)
Finestone [169]	2008	Israel	Army	Light Infantry training	P	36 m, 99 f	Yes
Grier [86]	2017	USA	Army	Infantry brigade	R	4,236 m	Yes (m)
Hruby [48]	2016	USA	Army		R	736,608	Yes
Jones [34]	2017	USA	Army	Recruits BCT	R	143,398 m, 41,727 f	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [47]	2012	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	No
Packnett [41]	2011	USA	Army	Recruits BCT	R	217,468 m, 47,813 f	Yes
Reynolds [103]	2009	USA	Army	Infantry	P	181	Yes
Taanila [110]	2015	Finland	Army	Conscripts	P	1,411 m	Yes (m)
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	No (m)
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, IET = Initial Entry Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **strong** scientific evidence for being underweight (BMI < 18.5 kg/m²) as a **modifiable** risk factor for MSkIs.

3.4.4.8 Body Fat (Higher)

Eight studies focused on body fat as a risk factor for MSkIs (see Table 3-28). The research was conducted within the armies of Greece (2 studies), Iran (1 study), Israel (2 studies), and the US (3 studies); the studies included different methods for measuring body fat (e.g., self-report, circumference, dual-energy X-ray absorptiometry, 4-site skinfold test). The sizes of the study populations ranged from 44 to 583,651 participants. Six of the 8 studies identified a higher percentage of body fat as a risk factor for MSkIs, and 2 studies did not find a significant association. A retrospective study by Knapik et al. [46], with more than a half million participants, showed a relationship between a greater percentage of body fat and a higher risk for MSkIs.

Table 3-28: Summary of All Studies that Focused on Body Fat as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Anderson [79]	2017	USA	Army	Light Infantry	R	4,384 m, 363 f	Yes
Havenetidis [164]	2017	Greece	Army	Officer recruits	P	268 m	Yes (m)
Havenetidis [146]	2011	Greece	n/a	Recruits	P	253	Yes
Knapik [46]	2018	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Kodesh [165]	2015	Israel	n/a	Combat Fitness Instructor Course	P	158 f	Yes (f)
Krauss [170]	2017	USA	Army	Recruits BCT	R	1,900 f	Yes (f)
Moran [152]	2013	Israel	Army	Recruits	P	44	No
Sobhani [157]	2015	Iran	n/a	Recruits	R	181 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **strong** scientific evidence for higher body fat as a **modifiable** risk factor for MSkIs.

3.4.4.9 Body Height (Higher)

Forty-six studies focused on body height as a risk factor for MSkIs (see Table 3-29). Most of the research was conducted within different branches of the US Armed Forces (18 studies); 8 within the military of the UK, 7 within the military of Finland, and 6 studies within the IDF; the other studies were conducted within the military of China (3 studies), Belgium, Iran, Poland, and Sweden (1 study each). The sizes of the study populations ranged from 44 to 583,651 participants. Eight of the 46 studies identified a taller stature as a risk factor for MSkIs, and 35 studies did not find a significant association. One study found a significant increase in MSkIs associated with a taller stature for men but not for women, and one study found that a shorter stature was a significant risk factor for MSkIs.

Table 3-29: Summary of All Studies that Focused on Body Height as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Beck [143]	2000	USA	Marines		P	624 m, 693 f	Yes (m), No (f)
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	No
Cosa-Lima [64]	2013	USA	Army	Sergeants Major Academy	R	149	No
Davey [84]	2015	UK	Marines		P	1,090 m	No (m)
Fallowfield [85]	2018	UK	Air Force	Recruits	P	990 m, 203 f	Yes
Finestone [117]	2011	Israel	Army	Elite infantry soldier	P	77 m	No (m)
Givon [70]	2000	Israel	n/a		P	2,306 m	No (m)
Kelly [88]	2000	USA	Navy	Recruits BCT	R	86 f	Yes (f)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [47]	2012	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes
Knapik [148]	2006	USA	Army	Recruits BCT	P	1,174 m, 898 f	No
Knapik [149]	2007	USA	Army	Mechanics	R	518 m, 43 f	No
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	No
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	No
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	No
Kodesh [165]	2015	Israel	n/a	Combat Fitness Instructor Course	P	158 f	No
Korvala [57]	2010	Finland	n/a	Conscripts	P	192	Yes
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	No
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	No (fF)
Ma [150]	2016	China	n/a		R	2,479	No
Mahieu [151]	2006	Belgium	n/a	Recruits Royal Military Academy	P	69 m	No (m)
Mattila [38]	2007	Finland	Army	Conscripts	P	149,750 m, 2,345 f	No
Monnier [123]	2019	Sweden	Marines	Training course	P	48 m, 5 f	Yes
Moran [152]	2013	Israel	Army	Recruits	P	44	No
Moran [72]	2012	Israel	Army	Elite combat unit BCT	P	74	No
Moran [129]	2008	Israel	Army	Recruits	P	227 f	Yes (f)
Munnoch [98]	2007	UK	Marines		P	1,115 m	No (m)
Nunns [153]	2016	UK	Marines	Recruits	P	160 m	No (m)
Parr [155]	2015	USA	Army	Special Operations Forces	P	106	No
Reynolds [103]	2009	USA	Army	Infantry	P	181	No

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Reynolds [104]	2002	USA	Army	Construction engineers and Combat artillery soldiers	P	313	Yes (to be shorter)
Reynolds[55]	2000	USA	Marines	Winter mountain training	P	356	No
Ruohola [106]	2006	Finland	n/a	Recruits	P	756 m	No (m)
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	No (f)
Sharma [108]	2019	UK	Army	Infantry recruits	P	562 m	No (m)
Sharma [109]	2011	UK	Army	Infantry recruits	P	468 m	No (m)
Sillanpää [51]	2008	Finland	n/a	Conscripts	R	128,508 m	Yes (m)
Sobhani [157]	2015	Iran	n/a	Recruits	R	181 m	No (m)
Sormaala [39]	2006	Finland	n/a	Recruits	R	118,149	No
Sulsky [42]	2018	USA	Army	Recruits BCT	R	278,045 m, 55,302 f	Yes
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	No (m)
Trybulec [158]	2016	Poland	Army	Airborne Brigade	R	162 m, 3 f	No
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	No (m)
Waterman [167]	2010	USA	Military Academy		R	10,511 person years	Yes
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **insufficient** scientific evidence for body height as a non-**modifiable** risk factor for MSkIs.

3.4.4.10 Body Weight (Higher)

Forty-five studies focused on body weight as a risk factor for MSkIs (see Table 3-30). Most of the research was conducted within different branches of the US Armed Forces (16 studies); 11 studies within the military of the UK, and 6 within the IDF. The remaining studies were conducted within the militaries of Finland (4 studies), China (2 studies), Australia, Belgium, Greece, Iran, Poland, and Sweden (1 study each). The sizes of the study populations ranged from 44 to 583,651 participants. Thirteen of the 45 studies identified a higher body weight as a risk factor for MSkIs, 27 did not find a significant association between body weight and MSkIs, and 3 studies found a significant increase in MSkIs for a lower body weight. Two studies found different outcomes regarding the participants' sex.

Table 3-30: Summary of All Studies that Focused on Body Weight as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Beck [143]	2000	USA	Marines		P	624 m, 693 f	Yes (m), No (f)
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	No
Davey [84]	2015	UK	Marines		P	1,090 m	No (m)
Davey [52]	2016	UK	Marines		P	1,082 m	No (m)
Finestone [117]	2011	Israel	Army	Elite infantry soldier	P	77 m	No (m)
Givon [70]	2000	Israel	n/a		P	2,306 m	Yes (m)
Havenetidis [164]	2017	Greece	Army	Officer recruits	P	268 m	Yes (m)
Hughes [171]	2008	Australia	Special Operation Forces	Active duty	R	554 descents	Yes
Kelly [88]	2000	USA	Navy	Recruits BCT	R	86 f	Yes (f)
Knapik [47]	2012	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes (invers)
Knapik [148]	2006	USA	Army	Recruits BCT	P	1,174 m, 898 f	No
Knapik [149]	2007	USA	Army	Mechanics	R	518 m, 43 f	Yes
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	Yes
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	No
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	No (m), Yes (f)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Kodesh [165]	2015	Israel	n/a	Combat Fitness Instructor Course	P	158 f	No (f)
Korvala [57]	2010	Finland	n/a	Conscripts	P	192	Yes
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	Yes (f)
Ma [150]	2016	China	n/a		R	2,479	No
Mahieu [151]	2006	Belgium	n/a	Recruits Royal Military Academy	P	69 m	No (m)
Moran [152]	2013	Israel	Army	Recruits	P	44	No
Moran [72]	2012	Israel	Army	Elite combat unit BCT	P	74	No
Monnier [123]	2019	Sweden	Marines	Training course	P	48 m, 5 f	No
Munnoch [98]	2007	UK	Marines		P	1,115 m	No (m)
Nunns [153]	2016	UK	Marines	Recruits	P	160 m	No (m)
Parr [155]	2015	USA	Army	Special Operations Forces	P	106	No
Reynolds [103]	2009	USA	Army	Infantry	P	181	No
Reynolds [104]	2002	USA	Army	Construction engineers and Combat artillery soldiers	P	313	Yes
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	No
Rice [124]	2017	UK	Marines	Recruits	P	147 m	Yes (m) (invers)
Robinson [67]	2016	UK	Army	Recruits	P	1,810	Yes
Ruohola [106]	2006	Finland	n/a	Recruits	P	756 m	No (m)
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	Yes (m) (invers)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Schermann [132]	2018	Israel	Army	Infantry unit vs. female unit working with dogs	R	7,949	Yes
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	No (f)
Sharma [108]	2019	UK	Army	Infantry recruits	P	562 m	No (m)
Sharma [109]	2011	UK	Army	Infantry recruits	P	468 m	No (m)
Sillanpää [51]	2008	Finland	n/a	Conscripts	R	128,508 m	Yes (m)
Sobhani [157]	2015	Iran	n/a	Recruits	R	181 m	No (m)
Sormaala [39]	2006	Finland	n/a	Recruits	R	118,149	No
Trybulec [158]	2016	Poland	Army	Airborne Brigade	R	162 m, 3 f	No
Waterman [167]	2010	USA	Military Academy		R	10,511 person years	Yes
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **insufficient** scientific evidence for higher body weight as a **modifiable** risk factor.

3.4.4.11 Bone (Mineral) Density (Low)

Three studies focused on low bone (mineral) density as a risk factor for MSkIs (see Table 3-31). All 3 studies were conducted in the US Army. The sizes of the study populations ranged from 230 to 891 participants. Two studies identified low bone (mineral) density as a risk factor for MSkIs; one study did not find a significant association.

Table 3-31: Summary of All Studies that Focused on Bone (Mineral) Density as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Cosman [73]	2013	USA	Army	Military Academy	P	755 m, 136 f	Yes
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	No
Lauder [97]	2000	USA	Army	Active duty	P	230 f	Yes (f)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? P = prospective study, m = male, f = female, (f) = RF only for females

There is **insufficient** scientific evidence for low bone (mineral) density as a **non-modifiable** risk factor.

3.4.4.12 External Rotation of the Hip (Higher)

Five studies focused on external rotation (range of motion) of the hip as a risk factor for MSkIs (see Table 3-32). The research was conducted within the militaries of Australia (2 studies), Iran, Israel, and the US (each 1 study). The range of motion of the hip was measured in different ways across the identified studies. The sizes of the study populations ranged from 77 to 748 participants. Three studies (including the two with the most participants) identified that higher external rotation of the hip is a risk factor for MSkIs; two studies did not find a significant association.

Table 3-32: Summary of All Studies that Focused on External Rotation of the Hip as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Burne [172]	2004	Australia	Military Academy		P	122 m, 25 f	No
Finestone [117]	2011	Israel	Army	Elite infantry soldier	P	77 m	No (m)
Garnock [118]	2018	Australia	Navy	Recruits	P	95 m, 39 f	Yes
Rauh [173]	2010	USA	Marines	Recruits BCT	P	748 f	Yes (f)
Sobhani [157]	2015	Iran	n/a	Recruits	R	181 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **insufficient** scientific evidence for higher external rotation of the hip as a **non-modifiable** risk factor.

3.4.4.13 Flexibility (Lower)

Five studies focused on flexibility at different anatomical locations as a risk factor for MSkIs (see Table 3-33). Most of the research was conducted within different branches of the US Armed Forces (4 studies), and 1 study was conducted by armed forces from China. The sizes of the study populations ranged from 95 to 805 participants. Only 1 study identified low flexibility as a risk factor for MSkIs, and 5 studies did not find a significant association.

Table 3-33: Summary of All Studies that Focused on Flexibility as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Heebner [159]	2017	USA	Army	Special Operations Forces	P	95	No
Keenan [174]	2017	USA	multiple	Special Forces	P	726	Yes[1,2]
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	No[1]
Nagai [98]	2017	USA	Army	Airborne Division	P	275	No[3]
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, [1]Hamstring-flexibility; [2]Gastrocnemius-soleus flexibility; [3]Several muscle groups (shoulder, trunk rotation, hip extension, active knee extension, ankle dorsiflexion, ankle plantarflexion)

There is **insufficient** scientific evidence for lower flexibility as a **modifiable** risk factor.

3.4.4.14 Foot Type

Eight studies focused on foot type (e.g., anatomic differences such as a pes planus, a wide malleolar or a forefoot varus) as a risk factor for MSkIs (see Table 3-34). The studies were conducted within the militaries of the UK (3 studies), USA (2 studies), Australia, Israel, and Malta (1 study from each country). The sizes of the study populations ranged from 124 to 504 participants. Five studies identified different foot types as a risk factor for MSkI, while 3 studies did not.

Table 3-34: Summary of All Studies that Focused on Foot Type as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Esterman [175]	2005	Australia	Air Force	Recruits	P	230	No
Hetsroni [176]	2006	Israel	Army	Recruits	P	405 m	No[1]

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Levy [177]	2006	USA	n/a	Military Academy Cadets	R	431 m, 73 f	Yes[2]
Nunns [153]	2016	UK	Marines	Recruits	P	160 m	Yes (m)[3,4]
Psaila [101]	2017	Malta	n/a	Recruits BCT	P	114 m, 13 f	No
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	Yes[5]
Rice [124]	2017	UK	Marines	Recruits	P	147 m	Yes (m)[3]
Yates [178]	2004	UK	Navy	Recruits	P	84 m, 40 f	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, [1]For any type for foot pronation; [2]Pes planus; [3]Width malleolar; [4]Arch index, corrected calf girth; [5]Forefoot varus

There is **moderate** scientific evidence for different foot types as a **non-modifiable** risk factor.

3.4.4.15 Genetic Factors

Two studies focused on genetic factors as risk factors for MSkIs (see Table 3-35). One study was conducted within the military of China and 1 within the military of Finland. The study populations ranged from 192 to 1398 participants. Both studies identified an association between certain genetic factors and an increased risk for MSkIs. The analyzed genetic factors were different between the 2 studies, so a comparison was not possible. Korvala et al. [57] examined genes involved in bone metabolism and pathology, and Zhao et al. [58] looked at a specific growth differentiation factor 5 (GDF5) polymorphism between recruits with and without stress fractures.

Table 3-35: Summary of All Studies that Focused on Genetic Factors as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Korvala [57]	2010	Finland	n/a	Conscripts	P	192	Yes
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? n/a = not available, P = prospective study, m = male, (m) = RF only for males

There is **weak** scientific evidence for genetic factors as a **non-modifiable** risk factor.

3.4.4.16 Late Menarche

Seven studies focused on late menarche as a risk factor for MSkIs (see Table 3-36). All of the research was conducted within different branches of the US Armed Forces. The sizes of the study populations ranged from 136 to 3758 participants. Two studies identified late menarche as a risk factor for MSkIs, and 5 studies did not find a significant association.

Table 3-36: Summary of All Studies that Focused on Late Menarche as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Cosman [73]	2013	USA	Army	Military Academy	P	136 f	Yes
Knapik [89]	2010	USA	Air Force	Recruits BCT	P	375 f	No
Knapik [95]	2008	USA	Army	Recruits BCT	P	920 f	No
Knapik [96]	2009	USA	Marines	Recruits BCT	P	571 f	No
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	No
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	No
Trone [111]	2014	USA	Marine Corp Air Force Army	Recruits BCT	R	597 f	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, f = female

There is **no** scientific evidence for late menarche as a **non-modifiable** risk factor for MSkIs.

3.4.4.17 Muscular Strength (Lower)

Eleven studies focused on muscular strength as a risk factor for MSkIs (see Table 3-37), although it was measured in different ways depending on the study. Most of the research was conducted within the US Army (5 studies) or the military of Finland (4 studies). Additional studies were conducted within the militaries of Switzerland and the UK (1 study from each country). The sizes of the study populations ranged from 95 to 152,095 participants. Six studies identified low muscular strength as a risk factor for MSkIs, while 5 studies did not find a significant association. Notably, two studies with more than 100,000 participants found an inverse association between muscular strength and the risk for MSkIs, the other study found no association, but this study focused on traumatic patellar luxation.

Table 3-37: Summary of All Studies that Focused on Muscular Strength as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	No
Heebner [159]	2017	USA	Army	Special Operation Forces	P	95	Yes
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	Yes
Mattila [38]	2007	Finland	Army	Conscripts	P	149,750 m, 2,345 f	Yes
Nagai [99]	2017	USA	Army	Airborne Division	P	275	No
Parr [155]	2015	USA	Army	Special Operations Forces	P	106	No[2]
Roy [179]	2012	USA	Army	Brigade Combat Team[1]	R	593	Yes
Ruohola [106]	2006	Finland	n/a	Recruits	P	756 m	Yes (m)
Sillanpää [51]	2008	Finland	n/a	Conscripts	R	128,508 m	No (m)
Wunderlin [113]	2015	Switzerland	Army	Recruits	P	230 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, [1]Deployment, [2]Shoulder

There is **moderate** scientific evidence for lower muscular strength as a **modifiable** risk factor.

3.4.4.18 Physical Fitness (Low)

Seventy-four studies focused on physical fitness, based on results from physical fitness tests, as a risk factor for MSkIs (see Table 3-38). Most of the research was conducted in different branches of the US Armed Forces (45 studies); 12 studies were conducted within the military of the UK, and 9 were conducted within the military of Finland. The remaining studies were conducted within the militaries of Israel and Switzerland (2 studies each) as well as China, Denmark, Germany, and Malta (1 study each). The size of the study population ranged from 44 to 238,772 participants. Fifty studies identified low physical fitness as a risk factor for MSkIs. Out of these 50 studies, 4 studies explored low physical endurance. Two studies found an association between low physical fitness and an increased risk for MSkI, but not for both sexes, and 20 studies did not find a significant association. In two studies, there was an inverse effect; high physical fitness was associated with an increased risk for MSkIs. A meta-analysis that included 27 publications found that the relative risk is 2.34 (95% CI, 2.02 – 2.70) for injuries incurred during training, as well as for personnel who perform in the bottom quartile or quintile when compared to their peers in the top quartile or quintile of physical fitness [25].

Table 3-38: Summary of All Studies that Focused on Physical Fitness as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Allsopp [161]	2003	UK	Navy	Recruits	R	1,287 m, 354 f	Yes
Anderson [78]	2015	USA	Army	Light Infantry Brigade	R	2,101	Yes
Anderson [79]	2017	USA	Army	Light Infantry	R	4,384 m, 363 f	Yes
Beck [143]	2000	USA	Marines		P	624 m, 693 f	Yes
Bedno [80]	2013	USA	Army	IET	P	8,456 m	Yes (m)
Bedno [35]	2019	USA	Army	Recruits BCT	R	238,772	No (m), Yes (f)
Bell [27]	2000	USA	Army	Recruits	P	861	Yes
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	Yes
Brooks [81]	2019	USA	Army	Recruits BCT	R	1,460 m, 540 f	Yes
Canham-Chervak [144]	2000	USA	Army	Recruits BCT	P	655 m, 498 f	Yes
Canham-Chervak [62]	2006	USA	Army	Recruits BCT	P	1,156 m, 746 f	Yes
Cosa-Lima [64]	2013	USA	Army	Sergeants Major Academy	R	149	No
Cosman [73]	2013	USA	Army	Military Academy	P	755 m, 136 f	No
Cowan [82]	2012	USA	Army	Trainees	P	1,568 f	Yes (f)
Davey [84]	2015	UK	Marines		P	1,090 m	No (m)
Davey [52]	2016	UK	Marines		P	1,082 m	No (m)
Fallowfield [85]	2018	UK	Air Force	Recruits	P	990 m, 203 f	Yes
George [119]	2012	USA	Army	Combat medics	P	1,230	No

Study	Publ. Year	Country	Branches	Unit/ Training	Stud y Type	n	RF?
Grier [86]	2017	USA	Army	Infantry brigades	R	4,236 m	Yes (m)
Grier [180]	2011	USA	Army	Ordinance school students	P	4,255	Yes (m), No (f)
Hall [181]	2017	UK	Army	Recruits	R	3,050 m	Yes (m)
Hauret [182]	2018	USA	Army	Recruits BCT	P	1,181	Yes (endurance)
Heller [183]	2020	USA	Army	Recruits BCT	R	227 f	Yes (f)
Jones [34]	2017	USA	Army	Recruits BCT	R	143,398 m, 41,727 f	Yes
Keenan [174]	2017	USA	multiple	Special Forces	P	726	Yes
Kelly [88]	2000	USA	Navy	Recruits BCT	R	86 f	No (f)
Knapik [89]	2010	USA	Air Force	Recruits BCT	P	1,042 m, 375 f	Yes
Knapik [148]	2006	USA	Army	Recruits BCT	P	1,174 m, 898 f	Yes
Knapik [91]	2013	USA	Army	Brigade combat team[1]	P	805	No
Knapik [184]	2003	USA	Army		R	1,414 m, 1,166 f	Yes
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	Yes
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	Yes
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	Yes
Knapik [185]	2009	USA	Army	Recruits BCT	P	2,689 m, 1,263 f	Yes
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	Yes
Kodesh [165]	2015	Israel	n/a	Combat Fitness Instructor Course	P	158 f	Yes (f) (running)

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Krauss [170]	2017	USA	Army	Recruits BCT	R	1,900 f	Yes
Kuikka [36]	2013	Finland	Army	Conscripts	R	128,584	No
Kupferer [166]	2014	USA	Air Force	Trainees	R	141	Yes
Lisman [122]	2013	USA	Marines	Officer candidate training	P	874	Yes (running)
Martin [186]	2018	USA	Army	Light infantry division	R	6,865	Yes
Mattila [37]	2007	Finland	n/a	Conscripts	R	133,943 m, 2,044 f	Yes (invers)
Mattila [38]	2007	Finland	Army	Conscripts	P	149,750 m, 2,345 f	Yes
Moran [152]	2013	Israel	Army	Recruits	P	44	No
Müller-Schilling [187]	2019	Germany	Army	Recruits	P	774	Yes
Munnoch [98]	2007	UK	Marines		P	1,115 m	No (m)
Nye [59]	2016	USA	Air Force	Recruits BCT	R	67,525	Yes
Psaila [101]	2017	Malta	n/a	Recruits BCT	P	114 m, 13 f	Yes
Rauh [188]	2006	USA	Marines		P	824 f	Yes (f)
Reynolds [103]	2009	USA	Army	Infantry	P	181	Yes
Reynolds [104]	2002	USA	Army	Construction engineers and Combat artillery soldiers	P	313	No
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	No
Robinson [67]	2016	UK	Army	Recruits	P	1,810	Yes (running)
Rosendal [189]	2003	Denmark	n/a	Conscripts BCT	P	330	Yes
Ruohola [106]	2006	Finland	n/a	Recruits	P	756 m	Yes (m)
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	No (m)

Study	Publ. Year	Country	Branches	Unit/ Training	Study Type	n	RF?
Schneider [68]	2000	USA	Army	Airborne Division	R	1,214	Yes
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	No
Sefton [140]	2016	USA	Army	Recruits IET	P	1,788 m	Yes (m)
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	Yes (f)
Sharma [108]	2019	UK	Army	Infantry recruits	P	562 m	Yes (m)
Sharma [109]	2011	UK	Army	Infantry recruits	P	468 m	Yes (m)
Sillanpää [51]	2008	Finland	n/a	Conscripts	R	128,508 m	No (m)
Sormaala [39]	2006	Finland	n/a	Recruits	R	118,149	No
Taanila [127]	2010	Finland	n/a	Conscripts	P	944 m	Yes (m)
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	Yes (m)
Trone [111]	2014	USA	Marine Corp Air Force Army	Recruits BCT	R	900 m, 597 f	Yes
Välimäki [190]	2005	Finland	Army	Conscripts	P	179	Yes
Waterman [167]	2010	USA	Military Academy		R	10,511 person years	Yes (invers)
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No
Wyss [76]	2014	Switzerland	Army	Recruits BCT	P	1,676	No
Wyss [191]	2012	Switzerland	Army		R	459	Yes
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females, [1]Deployment

There is **strong** scientific evidence for low physical fitness as a **modifiable** risk factor for MSkIs. Low physical fitness has an increased relative risk of 2.34 for MSkIs.

3.4.4.19 Secondary Amenorrhea

Eight studies focused on having no menses in the last months (secondary amenorrhea) as a risk factor for MSkIs (see Table 3-39). All of the research was conducted within different branches of the US Armed Forces. The sizes of the study populations ranged from 86 to 2962 participants. Three studies identified secondary amenorrhea as a risk factor for MSkIs, and 5 studies did not find a significant association.

Table 3-39: Summary of All Studies that Focused on Secondary Amenorrhea as a Risk Factor for MskI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Canham-Chervak [62]	2006	USA	Army	Recruits	P	746 f	No
Kelly [88]	2000	USA	Navy	Recruits BCT	R	86 f	No
Knapik [89]	2010	USA	Air Force	Recruits BCT	P	375 f	No
Knapik [90]	2013	USA	Army	Army military police training	P	553 f	Yes
Knapik [95]	2008	USA	Army	Recruits BCT	P	920 f	No
Knapik [96]	2009	USA	Marines	Recruits BCT	P	571 f	No
Rauh [188]	2006	USA	Marines		P	824 f	Yes
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, f = female

There is **insufficient** scientific evidence for secondary amenorrhea as a **modifiable** risk factor.

3.4.4.20 Sex (Female)

Thirty-eight studies focused on sex as a risk factor for MSkIs (Table 3-40). Most of the research was conducted within different branches of the US Armed Forces (24 studies). Additional studies were conducted within the militaries of Israel and the UK (4 studies each), Finland (3 studies), Australia (2 studies), and Greece (1 study). The sizes of the study populations ranged from 124 to 5,580,875 participants. Twenty-nine studies identified being female as a risk factor for MSkIs (when compared to males), 8 studies did not find a significant association between sex and MSkIs, and 1 study found a significant increase in MSkIs for males when compared to females.

Table 3-40: Summary of All Studies that Focused on Sex as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Allsopp [161]	2003	UK	Navy	Recruits	R	1,287 m, 354 f	Yes
Anderson [79]	2017	USA	Army	Light Infantry	R	4,384 m, 363 f	No
Bell [27]	2000	USA	Army	Recruits	P	861	No
Billings [162]	2004	USA	Air Force	Recruits BCT	R	2,006	Yes
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	Yes
Bulathsinhala [49]	2017	USA	Army	Active duty	R	1,299,332	Yes
Burne [172]	2004	Australia	Military Academy		P	122 m, 25 f	Yes
Canham-Chervak [144]	2000	USA	Army	Recruits BCT	P	655 m, 498 f	Yes
Craig [40]	2000	USA	Army	Airborne Division	R	242,949 aircraft exits	Yes
Darakjy [8]	2006	USA	Army	Active duty	P	4,101 m, 413 f	Yes
Fallowfield [85]	2018	UK	Air Force	Recruits	P	990 m, 203 f	Yes
Finestone [169]	2008	Israel	Army	Light infantry training	P	36 m, 99 f	No
Finestone [192]	2014	Israel	Army	Cadets	P	78 m, 227 f	Yes
Gam [193]	2005	Israel	n/a	Recruits	P	375 m, 138 f	Yes
Garnock [118]	2018	Australia	Navy	Recruits	P	95 m, 39 f	Yes
Gemmell [193]	2002	UK	Army	Recruits	R	11,907 m, 1,483 f	Yes
George [119]	2012	USA	Army	Combat medics	P	1,230	Yes
Havenetidis [146]	2011	Greece	n/a	Recruits	P	253	Yes
Hill [54]	2013	USA	Army	Active duty	R	83,323	No
Itskoviz [32]	2011	Israel	Army	Recruits	R	n/a	Yes
Knapik [89]	2010	USA	Air Force	Recruits BCT	P	1,042 m, 375 f	No
Knapik [90]	2013	USA	Army	Army military police training	P	1,838 m, 553 f	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [91]	2013	USA	Army	Brigade Combat Team[1]	P	805	Yes (to be male)
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	Yes
Knapik [46]	2018	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes
Kupferer [166]	2014	USA	Air Force	Trainees	R	141	Yes
Mattila [37]	2007	Finland	n/a	Conscripts	R	133,943 m, 2,044 f	Yes
Mattila [38]	2007	Finland	Army	Conscripts	P	149,750 m, 2,345 f	Yes
Montain [45]	2013	USA	Army	Recruits BCT	R	421,461 m, 90,141 f	Yes
Nye [59]	2016	USA	Air Force	Recruits BCT	R	67,525	Yes
Owens [131]	2009	USA	Army, Marines, Navy, Air Force	Active duty	R	19,730	Yes
Roy [136]	2012	USA	Army	Brigade Combat Team[1]	P	246 m, 17 f	Yes
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	No
Snedecor [195]	2000	USA	Air Force	Recruits	R	8,656 m, 5,250 f	Yes
Sormaala [39]	2006	Finland	n/a	Recruits	R	118,149	No
Waterman [167]	2010	USA	Military Academy		R	10,511 person years	Yes
Waterman [31]	2016	USA	multiple	Active Duty	R	5,580,875	Yes
Yates [178]	2004	UK	Navy	Recruits	P	84 m, 40 f	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, [1]Deployment

There is **strong** scientific evidence that being female is a **non-modifiable** risk factor for MSkIs.

3.4.4.21 Plantar Pressure Assessment (of Walking Gait)

Five studies focused on plantar pressure assessment (of walking gait) as a risk factor for MSkIs (see Table 3-41). Most of the research was conducted within different branches of the UK military (3 studies). Additional studies were conducted within the militaries of Belgium and Israel (1 study from each country). The study populations ranged from 69 to 468 participants. All studies included males only. Two studies identified a particular foot pressure pattern while walking as a risk factor for MSkIs, and two studies did not find a significant association. In one study, this association was only found for a pressure pattern involving the little toe (digitus V).

Table 3-41: Summary of All Studies that Focused on Plantar Pressure Assessment (of Walking Gait) as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Finestone [117]	2011	Israel	Army	Elite infantry soldier	P	77 m	No (m)
Mahieu [151]	2006	Belgium	n/a	Recruits Royal Military Academy	P	69 m	Yes (m)
Nunns [153]	2016	UK	Marines	Recruits	P	160 m	No (m)
Rice [124]	2017	UK	Marines	Recruits	P	147 m	Yes[1] (m)
Sharma [109]	2011	UK	Army	Infantry recruits	P	468 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? n/a = not available, P = prospective study, m = male, (m) = RF only for males, 1Pressure on digital V

There is **insufficient** scientific evidence for specific plantar pressure patterns during walking as a **modifiable** risk factor.

3.4.4.22 Range of Tibial Rotation During Running (Lower)

Only one study focused on the range of tibial rotation (calculated as the difference between peak internal and external rotation) during running as a risk factor for MSkIs (see Table 3-42). This study was conducted within the UK Marines. In this prospective study with 160 male participants, a lower range of tibial rotation during running (the difference between peak internal and external lower leg segment rotation) was identified as a risk factor for MSkIs.

Table 3-42: Summary of All Studies that Focused on Range of Tibial Rotation During Running as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Nunns [153]	2016	UK	Marines	Recruits	P	160 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? P = prospective study, m = male, (m) = RF only for males

There is **weak** scientific evidence for a lower range of tibial rotation during running as a **modifiable** risk factor.

3.4.4.23 Tibia Length (Shorter)

Four studies focused on tibia length as a risk factor for MSkIs (see Table 3-43). The research was conducted within the IDF (2 studies) and within the US Marines (1 study) and within the army of China (1 study). The sizes of the study populations ranged from 44 to 1398 participants. Two studies identified a shorter tibia length as a risk factor for MSkIs, and the two studies did not find a significant association. Hence, one of these studies reported leg length, not tibia length.

Table 3-43: Summary of All Studies that Focused on Tibia Length as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Beck [143]	2000	USA	Marines		P	624 m, 693 f	Yes
Finestone [117]	2011	Israel	Army	Elite infantry soldier	P	77 m	Yes (m)
Goss [196]	2006	USA	Military Academy	Cadets	R	1,100	No[1]
Moran [152]	2013	Israel	Army	Recruits	P	44	No
Zhao [58]	2016	China	Army	Recruits	P	1,398 m	No (m)[2]

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, [1]Limb length inequality; [2]Leg length

There is **insufficient** scientific evidence for shorter tibia length as a **modifiable** risk factor.

3.4.4.24 Waist Circumference (Higher)

Five studies focused on high circumference as a risk factor for MSkIs (see Table 3-44). Three studies were conducted within the military of Finland, and two were carried out within the US Air Force. The size of the study populations ranged from 141 to 67,525 participants. Two studies from Finland identified high circumference as a risk factor for MSkIs, while the other 3 studies did not find a significant association. Especially, the retrospective study by Nye et al. [59], with 67,525 participants, found no association between high waist circumference and an increased risk for MSkIs.

Table 3-44: Summary of All Studies that Focused on Waist Circumference as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Kupferer [166]	2014	USA	Air Force	Trainees	R	141	No
Nye [59]	2016	USA	Air Force	Recruits BCT	R	67,525	No
Taanila [127]	2010	Finland	n/a	Conscripts	P	944 m	Yes (m)

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	No (m)
Taanila [110]	2015	Finland	Army	Conscripts	P	1,411 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, (m) = RF only for males

There is **insufficient** scientific evidence for a high waist circumference as a **modifiable** risk factor.

3.4.5 Social Factors

3.4.5.1 Education (Lower)

Thirteen studies focused on education as a risk factor for MSkIs (see Table 3-45). Nearly half of the research was conducted within different branches of the US Armed Forces (6 studies); the others were conducted within the militaries of Finland (4 studies), the UK (2 studies), and Israel (1 study). The sizes of the study populations ranged from 205 to 4029 participants. Five of the 13 studies identified a lower level of education as a risk factor for MSkIs, and 8 studies did not find a significant association between lower education and MSkIs. The definitions of lower education are different among the studies examined.

Table 3-45: Summary of All Studies that Focused on Education as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	Yes
Fallowfield [85]	2018	UK	Air Force	Recruits	P	990 m, 203 f	Yes
George [119]	2012	USA	Army	Combat medics	P	1230	No
Givon [70]	2000	Israel	n/a		P	2,306 m	No (m)
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	No
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	No
Munnoch [98]	2007	UK	Marines		P	1,115 m	No (m)
Pihlajamäki [99]	2019	Finland	n/a	Full duty	R	4,029 m	No (m)
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Taanila [127]	2010	Finland	n/a	Conscripts	P	944 m	Yes (m)
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	Yes (m)
Taanila [110]	2015	Finland	Army	Conscripts	P	1,411 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males

There is **weak** scientific evidence for a lower level of education as a **non-modifiable** risk factor for MSkIs.

3.4.5.2 Marital Status

Six studies focused on marital status as a risk factor for MSkIs (see Table 3-46). All of the research was conducted within different branches of the US Armed Forces (mostly in the army). The sizes of the study populations ranged from 205 to 83,323 participants. Only one study (with the largest number of participants examined) identified being married as a risk factor for MSkI. Another study identified being divorced or widowed as a risk factor for MSkIs. The remaining 4 studies did not find a significant association between marital status and MSkIs.

Table 3-46: Summary of All Studies that Focused on Marital Status as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	No
Hill [54]	2013	USA	Army	Active duty	R	83,323	Yes
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	No
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	Yes[1]
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	No
Schneider [68]	2000	USA	Army	Airborne Division	R	1,214	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, [1]Divorced or widowed

There is **insufficient** scientific evidence for marital status as a **non-modifiable** risk factor.

3.4.5.3 Race/Ethnicity

Twenty-seven studies focused on race/ethnicity as a risk factor for MSkIs (see Table 3-47). Most of the research was conducted within different branches of the US Armed Forces (24 studies); 2 studies were conducted within the militaries of the UK, and 1 was conducted in Israel. The sizes of the study populations ranged from 86 to 5,580,875 participants. Seventeen studies identified race/ethnicity as a risk factor for MSkIs, while 10 studies did not find a significant association. When only studies with more than 10,000 participants were taken into account (9 studies, total: 8,640,581 participants), all studies found an association between race/ethnicity and the risk for MSkIs, but the findings were contradictory in that there was no clear association as to which race/ethnicity was at the highest risk.

Table 3-47: Summary of All Studies that Focused on Race/Ethnicity as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Bedno [80]	2013	USA	Army	IET	P	8,456 m	No (m)[1]
Billings [162]	2004	USA	Air Force	Recruits BCT	R	2,006	Yes[2]
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	Yes[3]
Bulathsinhala [49]	2017	USA	Army	Active duty	R	1,299,332	Yes[4]
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	No[5]
Cowan [82]	2012	USA	Army	Trainees	P	1,568 f	No (f)[1]
Cowan [83]	2011	USA	Army	Recruits	P	7,323	No[1]
Givon [70]	2000	Israel	n/a		P	2,306 m	No (m)[6]
Grier [87]	2010	USA	multiple		R	24,177 m	Yes[7]
Hughes [50]	2019	USA	Army	Active duty	R	120,730	Yes[8]
Kelly [88]	2000	USA	Navy	Recruits BCT	R	86 f	Yes[9]
Knapik [47]	2012	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes[10]
Knapik [149]	2007	USA	Army	Mechanics	R	518 m, 43 f	No[11]
Knapik [46]	2018	USA	Army	Recruits BCT	R	475,745 m, 107,906 f	Yes[10]
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	No[12]
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	No[13]
Lappe [65]	2005	USA	Army	Recruits BCT	R	4,139 f	Yes[14]
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	Yes[15]

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Lauder [97]	2000	USA	Army	Active duty	P	230 f	No (f)[16]
Montain [45]	2013	USA	Army	Recruits BCT	R	421,461 m, 90,141 f	Yes[17]
Owens [154]	2007	USA	n/a	Active duty	R	4,451	Yes[18]
Owens [131]	2009	USA	Army, Marines, Navy, Air Force	Active duty	R	19,730	Yes[19]
Reynolds [103]	2009	USA	Army	Infantry	P	181	Yes[20]
Reynolds [104]	2002	USA	Army	Construction engineers and Combat artillery soldiers	P	313	Yes[21]
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	Yes[22]
Waterman [31]	2016	USA	multiple	Active Duty	R	5,580,875	Yes[19]
Wilkinson[56]	2009	UK	Army	Infantry	P	660	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, IET = Initial Entry Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females, [1]White vs. Black vs. other; [2]Other > African American > Hispanic > Caucasian; [3]Caucasian > others; [4]Non-Hispanic white > Hispanic > American Indian/Native Alaskan > Asian > Native Hawaiian/Pacific Islander > Non-Hispanic Black > others; [5]White vs. Black vs. Hispanic; [6]Ashkenazi versus non-Ashkenazi; [7]Black > (Native, Causasian, Asian, Hispanic, other); [8]White > Black (and Asian, American Indian, other); [9]Hispanic and Asian and other > white and African American; [10]White, Hispanic, Asian, American Indian, other > Black; [11]Caucasian vs. African American vs. other; [12]White, Hispanic, Asian, American Indian, Black and others; [13]White, Hispanic, Black, Other; [14]Hispanic and White > Black, American Indians, Asian; [15]All others races and White > Black; [16]Hispanic and Asian > African American or Caucasian; [17]White, Hispanic, Asian, American Indian, others > Black; [18]Black vs. White and others; [19]White > others > Black; [20]Caucasian > African American, Hispanic, others; [21]Caucasian was identified as a risk factor; [22]White was identified as a risk factor; [23]White vs. others

There is strong scientific evidence for race/ethnicity as a **non-modifiable** risk factor for MSkIs.

3.4.5.4 Rank (Lower)

Eleven studies focused on rank as a risk factor for MSkIs (see Table 3-48). All except one of the studies were conducted within different branches of the US Armed Forces, and the exception was conducted within the British Army. The sizes of the study populations ranged from 230 to 242,949 participants or aircraft exits. Six studies identified as having a lower rank as a risk factor for MSkIs, and 5 studies did not find a significant association between rank and MSkIs (3 of the 5 had less than 1000 participants).

Table 3-48: Summary of All Studies that Focused on Lower Rank as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	No
Craig [40]	2000	USA	Army	Airborne Division	R	242,949 aircraft exits	Yes
Darakjy [8]	2006	USA	Army	Active duty	P	4,101 m, 413 f	Yes
Grier [87]	2010	USA	multiple		R	24,177 m	No (m)
Hill [54]	2013	USA	Army	Active duty	R	83,323	Yes
Lauder [97]	2000	USA	Army	Active duty	P	230 f	No (f)
Owens [131]	2009	USA	Army, Marines, Navy, Air Force	Active duty	R	19,730	Yes
Reynolds [55]	2000	USA	Marines	Winter mountain training	P	356	Yes
Roy [136]	2012	USA	Army	Brigade Combat Team[1]	P	246 m, 17 f	No
Skeehan [142]	2009	USA	Army, Marine, Navy	Active duty[1]	R	3,367	Yes
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females, [1]Deployment

There is **weak** scientific evidence for lower rank as a **non-modifiable** risk factor.

3.4.5.5 Seasons of the Year (Summertime)

Four studies focused on the seasons of the year as a risk factor for MSkIs (see Table 3-49). Two studies were conducted within the Finnish armed forces and two within the US Army. The study populations ranged from 955 to 2568 participants, and one study examined 213,500 person years. All 4 studies identified the effect of the season of the year as a risk factor for MSkIs, with a higher risk in the summer months.

Table 3-49: Summary of All Studies that Focused on Seasons of the Year as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Jones [33]	2008	USA	Army	Ordinance school students	P	n/a	Yes[1]
Knapik [197]	2002	USA	Army	Recruits BCT	R	1,543 m, 1,025 f	Yes[1]
Mattila [198]	2006	Finland	n/a		P	213,500 person years	Yes[1]
Taanila [199]	2009	Finland	Army	Conscripts	P	955 m	Yes (m)[2]

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, [1]Summer and autumn, [2]Summer

There is **strong** scientific evidence for the season of the year (summertime) as a **non-modifiable** risk factor for MSkIs.

3.4.5.6 UV Index (Higher)

Only one study focused on the UV index (a surrogate for vitamin D exposure) as a risk factor for MSkIs (see Table 3-50). This study was conducted within the US Army. In this retrospective study, with 511,602 participants, a higher UV index at a recruit's home before basic combat training (BCT) was identified as a risk factor for MSkIs during BCT. The relative risk reduction for a lower UV index was small (0.92 and 0.89 vs. 1, $P < 0.01$).

Table 3-50: Summary of All Studies that Focused on UV Index as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Montain [45]	2013	USA	Army	Recruits BCT	R	421,461 m, 90,141 f	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, m = male, f = female

There is **weak** scientific evidence for a higher UV index as a **non-modifiable** risk factor.

3.4.6 Training Factors

3.4.6.1 Equipment: Running Shoes

Only one study focused on running shoes as a risk factor for MSkIs (see Table 3-51). This study was conducted within the US Armed Forces. In this prospective study, with 827 participants, no association between the kinds of running shoes and an increased risk for MSkIs could be identified.

Table 3-51: Summary of All Studies that Focused on Running Shoes as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Helton [200]	2019	USA	Military Academy	Cadets	P	827	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? P = prospective study

There is **no** scientific evidence for the kinds of running shoes as a **modifiable** risk factor.

3.4.6.2 Participation in Sports Before Military Service (No or Low)

Twenty-four studies focused on a history of participation in sports before military service as a risk factor for MSkIs (see Table 3-52). Most of the research was conducted among recruits or those new to military service within different branches of the US Armed Forces (13 studies). The militaries of China, Finland, and Israel conducted 2 studies each; the remaining studies were conducted within the militaries of Australia, Denmark, India, Sweden, and the UK (1 study each). The sizes of the study populations ranged from 53 to 8570 participants. Fifteen studies identified no or low participation in sports before military service time as a risk factor for MSkIs, and 6 studies (all with fewer than 350 participants) did not find a significant association. In two studies, an association was found only for men, and in another study, an inverse association was found (higher participation in a sport before military service was a risk factor for MSkIs).

Table 3-52: Summary of All Studies that Focused on Participation in Sports Before Military Service as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Canham-Chervak [62]	2006	USA	Army	Recruits	P	1,156 m, 746 f	Yes
Dash [74]	2012	India	Army	Recruits	P	8,570	Yes
Finestone [117]	2011	Israel	Army	Elite Infantry soldier	P	77 m	Yes (only for ball sports)
Garnock [118]	2018	Australia	Navy	Recruits	P	95 m, 39 f	No (running)
Kelly [88]	2000	USA	Navy	Recruits BCT	R	86 f	No (f)
Knapik [90]	2013	USA	Army	Army military police training	P	1,838 m, 553 f	Yes
Knapik [120]	2013	USA	Army	Combat engineer enlisted trainees	P	1,633	Yes

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [93]	2001	USA	Army	Recruits	P	182 m, 168 f	No
Knapik [95]	2008	USA	Army	Recruits BCT	P	2,147 m, 920 f	Yes (m), No (f)
Knapik [96]	2009	USA	Marines	Recruits BCT	P	840 m, 571 f	Yes (m), No (f)
Lappe [65]	2005	USA	Army	Recruits BCT	R	4,139 f	Yes (f)
Lappe [66]	2001	USA	Army	Recruits BCT	P	3,758 f	Yes (f)
Lisman [122]	2013	USA	Marines	Officer candidate training	P	874	Yes
Monnier [123]	2019	Sweden	Marines	Training course	P	48 m, 5 f	No
Pihlajamäki [99]	2019	Finland	n/a	Full duty	R	4,029 m	Yes (m)
Rauh [188]	2006	USA	Marines		P	824 f	Yes (f)
Rosendal [189]	2003	Denmark	n/a	Conscripts BCT	P	330	Yes
Sanchez-Santos [53]	2017	UK	Marines	Recruits	P	1,082 m	Yes (m) (invers)
Scheinowitz [107]	2017	Israel	Army	Recruits	P	350 f	No (f)
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	No
Taanila [110]	2015	Finland	Army	Conscripts	P	1,411 m	Yes (m)
Trone [111]	2014	USA	Marine Corp Air Force Army	Recruits BCT	R	900 m, 597 f	Yes
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	Yes (m)
Zhao [58]	2016	China	Army	Recruits	P	1398 m	Yes (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

> There is **strong** scientific evidence for no or low participation in sports before military service time as a **non-modifiable** risk factor for MSkIs.

3.4.6.3 Physical Training: Available Participation Time (Low)

Two studies focused on the amount of time available to take part in physical training as a risk factor for MSkIs (see Table 3-53). The research was conducted within the US Army (1 study) and the army of Switzerland (1 study). The sizes of the study populations were 1677 and 1676 participants. The study from Switzerland found an association between having little time for physical training and an increased risk for MSkIs, while the study from the US military did not show a significant association.

Table 3-53: Summary of All Studies that Focused on Time Available for Physical Training as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [94]	2008	USA	Army	Paratrooper training	R	1,677	No
Wyss [76]	2014	Switzerland	Army	Recruits BCT	P	1,676	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study

There is **insufficient** scientific evidence for having little time available for taking part in physical training as a **modifiable** risk factor.

3.4.6.4 Physical Training: Participation Rate (Low)

Six studies focused on participation in physical training as a risk factor for MSkIs (see Table 3-54). Most of the research was conducted within different branches of the US Armed Forces (5 studies). An additional study was conducted within the military of the UK. The study populations ranged from 195 to 6865 participants. Three studies identified a low participation rate in physical training as a risk factor for MSkIs, and 3 studies did not find a significant association.

Table 3-54: Summary of All Studies that Focused on Participation Rate for Physical Training as a Risk Factor for MSkI.

Study	Publ. year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [92]	2007	USA	Army	Band	R	159 m, 46 f	Yes
Martin [186]	2018	USA	Army	Light Infantry division	R	6,865	Yes
Roy [136]	2012	USA	Army	Brigade Combat Team[1]	P	246 m, 17 f	No
Roy [125]	2014	USA	Army	Active duty	R	625 f	Yes (f)

Study	Publ. year	Country	Branches	Unit/Training	Study Type	n	RF?
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	No
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? R = retrospective study, P = prospective study, m = male, f = female, (f) = RF only for females, [1]Deployment

There is **insufficient** scientific evidence for the participation rate in physical training as a **modifiable** risk factor.

3.4.6.5 Physical Training: Personnel, Non-Military Training (High Amounts)

Eight studies focused on high amounts of training during free time (non-military training) as a risk factor for MSkIs (see Table 3-55). Most of the research was conducted within the army and the Marines Corp of the US Armed Forces (5 studies in total). Additional studies were conducted within the militaries of Finland, Israel, and Switzerland (1 study from each country). The sizes of the study populations ranged from 116 to 4,236 participants. Three studies identified a high amount of personal training during free time as a risk factor for MSkIs, and 3 studies did not find a significant association. Two studies found an inverse effect; a low amount of personal training was associated with an increased risk of MSkIs.

Table 3-55: Summary of All Studies that Focused on Personal Non-Military Training as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
George [119]	2012	USA	Army	Combat medics	P	1230	No
Grier [86]	2017	USA	Army	Infantry brigade	R	4,236 m	Yes (m) (invers)
Lisman [122]	2013	USA	Marines	Officer candidate training	P	874	No
Moran [70]	2012	Israel	Army	Recruits of elite combat unit	P	116	Yes
Rappole [135]	2018	USA	Army	Active duty	R	368 f	Yes (f) (invers)
Shaffer [114]	2006	USA	Marines	Recruits BCT	R	2,962 f	Yes (f)
Taanila [69]	2012	Finland	Army	Conscripts	P	982 m	No (m)
Wyss [76]	2014	Switzerland	Army	Recruits BCT	P	1,676	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **insufficient** scientific evidence for high amounts of personnel training during free time as a **modifiable** risk factor.

3.4.6.6 Physical Training: Unit Training (High Amount)

Eleven studies focused on physical training during unit training as a risk factor for MSkIs (see Table 3-56). Most of the research was conducted within different branches of the US Armed Forces (8 studies). Additional studies were conducted within the militaries of China, Israel, and Switzerland (1 study from each). The study populations ranged from 44 to 67,525 participants. Eight studies identified a high amount of training during unit training as a risk factor for MSkIs, whereas 3 studies did not find a significant association.

Table 3-56: Summary of All Studies that Focused on Age as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Grier [86]	2017	USA	Army	Infatery brigades	R	4,236 m	Yes (m)
Knapik [201]	2011	USA	Army	Recruits BCT	P	2,072	Yes
Lauder [97]	2000	USA	Army	Active duty	P	230 f	Yes (f)
Lisman [122]	2013	USA	Marines	Officer candidate training	P	874	No
Moran [152]	2013	Israel	Army	Recruits	P	44	Yes
Nye [59]	2016	USA	Air Force	Recruits BCT	R	67,525	Yes
Roos [105]	2015	Switzerland	Army	Recruits	P	651 m	Yes (m)
Roy [179]	2012	USA	Army	Brigade Combat Team	R	593	No
Schuh [202]	2017	USA	Army	Infantry soldiers	R	831	Yes
Scott [126]	2015	USA	Army	Reserve Officer Training	R	165 m, 30 f	Yes
Wang [112]	2003	China	n/a	Military Police Forces Training	R	805 m	No (m)

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males, (f) = RF only for females

There is **strong** scientific evidence for high amounts of training during unit training as a **modifiable** risk factor for MSkIs.

3.4.6.7 Training Program Content

Four studies focused on different training program content as a risk factor for MSkIs (see Table 3-57. Three studies were conducted within the US Armed Forces and 1 in the Army of Slovenia. The sizes of the study populations ranged from 129 to 1967 participants. One study included a total of 10,511 person years. Three studies identified that different training program content could be a risk factor for MSkIs, and the smallest study found no association.

Table 3-57: Summary of All Studies that Focused on Training Program Content as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Knapik [203]	2005	USA	Army	Recruits BCT	P	1,142 m, 825 f	Yes
Kovcan [75]	2019	Slovenia	Army	Infantry, active duty	R	118 m, 11 f	No
Rappole [135]	2018	USA	Army	Active duty	R	368 f	Yes[1]
Waterman [167]	2010	USA	Military Academy Students		R	10,511 person years	Yes

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? BCT = Basic Combat Training, R = retrospective study, P = prospective study, m = male, f = female, [1]Unit resistance training was associated with higher risk of MSkI

There is **weak** scientific evidence for training program content as a **modifiable** risk factor.

3.4.6.8 Training Site

Six studies focused on the training site as a risk factor for MSkIs (see Table 3-58). The studies were conducted within the militaries of the US Armed Forces (3 studies), the UK (2 studies), and Israel (1 study). The sizes of the study populations ranged from 660 to 24,177 participants. Three studies identified the training site as a risk factor for MSkIs (two of these studies had more than 10,000 participants), and 3 studies did not find a significant association between the training site and MSkIs. It should be taken into account that the training site is a combination of many different factors (e.g., training situation, climate, infrastructure, etc.), so it is very difficult to identify the true factor that influenced the MSkI risk.

Table 3-58: Summary of All Studies that Focused on Training Site as a Risk Factor for MSkI.

Study	Publ. Year	Country	Branches	Unit/Training	Study Type	n	RF?
Blacker [163]	2008	UK	Army	Recruits	R	11,937 m, 1,480 f	Yes
Givon [70]	2000	Israel	n/a		P	2,306 m	No (m)
Grier [87]	2010	USA	multiple		R	24,177 m	Yes (m)
Jones [33]	2008	USA	Army	Ordinance school students	P	n/a	Yes
Schneider [68]	2000	USA	Army	Airborne Division	R	1,214	No
Wilkinson [56]	2009	UK	Army	Infantry	P	660	No

Publ. year = publication year, RF? = risk factor for musculo-skeletal injuries? n/a = not available, R = retrospective study, P = prospective study, m = male, f = female, (m) = RF only for males

There is **weak** scientific evidence for training sites as a possibly **modifiable** risk factor.

3.5 SUMMARY

In sum, 57 potential risk factors for MSkIs in the military were identified. Twenty-one factors were classified as risk factors with a strong or moderate association with an increased risk for MSkIs. For 14 other potential risk factors, an association was possible, but the evidence in the scientific literature was considered weak. For the final 22 potential risk factors, the evaluation showed either insufficient evidence or no evidence. As such, they cannot be classified as risk factors for an increased risk for MSkIs at this time (see Table 3-59).

Table 3-59: Summary of All Factors and Categorization in Five Scientific Evidence Grades (Sorted Alphabetically) (n – Non-Modifiable, m – Modifiable).

Strong	Moderate	Weak	Insufficient	No
Body fat (higher) (m)	Age (nm)	Balance (low) (m)	Alcohol intake (m)	Ankle dorsiflexion (limited) (nm)
Branch (nm)	Foot type (nm)	Current illness (nm)	Available participation time (low) (m)	Body height (higher) (nm)
Load carriage (m)	Length of service (nm)	Genetic factors (nm)	BMI in general (m)	Equipment: running shoes (m)
Military occupational specialty (nm)	Muscular strength (lower) (m)	Prescription of non-steroidal anti-inflammatory drugs (m)	Body weight (higher) (m)	Late menarche (nm)
Obesity (m)	Previous deployment (nm)	Prior pregnancy (nm)	Bone (mineral) density (low) (nm)	Prescription of contraceptive (m)
Overweight (m)	Vitamin D status (low) (m)	Range of tibial rotation during running (lower) (m)	Calcium intake (low) (m)	Status (active vs. reserve) (nm)
Participation in sports before military service (no or low) (nm)		Rank (lower) (nm)	Education (lower) (nm)	Vegetables consumption (m)
Physical fitness (low) (m)		Serum iron/serum ferritin (lower) (m)	External rotation of hip (higher) (nm)	
Previous MSkI (nm)		Sleep time (reduced) (m)	Flexibility (lower) (m)	
Race/ethnicity (nm)		Training program content (m)	Marital status (nm)	
Season of the year (summer time) (nm)		Training site (m)	Milk consumption (low) (m)	
Sex (female) (nm)		UV index (higher) (nm)	Participation rate in physical training (m)	

Strong	Moderate	Weak	Insufficient	No
Smoking (m)		Vegetarian diet (m)	Personal non-military training (high amounts) (m)	
Underweight (m)		Waist circumference (higher) (m)	Plantar pressure assessment (of walking gait)	
Unit training (high amount) (m)			Secondary amenorrhoe (m)	
			Tibial length (shorter) (m)	

Based on this systematic literature review and an in-depth analysis, the NATO HFM-283 Research Task Group developed a model to classify the different risk factors identified. The classification model was based upon the rationale that some risk factors directly increase MSkI risk, whereas others merely increase the risk for MSkIs indirectly as a cofactor. As an example of a direct factor (1st order), high amounts of training during unit training increase the total volume of load placed upon the biological tissues of the soldier, directly resulting in injury. Alternatively, as an example of a cofactor, low vitamin D levels may lead to lower bone density, which may result in lower tissue resilience, which in turn may cause an MSkI due to the training load now exceeding the soldier's reduced tissue capacity. The term "order" was used to classify how close each risk factor was to a direct cause of injury. A 1st-order risk factor was thought to be most closely related to injury, whereas a 3rd-order factor was thought to follow a path through multiple cofactors. Table 3-12 shows all risk factors categorized as 1st, 2nd, or 3rd order of importance. Additionally, the model includes the established concepts of modifiable / non-modifiable and extrinsic/intrinsic risk factors. This prioritizing classification model may guide the planning and implementation of intervention strategies, introducing the notion that a larger risk reduction can likely be achieved if risk factors in a higher order are targeted (see Figure 3-2).

3.6 DISCUSSION

This review is the first systematic review of studies on risk factors for MSkIs in the military that has attempted to be all-inclusive. With a total of 179 original papers and 3 meta-analyses from the past two decades, a very large number of studies on MSkIs in the military were included. A total of 57 different risk factors were identified and evaluated.

The approach used in this study identified more risk factors for MSkIs in the military than previously reported [15] – [26]. The aim was to have an overview of all risk factors in one place. Further, the project is one of the first to include the classification of risk factors for MSkIs in the military into modifiable or non-modifiable categories. This additional distinction (modifiable vs. non-modifiable) helps us to understand which risk factors can be addressed and which ones cannot be addressed when an intervention is planned.

In addition to listing all potential risk factors, the members of the multidisciplinary expert panel assessed the combined evidence presented for each risk factor on a five-grade scale (strong evidence to no evidence). The number of participants (e.g., > 10,000 subjects) significantly influenced the evaluation of available evidence. Some classifications of available evidence had to be made based on a small number of studies with a small number of participants. The final rating also included the subjective professional experience (opinion) of the experts on the panel.

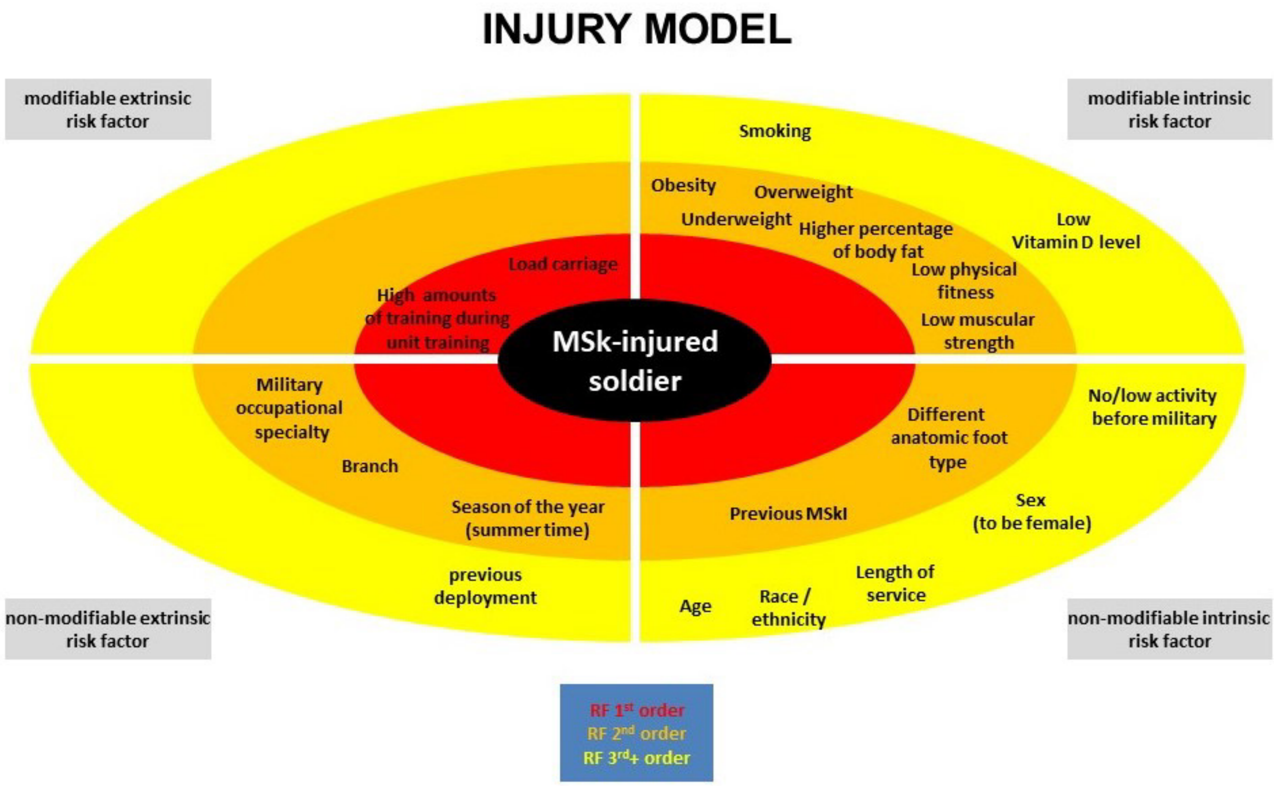

Figure 3-2: Injury Model with a Classification in 1st, 2nd and 3rd Order, RF = Risk Factor.

This review introduces a new injury model for the military, incorporating the established principles of modifiable vs. non-modifiable and intrinsic vs. extrinsic risk factors. The model clearly illustrates differences between risk factors; some increase the risk for MSkIs directly (1st order), whereas others influence the injury risk only indirectly (2nd or 3rd order). The model may explain why many of the interventions that have been attempted over the past decades to reduce MSkIs were not successful. In fact, a systematic review of successful interventions in reducing MSkIs in the military [6] shows that the only successful interventions are those that target 1st- and 2nd-order modifiable risk factors (i.e., in the upper half of the model).

Hence, most of the scientific publications are from the US Armed Forces, with studies conducted by other countries much less frequently. As such, the findings may not be generalizable across all nations. In addition, most studies focused on one branch of the armed forces – the army – which might not be representative of all service branches. Transferring the information from one country to another or from one military branch to another must be done with great caution.

Even with the very broad systematic approach used in this review, no studies on psychological, cognitive, and/or behavioral risk factors for MSkIs in the military could be identified. In civilian sports, these risk factors have been reported for several years [60], [61]. It is possible that the search terms used in this review did not allow for psychological factors to be identified or the psychosocial aspects of injuries.

This review has several limitations. First, the method used is a variation of the strict PRISMA protocol for systematic reviews. The group of coauthors decided that the topic at hand deserved a broad approach, including all possible risk factors and all military studies, even those with a potentially poor scientific design. In addition, it was decided to include the multidisciplinary, professional experience of the group as a subjective element in assessing the level of evidence per risk factor reported. Second, all studies before 2000 were excluded. This was decided because training schedules and conditions in the militaries have changed significantly over the past two decades and anticipated that including studies from before 2000 would not yield additional, currently relevant insights. Third, this review did not include studies on risk factors for MSkIs in civilian sports activities. Although some of the risk factors for civilian sports injuries are the same, the military training environment has many unique aspects that make risk factors for MSkIs not comparable to civilian sports. Fourth, differences in how the risk factors were measured (e.g., self-report vs. direct measurements) or the potential interrelationships between risk factors (e.g., that the strong evidence for sex as a risk factor may be related to differences in the percentage of body fat or previous physical activity before service between the sexes) were not considered when assigning the level of evidence for each risk factor. However, these issues were taken into account when depicting the 1st-, 2nd-, or 3rd-order level of the risk factors in the model. Fifth, this review did not include calculated effect sizes or a meta-analysis of every risk factor. Of course, this could further enhance the scientific value of the current work. The authors propose that future scientific evaluations can now be done, concentrating on the risk factors that have been identified as high order and modifiable in this work.

This systematic review presents an all-inclusive, graded overview of risk factors for MSkIs in the military. Experts with a multidisciplinary background, from a total of seven nations as part of the NATO Research Task Group, introduced a new prioritizing injury model for the military. The model provides a foundation for understanding which risk factors would be most important to address and in which order when an intervention is planned.

3.7 REFERENCES

[1] No authors listed (2019). Absolute and relative morbidity burdens attributable to various illnesses and injuries, active component, U.S. Armed Forces, 2018. MSMR 26(5), 2-10.

[2] Dijksma, I., Bekkers, M., Spek, B., Lucas, C., Stuiver, M. (2020). Epidemiology and financial burden of musculoskeletal injuries as the leading health problem in the military. Mil Med 185 (3-4), e480-e486.

[3] Orr, R.M., Johnston, V., Coyle, J., Pope, R. (2015). Reported load carriage injuries of the Australian army soldier. J Occup Rehabil 25(2), 316-22.

[4] Sammito, S. (2011). Direct and indirect costs caused by accidents at workplace sport activities. Präv Gesundheitsf 6(4), 245-8.

[5] Strowbridge, N.F., Burgess KR. (2002). Sports and training injuries in British soldiers: The Colchester Garrison Sports Injury and Rehabilitation Centre. J R Army Med Corps 148(3), 236-43.

[6] Wardle, S.L., Greeves, J.P. (2017). Mitigating the risk of musculoskeletal injury: A systematic review of the most effective injury prevention strategies for military personnel. J Sci Med Sport 20 Suppl 4, S3-S10.

[7] Reis, J.P., Trone, D.W., Macera, C.A., Rauh, M.J. (2007). Factors associated with discharge during marine corps basic training. Mil Med 172(9), 936-41.

[8] Darakjy, S., Marin, R.E., Knapik, J.J., Jones, B.H. (2006). Injuries and illnesses among armor brigade soldiers during operational training. Mil Med 171(11), 1051-6.

[9] Patel, A.A., Hauret, K.G., Taylor, B.J., Jones, B.H. (2017). Non-battle injuries among U.S. Army soldiers deployed to Afghanistan and Iraq, 2001 – 2013. J Safety Res 60, 29-34.

[10] Belmont, P.J. Jr, Goodman, G.P., Waterman, B., DeZee, K., Burks, R., Owens, B.D. (2010). Disease and nonbattle injuries sustained by a U.S. Army Brigade Combat Team during Operation Iraqi Freedom. Mil Med 175(7), 469-76.

[11] Goodman, G.P., Schoenfeld, A.J., Owens, B.D., Dutton, J.R., Burks, R., Belmont, P.J. (2012). Non-emergent orthopaedic injuries sustained by soldiers in Operation Iraqi Freedom. J Bone Joint Surg Am 94(8), 728-35.

[12] Lincoln, A.E., Smith, G.S., Amoroso, P.J., Bell, N.S. (2002). The natural history and risk factors of musculoskeletal conditions resulting in disability among US Army personnel. Work 18(2), 99-113.

[13] Bergman, B.P., Miller, S.A. (2001). Equal opportunities, equal risks? Overuse injuries in female military recruits. J Public Health Med 23(1), 35-9.

[14] Taanila, H., Hemminki, A.J.M., Suni, J.H., Pihlajamäki, H., Parkkari, J. (2011). Low physical fitness is a strong predictor of health problems among young men: A follow-up study of 1411 male conscripts. BMC Public Health 11, 590.

[15] de la Motte, S.J., Lisman, P., Gribbin, T.C., Murphy, K., Deuster, P.A. (2017). Systematic review of the association between physical fitness and musculoskeletal injury risk: Part 3-Flexibility, Power, Speed, Balance, and Agility. J Strength Cond Res 33(6), 1723-35.

[16] Lisman, P.J., de la Motte, S.J., Gribbin, T.C., Jaffin, D.P., Murphy, K., Deuster, P.A. (2017). A systematic review of the association between physical fitness and musculoskeletal injury risk: Part 1-Cardiorespiratory Endurance. J Strength Cond Res 31(6), 1744-57.

[17] Knapik, J., Steelman, R. (2016). Risk factors for injuries during military static-line airborne operations: A systematic review and meta-analysis. J Athl Train 51(11), 962-80.

[18] Molloy, J.M. (2016). Factors influencing running-related musculoskeletal injury risk among U.S. Military Recruits. Mil Med 181(6), 512-23.

[19] Knapik, J.J. (2015). The importance of physical fitness for injury prevention: Part 1. J Spec Oper Med 15(1), 123-7.

[20] Knapik, J.J. (2015). The importance of physical fitness for injury prevention: Part 2. J Spec Oper Med 15(2), 112-5.

[21] Bulzacchelli, M.T., Sulsky, S.I., Rodriguez-Monguio, R., Karlsson, L.H., Hill, M.O.T. (2014). Injury during U.S. Army basic combat training: A systematic review of risk factor studies. Am J Prev Med 47(6), 813-22.

[22] Wentz, L., Liu, P.Y., Haymes. E., Ilich, J.Z. (2011). Females have a greater incidence of stress fractures than males in both military and athletic populations: A systemic review. Mil Med 176(4), 420-30.

[23] Dao, D., Sodhi, S., Tabasinejad, R., Peterson, D., Ayeni, O.R., Bhandari, M. et al. (2015). Serum 25-hydroxyvitamin D levels and stress fractures in military personnel: A systematic review and meta-analysis. Am J Sports Med 43(8), 2064-72.

[24] Bedno, S.A., Jackson, R., Feng, X., Walton, I.L., Boivi,n M.R., Cowan, D.N. (2017). Meta-analysis of cigarette smoking and musculoskeletal injuries in military training. Med Sci Sports Exerc 49(11), 2191-7.

[25] Tomes, C.D., Sawyer, S., Orr, R., Schram, B. (2020). Ability of fitness testing to predict injury risk during initial tactical training: A systematic review and meta-analysis. Inj Prev 26(1), 67-81.

[26] Knapik, J.J., Steelman, R. (2014). Risk factors for injuries during airborne static line operations. J Spec Oper Med 14(3), 95-7.

[27] Bell, N.S., Mangione, T.W., Hemenway, D., Amoroso, P.J., Jones, B.H. (2000). High injury rates among female army trainees: A function of gender? Am J Prev Med 18(3 Suppl), 141-6.

[28] Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P.A, et al. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. PLoS Med 6(7), e1000100.

[29] Greenhalgh, T., Peacock, R. (2005). Effectiveness and efficiency of search methods in systematic reviews of complex evidence: Audit of primary sources BMJ 331(7524), 1064-5.

[30] Dixon, S.J., Creaby, M.W., Allsopp, A.J. (2006). Comparison of static and dynamic biomechanical measures in military recruits with and without a history of third metatarsal stress fracture. Clin Biomech (Bristol, Avon) 21(4), 412-9.

[31] Waterman, B.R., Gun, B., Bader, J.O., Orr, J.D., Belmont, P.J. (2016). Epidemiology of lower extremity stress fractures in the United States Military. Mil Med 181(10), 1308-13.

[32] Itskoviz, D., Marom, T., Ostfeld, I. (2011). Trends of stress fracture prevalence among Israel Defense Forces basic trainees. Mil Med 176(1), 56-9.

[33] Jones, S.B., Knapik, J.J., Jones, B.H. (2008). Seasonal variations in injury rates in U.S. Army ordnance training. Mil Med 173(4), 362-8.

[34] Jones, B.H., Hauret, K.G., Dye, S.K., Hauschild, V.D., Rossi, S.P., Richardson, M.D., Friedl, K.E. (2017). Impact of physical fitness and body composition on injury risk among active young adults: A study of Army trainees. J Sci Med Sport 20 Suppl 4, S17-S22.

[35] Bedno, S.A., Nelson, D.A., Kurina, L.M., Choi, Y.S. (2019). Gender differences in the associations of body mass index, physical fitness and tobacco use with lower extremity musculoskeletal injuries among new US Army soldiers. Inj Prev 25(4), 295-300.

[36] Kuikka, P.I., Pihlajamäki, H.K., Mattila, V.M. (2013). Knee injuries related to sports in young adult males during military service – incidence and risk factors. Scand J Med Sci Sports 23(3), 281-7.

[37] Mattila, V.M., Kuronen, P., Pihlajamäki, H. (2007). Nature and risk factors of injury hospitalization in young adults: A follow-up of 135,987 military conscripts. Scand J Public Health 35(4), 418-23.

[38] Mattila, V.M., Niva, M., Kiuru, M., Pihlajamäki, H. (2007). Risk factors for bone stress injuries: A follow-up study of 102,515 person-years. Med Sci Sports Exerc 39(7), 1061-6.

[39] Sormaala, M.J., Niva, M.H., Kiuru, M.J., Mattila, V.M., Pihlajamäki, H.K. (2006). Stress injuries of the calcaneus detected with magnetic resonance imaging in military recruits. J Bone Joint Surg Am 88(10), 2237-42.

[40] Craig, S.C., Lee, T. (2000). Attention to detail: Injuries at altitude among U.S. Army Military static line parachutists. Mil Med 165(4), 268-71.

[41] Packnett, E.R., Niebuhr, D.W., Bedno, S.A., Cowan, D.N. (2011). Body mass index, medical qualification status, and discharge during the first year of US Army service. Am J Clin Nutr 93(3), 608-14.

[42] Sulsky, S.I., Bulzacchelli, M.T., Zhu, L., Karlsson, L., McKinnon, C.J., Hill, O.T., Kardouni, J.R. (2018). Risk factors for training-related injuries during U.S. Army Basic Combat Training. Mil Med 183(suppl_1), 55-65.

[43] Army Medical Surveillance Activity (2000). Relationship between body mass index and musculoskeletal system and connective tissue disorders, US Army, 1990 – 1999. Med Surveill Mon Rep 6, 2-10.

[44] Cameron, K.L., Owens, B.D., DeBerardino, T.M. (2010). Incidence of ankle sprains among active-duty members of the United States Armed Services from 1998 through 2006. J Athl Train 45(1), 29-38.

[45] Montain, S.J., McGraw, S.M., Ely, M.R., Grier, T.L., Knapik, J.J. (2013). A retrospective cohort study on the influence of UV index and race/ethnicity on risk of stress and lower limb fractures. BMC Musculoskelet Disord 14, 135.

[46] Knapik, J.J., Sharp, M.A., Montain, S.J. (2018). Association between stress fracture incidence and predicted body fat in United States Army Basic Combat Training recruits. BMC Musculoskelet Disord. 19(1), 161.

[47] Knapik, J., Montain, S.J., McGraw, S., Grier, T., Ely, M., Jones, B.H. (2012). Stress fracture risk factors in basic combat training. Int J Sports Med 33(11), 940-6.

[48] Hruby, A., Bulathsinhala, L., McKinnon, C.J., Hill, O.T., Montain, S.J., Young, A.J. et al. (2016). BMI and lower extremity injury in U.S. Army soldiers, 2001 – 2011. Am J Prev Med 50(6), e163-e171.

[49] Bulathsinhala, L., Hughes, J.M., McKinnon, C.J., Kardouni, J.R., Guerriere, K.I., Popp, K.L. et al. (2017). Risk of stress fracture varies by race/ethnic origin in a cohort study of 1.3 million US Army soldiers. J Bone Miner Res 32(7), 1546-53.

[50] Hughes, J.M., McKinnon, C.J., Taylor, K.M., Kardouni, J.R., Bulathsinhala, L., Guerriere, K.I. et al. (2019). Nonsteroidal anti-inflammatory drug prescriptions are associated with increased stress fracture diagnosis in the US Army population. J Bone Miner Res 34(3), 429-36.

[51] Sillanpää, P., Mattila, V.M., Iivonen, T., Visuri, T., Pihlajamäki, H. (2008). Incidence and risk factors of acute traumatic primary patellar dislocation. Med Sci Sports Exerc 40(4), 606-11.

[52] Davey, T., Lanham-New, S.A., Shaw, A.M., Hale, B., Cobley, R., Berry, J.L. et al. (2016). Low serum 25-hydroxyvitamin D is associated with increased risk of stress fracture during Royal Marine recruit training. Osteoporos Int 7(1), 171-9.

[53] Sanchez-Santos, M.T., Davey, T., Leyland, K.M., Allsopp, A.J., Lanham-New, S.A., Judge, A. et al. (2017). Development of a prediction model for stress fracture during an intensive Physical Training Program: The Royal Marines Commandos. Orthop J Sports Med 5(7), 2325967117716381.

[54] Hill, O.T., Bulathsinhala, L., Scofield, D.E., Haley, T.F., Bernasek, T.L. (2013). Risk factors for soft tissue knee injuries in active duty U.S. Army soldiers, 2000 – 2005. Mil Med 178(6), 676-82.

[55] Reynolds, K., Williams, J., Miller, C., Mathis, A., Dettori, J. (2000). Injuries and risk factors in an 18-day Marine winter mountain training exercise. Mil Med 165(12), 905-10.

[56] Wilkinson, D.M., Blacker, S.D., Richmond, V.L., Horner, F.E., Rayson, M.P., Spiess, A., Knapik, J.J. (2009). Injury rates and injury risk factors among British Army Infantry Soldiers: Final Report. QINETIQ/09/02508/1.0.

[57] Korvala, J., Hartikka, H., Pihlajamäki, H., Solovieva, S., Ruohola, J.P., Sahi, T. et al. (2010). Genetic predisposition for femoral neck stress fractures in military conscripts. BMC Genet 11, 95.

[58] Zhao, L., Chang, Q., Huang, T., Huang, C. (2016). Prospective cohort study of the risk factors for stress fractures in Chinese male infantry recruits. J Int Med Res 44(4), 787-95.

[59] Nye, N.S., Pawlak, M.T., Webber, B.J., Tchandja, J.N., Milner, M.R. (2016). Description and rate of musculoskeletal injuries in air force basic military trainees, 2012 – 2014. J Athl Train 51(11), 858-65.

[60] Ivarsson, A., Johnson, U., Andersen, M.B., Tranaeus, U., Stenling, A., Lindwall, M. (2017). Psychosocial factors and sport injuries: Meta-analyses for prediction and prevention. Sports Med 47(2), 353-65.

[61] Junge, A. (2000). The influence of psychological factors on sports injuries. Review of the literature. Am J Sports Med 28(5 Suppl), S10-5.

[62] Canham-Chervak, M. (2006). The association of health risk behaviors and training-related injury among U.S. Army basic trainees. http://www.dtic.mil/get-tr-doc/pdf?AD=ADA568679. Accessed 14 Feb 2019.

[63] Chatzipapas, C.N., Drosos, G.I., Kazakos, K.I., Tripsianis, G., Iatrou, C., Verettas, D.A.J. (2008). Stress fractures in military men and bone quality related factors. Int J Sports Med 29(11), 922-6.

[64] Cosio-Lima, L., Brown, K., Reynolds, K.L., Gregg, R., Perry, R.A. Jr. (2013). Injury and illness incidence in a Sergeants Major Academy class. Mil Med 178(7), 735-41.

[65] Lappe, J., Davies, K., Recker, R., Heaney, R. (2005). Quantitative ultrasound: Use in screening for susceptibility to stress fractures in female army recruits. J Bone Miner Res 20(4), 571-8.

[66] Lappe, J.M., Stegman, M.R., Recker, R.R. (2001). The impact of lifestyle factors on stress fractures in female Army recruits. Osteoporos Int 12(1), 35-42.

[67] Robinson, M., Siddall, A., Bilzon, J., Thompson, D., Greeves, J., Izard, R. et al. (2016). Low fitness, low body mass and prior injury predict injury risk during military recruit training: A prospective cohort study in the British Army. BMJ Open Sport Exerc Med 2(1), e000100.

[68] Schneider, G.A., Bigelow, C., Amoroso, P.J. (2000). Evaluating risk of re-injury among 1214 army airborne soldiers using a stratified survival model. Am J Prev Med 18(3 Suppl), 156-63.

[69] Taanila, H.P., Suni, J.H., Pihlajamaki, H.K., Mattila, V.M., Ohrankammen, O., Vuorinen, P., Parkkari, J.P. (2012). Predictors of low back pain in physically active conscripts with special emphasis on muscular fitness. Spine J 12(9), 737-48.

[70] Givon, U., Friedman, E., Reiner, A., Vered, I., Finestone, A., Shemer, J. (2000). Stress fractures in the Israeli defense forces from 1995 to 1996. Clin Orthop Relat Res 373, 227-32.

[71] Moran, D.S., Finestone, A.S., Arbel, Y., Shabshin, N., Laor, A. (2012). A simplified model to predict stress fracture in young elite combat recruits. J Strength Cond Res 26(9), 2585-92.

[72] Moran, D.S., Heled, Y., Arbel, Y., Israeli, E., Finestone, A.S., Evans, R.K. et al. (2012). Dietary intake and stress fractures among elite male combat recruits. J Int Soc Sports Nutr 9(1), 6.

[73] Cosman, F., Ruffing, J., Zion, M., Uhorchak, J., Ralston, S., Tendy, S. et al. (2013). Determinants of stress fracture risk in United States Military Academy cadets. Bone 55(2), 359-66.

[74] Dash, N., Kushwaha, A. (2012). Stress fractures-a prospective study amongst recruits. Med J Armed Forces India 68(2), 118-22.

[75] Kovcan, B., Vodicar, J., Šimenko, J., Videmšek, M., Pori, P., Vedran, H. (2019). Retrospective and cross-sectional analysis of physical training-related musculoskeletal injuries in Slovenian Armed Forces. Mil Med 184(1-2), e195-e199.

[76] Wyss, T., Roos, L., Hofstetter, M.C., Frey, F., Mäder, U. (2014). Impact of training patterns on injury incidences in 12 Swiss Army basic military training schools. Mil Med 179(1), 49-55.

[77] Altarac, M., Gardner, J.W., Popovich, R.M., Potter, R., Knapik, J.J., Jones, B.H. (2000). Cigarette smoking and exercise-related injuries among young men and women. Am J Prev Med 18(3 Suppl), 96-102.

[78] Anderson, M.K., Grier, T., Canham-Chervak, M., Bushman, T.T., Jones, B.H. (2015). Occupation and other risk factors for injury among enlisted U.S. Army Soldiers. Public Health 129(5), 531-8.

[79] Anderson, M.K., Grier, T., Dada, E.O., Canham-Chervak, M., Jones, B.H. (2017). The role of gender and physical performance on injuries: An army study. Am J Prev Med 52(5), e131-e138.

[80] Bedno, S.A., Cowan, D.N., Ur ban, N., Niebuhr, D.W. (2013). Effect of pre-accession physical fitness on training injuries among US Army recruits. Work 44(4), 509-15.

[81] Brooks, R.D., Grier, T., Dada, E.O., Jones, B.H. (2019). The combined effect of cigarette smoking and fitness on injury risk in men and women. Nicotine Tob Res 21(12), 1621-8.

[82] Cowan, D.N., Bedno, S.A., Urban, N., Lee, D.S., Niebuhr, D.W. (2012). Step test performance and risk of stress fractures among female army trainees. Am J Prev Med 42(6), 620-4.

[83] Cowan, D.N., Bedno, S.A., Urban, N., Yi, B., Niebuhr, D.W. (2011). Musculoskeletal injuries among overweight army trainees: Incidence and health care utilization. Occup Med 61(4), 247-52.

[84] Davey, T., Lanham-New, S.A., Shaw, A.M., Cobley, R., Allsopp, A.J., Hajjawi, M.O.R, et al. (2015). Fundamental differences in axial and appendicular bone density in stress fractured and uninjured Royal Marine recruits – A matched case-control study. Bone 73, 120-6.

[85] Fallowfield, J.L., Leiper, R.G., Shaw, A.M., Whittamore, D.R., Lanham-New, S.A., Allsopp, A.J. et al. (2020). Risk of injury in Royal Air Force Training: Does sex really matter? Mil Med 185(1-2) 170-1772018. doi: 10.1093/milmed/usy177.

[86] Grier, T.L., Canham-Chervak, M., Anderson, M.K., Bushman, T.T., Jones, BH. (2017). Effects of physical training and fitness on running injuries in physically active young men. J Strength Cond Res 31(1), 207-16.

[87] Grier, T.L., Knapik, J.J., Canada, S., Canham-Chervak, M., Jones, B.H. (2010). Risk factors associated with self-reported training-related injury before arrival at the US army ordnance school. Public Health 124(7), 417-23.

[88] Kelly, E.W., Jonson, S.R., Cohen, M.E., Shaffer, R. (2000). Stress fractures of the pelvis in female navy recruits: An analysis of possible mechanisms of injury. Mil Med 165(2), 142-6.

[89] Knapik, J.J., Brosch, L.C., Venuto, M., Swedler, D.I., Bullock, S.H., Gaines, L.S. et al. (2010). Effect on injuries of assigning shoes based on foot shape in air force basic training. Am J Prev Med 38(1 Suppl), S197-211.

[90] Knapik, J.J., Graham, B., Cobbs, J., Thompson, D., Steelman, R., Jones, B.H. (2013). A prospective investigation of injury incidence and injury risk factors among Army recruits in military police training. BMC Musculoskelet Disord 14, 32.

[91] Knapik, J.J., Graham, B.S., Rieger, J., Steelman, R., Pendergrass, T. (2013). Activities associated with injuries in initial entry training. Mil Med 178(5), 500-6.

[92] Knapik, J.J., Jones, S.B., Darakjy, S., Hauret, K.G., Nevin, R., Grier, T., Jones, B.H. (2007). Injuries and injury risk factors among members of the United States Army Band. Am J Ind Med 50(12), 951-61.

[93] Knapik, J.J., Sharp, M.A., Canham-Chervak, M., Hauret, K., Patton, J.F., Jones, B.H. (2001). Risk factors for training-related injuries among men and women in basic combat training. Med Sci Sports Exerc 33(6), 946-54.

[94] Knapik, J.J., Spiess, A., Swedler, D., Grier, T., Darakjy, S., Amoroso, P. et al. (2008). Injury risk factors in parachuting and acceptability of the parachute ankle brace. Aviat Space Environ Med 79(7), 689-94.

[95] Knapik, J.J., Swedler, D., Grier, T., Hauret, K.G., Bullock, S., Williams, K. et al. (2008). Injury reduction effectiveness of prescribing running shoes based on foot shape in basic combat training: Technical Report No. 12-MA-05SB-08. Aberdeen Proving Ground, MD.

[96] Knapik, J.J., Trone, D., Swedler, D.I., Villasenor, A., Schmied, E., Bullock, S., Jones, B.H. (2009). Injury reduction effectiveness of assigning running shoes based on foot shape in Marine Corps basic training: No. 12-MA-05SBA-08B. Aberdeen Proving Ground, MD.

[97] Lauder, T.D., Dixit, S., Pezzin, L.E., Williams, M.V., Campbell, C.S., Davis, G.D. (2000). The relation between stress fractures and bone mineral density: Evidence from active-duty Army women. Arch Phys Med Rehabil 81(1), 73-9.

[98] Munnoch, K., Bridger, R.S. (2007). Smoking and injury in Royal Marines' training. Occup Med 57(3), 214-6.

[99] Nagai, T., Lovalekar, M., Wohleber, M.F., Perlsweig, K.A., Wirt, M.D., Beals, K. (2017). Poor anaerobic power/capability and static balance predicted prospective musculoskeletal injuries among Soldiers of the 101st Airborne (Air Assault) Division. J Sci Med Sport 20 Suppl 4, S11-S16.

[100] Pihlajamäki, H., Parviainen, M., Kyröläinen, H., Kautiainen, H., Kiviranta, I. (2019). Regular physical exercise before entering military service may protect young adult men from fatigue fractures. BMC Musculoskelet Disord 20(1), 126.

[101] Psaila, M., Ranson, C. (2017). Risk factors for lower leg, ankle and foot injuries during basic military training in the Maltese Armed Forces. Phys Ther Sport 24, 7-12.

[102] Rappole, C., Grier, T., Anderson, M.K., Hauschild, V., Jones, B.H. (2017). Associations of age, aerobic fitness, and body mass index with injury in an operational Army brigade. J Sci Med Sport 20 Suppl 4, S45-S50.

[103] Reynolds, K., Cosio-Lima, L., Bovill, M., Tharion, W., Williams, J., Hodges, T. (2009). A comparison of injuries, limited-duty days, and injury risk factors in infantry, artillery, construction engineers, and special forces soldiers. Mil Med 174(7), 702-8.

[104] Reynolds, K., Cosio-Lima, L., Creedon, J., Gregg, R., Zigmont, T. (2002). Injury occurrence and risk factors in construction engineers and combat artillery soldiers. Mil Med 167(12), 971-7.

[105] Roos, L., Boesch, M., Sefidan, S., Frey, F., Mäder, U., Annen, H. et al. (2015). Adapted marching distances and physical training decrease recruits' injuries and attrition. Mil Med 180(3), 329-36.

[106] Ruohola, J.P., Laaksi, I., Ylikomi, T., Haataja, R., Mattila, V.M., Sahi, T. et al. (2006). Association between serum 25(OH)D concentrations and bone stress fractures in Finnish young men. J Bone Miner Res 21(9), 1483-8.

[107] Scheinowitz, M., Yanovich, R., Sharvit, N., Arnon, M., Moran, D.S. (2017). Effect of cardiovascular and muscular endurance is not associated with stress fracture incidence in female military recruits: A 12-month follow up study. J Basic Clin Physiol Pharmacol 28(3), 219-24.

[108] Sharma, J., Heagerty, R., Dalal, S., Banerjee, B., Booker, T. (2019). Risk factors associated with musculoskeletal injury: A prospective study of British Infantry Recruits. Curr Rheumatol Rev 15(1), 50-8.

[109] Sharma, J., Golby, J., Greeves, J., Spears, I.R. (2011). Biomechanical and lifestyle risk factors for medial tibia stress syndrome in army recruits: A prospective study. Gait Posture 33(3), 361-5.

[110] Taanila, H., Suni, J.H., Kannus, P., Pihlajamaki, H., Ruohola, J.P., Viskari, J. et al. (2015). Risk factors of acute and overuse musculoskeletal injuries among young conscripts: A population-based cohort study. BMC Musculoskelet Disord 16, 104.

[111] Trone, D.W., Cipriani, D.J., Raman, R., Wingard, D.L., Shaffer, R.A., Macera, C.A. (2014). Self-reported smoking and musculoskeletal overuse injury among male and female U.S. Marine Corps recruits. Mil Med 179(7), 735-43.

[112] Wang, X., Wang, P., Zhou, W. (2003). Risk factors of military training-related injuries in recruits of Chinese People's Armed Police Forces. Chin J Traumatol 6(1), 12-7.

[113] Wunderlin, S., Roos, L., Roth, R., Faude, O., Frey, F., Wyss, T. (2015). Trunk muscle strength tests to predict injuries, attrition and military ability in soldiers. J Sports Med Phys Fitness 55(5), 535-43.

[114] Shaffer, R.A., Rauh, M.J., Brodine, S.K., Trone, D.W., Macera, C.A. (2006). Predictors of stress fracture susceptibility in young female recruits. Am J Sports Med 34(1), 108-15.

[115] Cameron, K.L., Mountcastle, S.B., Nelson, B.J., DeBerardino, T.M., Duffey, M.L., Svoboda, S.J. et al. (2013). History of shoulder instability and subsequent injury during four years of follow-up: A survival analysis. J Bone Joint Surg Am 95(5), 439-45.

[116] Evans, R., Reynolds, K., Creedon, J., Murphy, M. (2005). Incidence of acute injury related to fitness testing of U.S. Army personnel. Mil Med 170(12), 1005-11.

[117] Finestone, A., Milgrom, C., Wolf, O., Petrov, K., Evans, R., Moran, D. (2011). Epidemiology of metatarsal stress fractures versus tibial and femoral stress fractures during elite training. Foot Ankle Int 32(1), 16-20.

[118] Garnock, C., Witchalls, J., Newman, P. (2018). Predicting individual risk for medial tibial stress syndrome in navy recruits. J Sci Med Sport 21(6), 586-90.

[119] George, S.Z., Childs, J.D., Teyhen, D.S., Wu, S.S., Wright, A.C., Dugan, J.L. et al. (2012). Predictors of occurrence and severity of first time low back pain episodes: Findings from a military inception cohort. PLoS One 7(2), e30597.

[120] Knapik, J.J., Graham, B., Cobbs, J., Thompson, D., Steelman, R., Jones, B.H. (2013). A prospective investigation of injury incidence and risk factors among army recruits in combat engineer training. J Occup Med Toxicol 8(1), 5.

[121] Kucera, K.L., Marshall, S.W., Wolf, S.H., Padua, D.A., Cameron, K.L., Beutler, A.I. (2016). Association of injury history and incident injury in Cadet Basic Military Training. Med Sci Sports Exerc 48(6), 1053-61.

[122] Lisman, P., O'Connor, F.G., Deuster, P.A., Knapik, J.J. (2013). Functional movement screen and aerobic fitness predict injuries in military training. Med Sci Sports Exerc 45(4), 636-43.

[123] Monnier, A., Larsson, H., Nero, H., Djupsjöbacka, M., Äng, B.O. (2019). A longitudinal observational study of back pain incidence, risk factors and occupational physical activity in Swedish marine trainees. BMJ Open 9(5), e025150.

[124] Rice, H., Nunns, M., House, C., Fallowfield, J., Allsopp, A., Dixon, S. (2017). A narrow bimalleolar width is a risk factor for ankle inversion injury in male military recruits: A prospective study. Clin Biomech (Bristol, Avon) 41, 14-9.

[125] Roy, T.C., Songer, T., Ye, F., LaPorte, R., Grier, T., Anderson, M. et al. (2014). Physical training risk factors for musculoskeletal injury in female soldiers. Mil Med 179(12), 1432-8.

[126] Scott, S.A., Simon, J.E., Van Der Pol, B., Docherty, C.L. (2015). Risk factors for sustaining a lower extremity injury in an Army Reserve Officer Training Corps Cadet Population. Mil Med 180(8), 910-6.

[127] Taanila, H., Suni, J., Pihlajamäki, H., Mattila, V.M., Ohrankämmen, O., Vuorinen, P. et al. (2010). Aetiology and risk factors of musculoskeletal disorders in physically active conscripts: A follow-up study in the Finnish Defence Forces. BMC Musculoskelet Disord 11, 146.

[128] Merkel, D., Moran, D.S., Yanovich, R., Evans, R.K., Finestone, A.S., Constantini, N. et al. (2008). The association between hematological and inflammatory factors and stress fractures among female military recruits. Med Sci Sports Exerc 40(11 Suppl), S691-7.

[129] Moran, D.S., Israeli, E., Evans, R.K., Yanovich, R., Constantini, N., Shabshin, N. et al. (2008). Prediction model for stress fracture in young female recruits during basic training. Med Sci Sports Exerc 40(11 Suppl), S636-44.

[130] Burgi, A.A., Gorham, E.D., Garland, C.F., Mohr, S.B., Garland, F.C., Zeng, K. et al. (2011). High serum 25-hydroxyvitamin D is associated with a low incidence of stress fractures. J Bone Miner Res 26(10), 2371-7.

[131] Owens, B.D., Dawson, L., Burks, R., Cameron, K.L. (2009). Incidence of shoulder dislocation in the United States military: Demographic considerations from a high-risk population. J Bone Joint Surg Am 91(4), 791-6.

[132] Schermann, H., Karakis, I., Ankory, R., Kadar, A., Yoffe, V., Shlaifer, A. et al. (2018). Musculoskeletal injuries among female soldiers working with dogs. Mil Med 183(9-10), e343-e348.

[133] Constantini, N., Finestone, A.S., Hod, N., Shub, I., Heinemann, S., Foldes, A.J. et al. (2010). Equipment modification is associated with fewer stress fractures in female Israel border police recruits. Mil Med 175(10), 799-804.

[134] Konitzer, L.N., Fargo, M.V., Brininger, T.L., Lim Reed, M. (2008). Association between back, neck, and upper extremity musculoskeletal pain and the individual body armor. J Hand Ther 21(2), 143-8; quiz 149.

[135] Rappole, C., Chervak, M.C., Grier, T., Anderson, M.K., Jones, B.H. (2018). Factors associated with lower extremity training-related injuries among Enlisted Women in U.S. Army Operational Units. J Mil Veterans Health 26(1), 18-28.

[136] Roy, T.C., Ritland, B.M., Knapik, J.J., Sharp, M.A. (2012). Lifting tasks are associated with injuries during the early portion of a deployment to Afghanistan. Mil Med 177(6), 716-22.

[137] Roy, T.C., Ritland, B.M., Sharp, M.A. (2015). A description of injuries in men and women while serving in Afghanistan. Mil Med 180(2), 126-31.

[138] Roy, T.C. (2011). Diagnoses and mechanisms of musculoskeletal injuries in an infantry brigade combat team deployed to Afghanistan evaluated by the brigade physical therapist. Mil Med 176(8), 903-8.

[139] Schwartz, O., Malka, I., Olsen, C.H., Dudkiewicz, I., Bader, T. (2018). Overuse injuries in the IDF's Combat Training Units: Rates, types, and mechanisms of injury. Mil Med 183(3-4), e196-e200.

[140] Sefton, J.M., Lohse, K.R., McAdam,. J.S. (2016). Prediction of injuries and injury types in Army basic training, infantry, armor, and cavalry trainees using a common fitness screen. J Athl Train 51(11), 849-57.

[141] Sharma, J., Dixon, J., Dalal, S., Heagerty, R., Spears, I. (2017). Musculoskeletal injuries in British Army recruits: A prospective study of incidence in different Infantry Regiments. J R Army Med Corps 163(6), 406-11.

[142] Skeehan, C.D., Tribble, D.R., Sanders, J.W., Putnam, S.D., Armstrong A.W., Riddle, M.S. (2009). Nonbattle injury among deployed troops: An epidemiologic study. Mil Med 174(12), 1256-62.

[143] Beck, T.J., Ruff, C.B., Shaffer, R.A., Betsinger, K., Trone, D.W., Brodine, S.K. (2000). Stress fracture in military recruits: Gender differences in muscle and bone susceptibility factors. Bone 27(3), 437-44.

[144] Canham-Chervak, M., Knapik. J.J., Hauret, K., Cuthie, J., Craig, S. (2000). Determining physical fitness criteria for entry into army basic combat training: Can these criteria be based on injury risk? http://www.dtic.mil/dtic/tr/fulltext/u2/a374717.pdf (Accessed 1 Mar 2014).

[145] Dixon, S., Nunns, M., House, C., Rice, H., Mostazir, M., Stiles, V. et al. (2019). Prospective study of biomechanical risk factors for second and third metatarsal stress fractures in military recruits. J Sci Med Sport 22(2), 135-9.

[146] Havenetidis, K., Paxinos, T. (2011). Risk factors for musculoskeletal injuries among Greek Army officer cadets undergoing Basic Combat Training. Mil Med 176(10), 1111-6.

[147] Henderson, N.E., Knapik, J.J., Shaffer, S.W., McKenzie, T.H., Schneider, G.M. (2000). Injuries and injury risk factors among men and women in U.S. army combat medic advanced individual training. Mil Med 165(9), 647-52.

[148] Knapik, J.J., Darakjy, S., Hauret, K.G., Canada, S., Scott, S., Rieger, W. et al. (2006). Increasing the physical fitness of low-fit recruits before basic combat training: An evaluation of fitness, injuries, and training outcomes. Mil Med 171(1), 45-54.

[149] Knapik, J.J., Jones, S.B., Darakjy, S., Hauret, K.G., Bullock, S.H., Sharp, M.A. et al. (2007). Injury rates and injury risk factors among U.S. Army wheel vehicle mechanics. Mil Med 172(9), 988-96.

[150] Ma, J.Z., Cui, S.F., Hu, F., Lu, Q.J., Li, W. (2016). Incidence and characteristics of meniscal injuries in cadets at a military school, 2013 – 2015. J Athl Train 51(11), 876-9.

[151] Mahieu, N.N., Witvrouw, E., Stevens, V., Van Tiggelen, D., Roget, P. (2006). Intrinsic risk factors for the development of achilles tendon overuse injury: A prospective study. Am J Sports Med 34(2), 226-35.

[152] Moran, D.S., Evans, R., Arbel, Y., Luria, O., Hadid, A., Yanovich, R. et al. (2013). Physical and psychological stressors linked with stress fractures in recruit training. Scand J Med Sci Sports 23(4), 443-50.

[153] Nunns, M., House, C., Rice, H., Mostazir, M., Davey, T., Stiles, V. et al. (2016). Four biomechanical and anthropometric measures predict tibial stress fracture: A prospective study of 1065 Royal Marines. Br J Sports Med 50(19), 1206-10.

[154] Owens, B., Mountcastle, S., White, D. (2007). Racial differences in tendon rupture incidence. Int J Sports Med 28(7), 617-20.

[155] Parr, J.J., Clark, N.C., Abt, J.P., Kresta, J.Y., Keenan, K.A., Kane, S.F. et al. (2015). Residual impact of previous injury on musculoskeletal characteristics in special forces operators. Orthop J Sports Med 3(11), 2325967115616581.

[156] Rabin, A., Kozol, Z., Finestone, A.S. (2014). Limited ankle dorsiflexion increases the risk for mid-portion Achilles tendinopathy in infantry recruits: A prospective cohort study. J Foot Ankle Res 7(1), 48.

[157] Sobhani, V., Shakibaee, A., Khatibi Aghda, A., Emami Meybodi, M.K., Delavari, A., Jahandideh, D. (2015). Studying the relation between medial tibial stress syndrome and anatomic and anthropometric characteristics of military male personnel. Asian J Sports Med 6(2), e23811.

[158] Trybulec, B., Majchrzak, E. (2016). Injuries and factors determining their occurrence in paratroopers of airborne forces. Balt J Health Phys A 8(2), 78-86.

[159] Heebner, N.R., Abt, J.P., Lovalekar, M., Beals, K., Sell, T.C., Morgan, J. et al. (2017). Physical and performance characteristics related to unintentional musculoskeletal injury in special forces operators: A prospective analysis. J Athl Train 52(12), 1153-60.

[160] Sell, T.C., Clark, N.C., Wood, D., Abt, J.P., Lovalekar, M., Lephart, S.M. (2014). Single-leg balance impairments persist in fully operational military special forces operators with a previous history of low back pain. Orthop J Sports Med 2(5), 2325967114532780.

[161] Allsopp, A.J., Scarpello, E.G., Andrews, S., Pethybridge, R.J. (2003). Survival of the fittest? The scientific basis for the Royal Navy pre-joining fitness test. J R Nav Med Serv 89(1), 11-8.

[162] Billings, C.E. (2004). Epidemiology of injuries and illnesses during the United States Air Force Academy 2002 basic cadet training program: Documenting the need for prevention. Mil Med 169(8), 664-70.

[163] Blacker, S.D., Wilkinson, D.M., Bilzon, J.L.J., Rayson, M.P. (2008). Risk factors for training injuries among British Army recruits. Mil Med 173(3), 278-86.

[164] Havenetidis, K., Paxinos, T., Kardaris, D., Bissas, A. (2017). Prognostic potential of body composition indices in detecting risk of musculoskeletal injury in army officer cadet profiles. Phys Sportsmed 45(2), 114-9.

[165] Kodesh, E., Shargal, E., Kislev-Cohen, R., Funk, S., Dorfman, L., Samuelly, G. et al. (2015). Examination of the effectiveness of predictors for musculoskeletal injuries in female soldiers. J Sports Sci Med 14(3), 515-21.

[166] Kupferer, K.R., Bush, D.M., Cornell, J.E., Lawrence, V.A., Alexander, J.L., Ramos, R.G. et al. (2014). Femoral neck stress fracture in Air Force basic trainees. Mil Med 179(1), 56-61.

[167] Waterman, B.R., Belmont, P.J. Jr, Cameron, K.L., DeBerardino, T.M., Owens, B.D. (2010). Epidemiology of ankle sprain at the United States Military Academy. Am J Sports Med 38(4), 797-803.

[168] Gundlach, N., Sammito, S., Böckelmann, I. (2012). [Risk factors for accidents during sports while serving in German armed forces]. Sportverletz Sportschaden 26(1), 45-8.

[169] Finestone, A., Milgrom, C., Evans, R., Yanovich, R., Constantini, N., Moran, D.S. (2008). Overuse injuries in female infantry recruits during low-intensity basic training. Med Sci Sports Exerc 40(11 Suppl), S630-5.

[170] Krauss, M.R., Garvin, N.U., Boivin, M.R., Cowan, D.N. (2017). Excess stress fractures, musculoskeletal injuries, and health care utilization among unfit and overweight female army trainees. Am J Sports Med 45(2), 311-6.

[171] Hughes, C.D., Weinrauch, P.C.L. (2008). Military static line parachute injuries in an Australian commando battalion. ANZ J Surg 78(10), 848-52.

[172] Burne, S.G., Khan, K.M., Boudville, P.B., Mallet, R.J., Newman, P.M., Steinman, L.J. et al. (2004). Risk factors associated with exertional medial tibial pain: A 12 month prospective clinical study. Br J Sports Med 38(4), 441-5.

[173] Rauh, M.J., Macera, C.A., Trone, D.W., Reis, J.P., Shaffer, R.A. (2010). Selected static anatomic measures predict overuse injuries in female recruits. Mil Med 175(5), 329-35.

[174] Keenan, K.A., Wohleber, M.F., Perlsweig, K.A., Baldwin, T.M., Caviston, M., Lovalekar, M. et al. (2017). Association of prospective lower extremity musculoskeletal injury and musculoskeletal, balance, and physiological characteristics in Special Operations Forces. J Sci Med Sport 20 Suppl 4, S34-S39.

[175] Esterman, A., Pilotto, L. (2005). Foot shape and its effect on functioning in Royal Australian Air Force recruits. Part 1: Prospective cohort study. Mil Med 170(7), 623-8.

[176] Hetsroni, I., Finestone, A., Milgrom, C., Ben Sira, D., Nyska, M., Radeva-Petrova, D. et al. (2006). Prospective biomechanical study of the association between foot pronation and the incidence of anterior knee pain among military recruits. J Bone Joint Surg Br 88(7), 905-8.

[177] Levy, J.C., Mizel, M.S., Wilson, L.S., Fox, W., McHale, K., Taylor, D.C. et al. (2006). Incidence of foot and ankle injuries in West Point cadets with pes planus compared to the general cadet population. Foot Ankle Int 27(12), 1060-4.

[178] Yates, B., White, S. (2004). The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. Am J Sports Med 32(3), 772-80.

[179] Roy, T.C., Knapik, J.J., Ritland, B.M., Murphy, N., Sharp, M.A. (2012). Risk factors for musculoskeletal injuries for soldiers deployed to Afghanistan. Aviat Space Environ Med 83(11), 1060-6.

[180] Grier, T.L., Morrison, S., Knapik, J.J., Canham-Chervak, M., Jones, B.H. (2011). Risk factors for injuries in the U.S. Army Ordnance School. Mil Med 176(11), 1292-9.

[181] Hall, L.J. (2017). Relationship between 1.5-mile run time, injury risk and training outcome in British Army recruits. J R Army Med Corps 163(6), 376-82.

[182] Hauret, K.G., Steelman, R.A., Pierce, J.R., Alemany, J.A., Sharp, M.A., Foulis, S.A. et al. (2018). Association of Performance on the Occupational Physical Assessment Test with Injuries and Attrition During Initial Entry Training – OPAT Phase I: PHR # S.0047229-18b. Aberdeen Proving Ground, MD: U.S. Army Public Health Center. DTIC: AD1061860.

[183] Heller, R., Stammers, H. (2020). Running to breaking point? The relationship between 1.5-mile run time and injury risk in female recruits during British Army basic training. J R Army Med Corps, 166(E), e3-e7.

[184] Knapik, J.J., Hauret, K.G., Arnold, S., Canham-Chervak, M., Mansfield, A.J., Hoedebecke, E.L. et al. (2003). Injury and fitness outcomes during implementation of physical readiness training. Int J Sports Med 24(5), 372-81.

[185] Knapik, J.J., Swedler, D.I., Grier, T.L., Hauret, K.G., Bullock, S.H., Williams, K.W. et al. (2009). Injury reduction effectiveness of selecting running shoes based on plantar shape. J Strength Cond Res, 23(3), 685-97.

[186] Martin, R.C., Grier, T., Canham-Chervak, M., Bushman, T.T., Anderson, M.K., Dada, E.O. et al. (2018). Risk factors for sprains and strains among physically active young men: A US Army study. US Army Med Dep J (2-18), 14-21.

[187] Müller-Schilling, L., Gundlach, N., Böckelmann, I., Sammito, S. (2019). Physical fitness as a risk factor for injuries and excessive stress symptoms during basic military training. Int Arch Occup Environ Health 92(6), 837-41.

[188] Rauh, M.J., Macera, C.A., Trone, D.W., Shaffer, R.A., Brodine, S.K. (2006). Epidemiology of stress fracture and lower-extremity overuse injury in female recruits. Med Sci Sports Exerc 38(9), 1571-7.

[189] Rosendal, L., Langberg, H., Skov-Jensen, A., Kjaer, M. (2003). Incidence of injury and physical performance adaptations during military training. Clin J Sport Med 13(3), 157-63.

[190] Välimäki, V.V., Alfthan, H., Lehmuskallio, E., Löyttyniemi, E., Sahi, T., Suominen, H. et al. (2005). Risk factors for clinical stress fractures in male military recruits: A prospective cohort study. Bone, 37(2), 267-73.

[191] Wyss, T., Von Vigier, R.O., Frey, F., Mäder, U. (2012). The Swiss Army physical fitness test battery predicts risk of overuse injuries among recruits. J Sports Med Phys Fitness 52(5), 513-21.

[192] Finestone, A.S., Milgrom, C., Yanovich, R., Evans, R., Constantini, N., Moran, D.S. (2014). Evaluation of the performance of females as light infantry soldiers. Biomed Res Int 2014, 572953.

[193] Gam, A., Goldstein, L., Karmon, Y., Mintser, I., Grotto, I., Guri, A. et al. (2005). Comparison of stress fractures of male and female recruits during basic training in the Israeli anti-aircraft forces. Mil Med 170(8), 710-2.

[194] Gemmell, I.M.M. (2002). Injuries among female army recruits: A conflict of legislation. J R Soc Med 95, 23-7.

[195] Snedecor, M.R., Boudreau, C.F., Ellis, B.E., Schulman, J., Hite, M., Chambers, B. (2000). U.S. Air force recruit injury and health study. Am J Prev Med 18(3 Suppl), 129-40.

[196] Goss, D.L., Moore, J.H., Slivka, E.M., Hatler, B.S. (2006). Comparison of injury rates between cadets with limb length inequalities and matched control subjects over 1 year of military training and athletic participation. Mil Med 171(6), 522-5.

[197] Knapik, J.J., Canham-Chervak, M., Hauret, K., Laurin, M.J., Hoedebecke, E., Craig, S. et al. (2002). Seasonal variations in injury rates during US Army Basic Combat Training. Ann Occup Hyg 46(1), 15-23.

[198] Mattila, V.M., Parkkari, J., Korpela, H., Pihlajamäki, H. (2006). Hospitalisation for injuries among Finnish conscripts in 1990 – 1999. Accid Anal Prev 38(1), 99-104.

[199] Taanila, H., Suni, J., Pihlajamäki, H., Mattila, V.M., Ohrankämmen, O., Vuorinen, P. et al. (2009). Musculoskeletal disorders in physically active conscripts: A one-year follow-up study in the Finnish Defence Forces. BMC Musculoskelet Disord 10, 89.

[200] Helton, G.L., Cameron, K.L., Zifchock, R.A., Miller, E., Goss, D.L., Song, J. et al. (2019). Association between running shoe characteristics and lower extremity injuries in United States military academy cadets. Am J Sports Med 47(12), 2853-62.

[201] Knapik, J.J., Hauret, K.G., Canada, S., Marin, R., Jones, B. (2011). Association between ambulatory physical activity and injuries during United States Army Basic Combat Training. J Phys Act Health 8(4), 496-502.

[202] Schuh, A., Grier, T., Canham-Chervak, M., Hauschild, V., Roy, T., Jones, B.J. (2017). Risk factors for injury associated with low, moderate, and high mileage road marching in a U.S. Army infantry brigade. J Sci Med Sport Nov, 20 Suppl 4, S28-S33.

[203] Knapik, J., Darakjy, S., Scott, S.J., Hauret, K.G., Canada, S., Marin, R. et al. (2005). Evaluation of a standardized physical training program for basic combat training. J Strength Cond Res 19(2), 246-53.

Chapter 4 – INTERVENTIONS

W.O. Zimmermann, V., Hadžić, T. Karakolis, K.R. Kelly, S.P. Proctor, S. Sammito, B. Sanz-Bustillo-Aguirre, A. Stepens, D. van Tiggelen, and G. White

4.1 SUMMARY

The goal of this chapter is to address the following key points:

- It is possible to reduce musculo-skeletal injuries in the military with a systematic scientific approach;
- Successful implementation of interventions aimed at injury reduction in the military requires critical attention to essential elements, and overcoming specific barriers; and
- NATO member states contributing to this Research Task Group (RTG-HFM-283) report similar musculo-skeletal injury problems, using different definitions, different registration systems and different solutions.

4.1.1 Outline of this Chapter

Part 1: Introduction to the prevention of musculo-skeletal injuries.

Part 2: Interventions in the NATO member states contributing to RTG-HFM-283: examples of success, failure and current directions.

4.2 INTRODUCTION

The impact of Musculo-Skeletal Injuries (MSkI) on military service members and the military health-care system has been described on multiple occasions and by several authors as critical. Four key points to highlight are as follows:

- MSkI are endemic within the military population and they pose the greatest health problem facing military service members during both peacetime and combat operations. MSkI and conditions are also the single greatest threat to military readiness. [1]
- MSkI in the military contribute to the largest number of lost duty days and financial burden more than any other disease or condition. [2]
- MSkI are the primary cause of medical discharge and medical downgrade in the United Kingdom Armed Forces. [3]
- MSkI account for more than 80% of soldiers' injuries and 65% of medically nondeployable in the united States Active Component soldiers. [4]

These points clearly call for action.

Part 1 of this chapter introduces the prevention of musculo-skeletal injuries in general, and specifically in the military. Current recommendations for interventions in the military are discussed, as well as essential elements for successful implementation. Finally, future directions for injury prevention interventions in the military, based on expert opinion, are presented.

In **Part 2** of this chapter, each NATO member state of HFM-RTG-238 presents examples of successful and failed or equivocal interventions to prevent MSkI, along with a description of the current direction their nation's military is taking with respect to the prevention of MSkI. Part 2 of this chapter reveals some unpublished interventions or strategies.

4.3 PART 1: INTRODUCTION TO THE PREVENTION OF MUSCULO-SKELETAL INJURIES

The impact of interventions on MSkIs in the military can be considered on three levels:

1) Primary prevention: Preventing MSkI occurrence;
2) Secondary prevention: Decreasing the impact of existing MSkIs with optimal treatment;
3) Tertiary prevention: Mitigating long-term effects of chronic MSkIs through reassignment to appropriate occupational specialties or medical separation from the armed forces. [4]

Successful risk reduction strategies require robust surveillance. Chapter 2 has already described many of the challenges with injury surveillance, and Chapter 5 will provide some recommendations on interventions to reduce MSkI and the principles to be applied when develop novel interventions. The present chapter will focus on primary prevention strategies.

4.3.1 Primary Prevention Strategies in Sports Medicine and Occupational Medicine

Musculo-skeletal injuries in the military and in sport are both closely associated with physical exertion, even though the type of physical activities vary between disciplines. Often, military personnel acquire their MSkIs from occupational tasks such as loaded road marching and/or lifting heavy objects. Meanwhile, sports injuries, are not restricted to the musculo-skeletal system and can include injuries to the skin or nervous system. A sports medicine approach, focusing on intrinsic risk factors combined with an occupational medicine approach, focusing on extrinsic risk factors are relevant to reduce MSkI in the military.

In 1992, van Mechelen described a four-step 'sequence of prevention' for sports injuries [5]. First, the extent of the injury problem must be identified and described. Second, the factors and mechanisms which play a part in the occurrence of the injuries have to be identified. Third, measures that are likely to reduce the future risk and/or severity of the injuries should be introduced. These measures should be based on the etiological factors and the mechanism identified in step two. Finally, the effect of the measures must be evaluated by repeating the step one. This model has been widely used to implement preventive measures to sports injuries.

Van Tiggelen proposed adding an assessment of efficiency of the intervention and of compliance and risk-taking behavior by the athlete to the model of van Mechelen [6]. The expanded model may better predict the outcome and challenges to implementation of an intervention to prevent injuries.

More recently, the model by van Mechelen was further challenged by stating that step two, the search for isolated risk factors for MSkIs, might be too simplistic. The cause of non-traumatic injuries is nearly always multifactorial and can better be described as "a complex interaction among a web of determinants." This means prevention strategies should not focus on isolated risk factors, but on altering risk patterns [7]. In Chapter 3, a model was introduced that illustrates the interplay and order of importance of risk factors for MSkI in the military. Complex problems, like primary injury prevention in the military, require an intense effort by a multidisciplinary team [8], [9].

4.3.2 Injury Prevention in the Military: A Summary of Reviews

Over the years, many successful interventions have been implemented in the military to reduce the impact of MSkI. By systematically addressing this issue, the percentage of MSkIs in specific military subpopulations have decreased [2], [10]. Several authors have even undertaken a systematic review of injury prevention strategies for military personnel [3], [11], [12]. These reviews and other studies cited below were used to identify prevention strategies that can be recommended, those that need more proof, and those that are not recommended or, possibly harmful.

To gain an appreciation for the strength of the science of a single intervention study, it must be qualitatively rated. Items to be qualitatively scored include sample, design, method and statistical analysis [11]. A study must show effectiveness of the intervention with pre-post changes in injury occurrence, or a difference in injury occurrence between control and intervention groups [3]. Once scored, interventions can be grouped and recommendations can be given per group of interventions.

4.3.3 Evidence-Based Recommendations

The following tables show interventions recommended (Table 4-1) and not recommended (Table 4-2) in two systematic reviews for the most effective injury prevention strategies within military populations. The Wardle and Greeves 2017 report [3] provides an updated position to the work of Bullock et al. 2010 [11]. Table 4-1 shows that the two independent reviews may not come to the exact same recommendations, as additional studies after 2010 have shown mixed results for multiaxial, neuromuscular, proprioceptive and agility training, and the reduction of injury rates could no longer be supported by the evidence. Leadership, supervision and awareness, recommended by Wardle and Greeves are, as previously proposed by Bullock et al., probably best considered essential elements of all injury prevention efforts.

Table 4-1: Recommended Interventions to Reduce Training Injuries in the Military, Drawn from Two Systematic Reviews.

Bullock et al. 2010	Wardle and Greeves 2017
Prevent overtraining (1)	Reduce physical activity volume (1)
	Improve baseline physical fitness (pre-accession) (2)
Perform multiaxial, neuromuscular proprioceptive and agility training (2)	
Wear mouth guards during high-risk activities (1)	
Wear semi-rigid ankle braces for high-risk activities (1)	Ankle bracing (potential to recommend for some populations) (1)
Wear synthetic-blend socks to prevent blisters (1)	
Consume nutrients to restore energy balance within 1 hour following high-intensity activity (2)	
	Leadership / supervision / awareness (1)

(1) 1st order risk factor intervention, as described in Chapter 3.

(2) 2nd order risk factor intervention, as described in Chapter 3.

Table 4-2: Not Recommended Interventions to Reduce Training Injuries in the Military, Drawn from Two Systematic Reviews.

Bullock et al. 2010	Wardle and Greeves 2017
Back braces, harnesses, support belts (1)	
Pre-exercise anti-inflammatory medication (2)	
	Footwear modification (1)

(1) 1st order risk factor intervention, as described in Chapter 3.

(2) 2nd order risk factor intervention, as described in Chapter 3.

Figure 4-1 places the recommended interventions in the model introduced in Chapter 3; where risk factors are placed in circles representing order of importance.

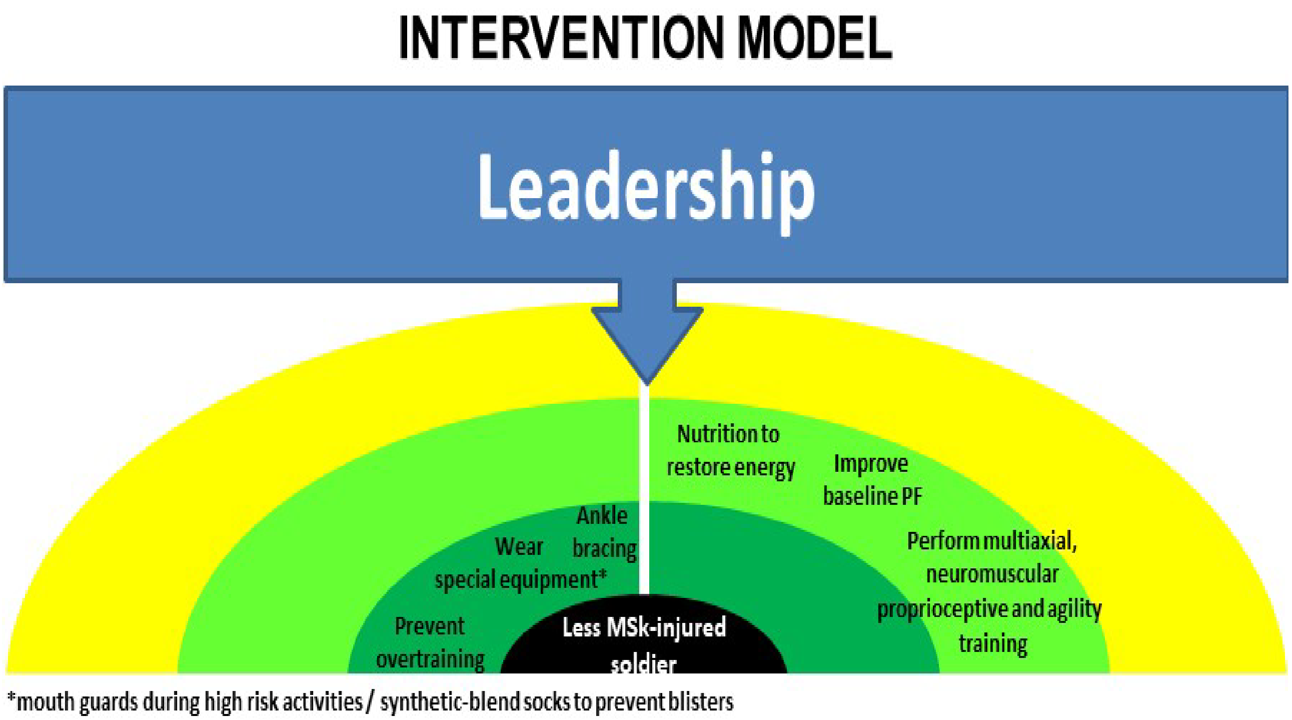

Figure 4-1: Recommended Interventions. *Note this model represents the top-half of the injury model, as introduced in Chapter 3. Risk factors to be addressed are placed in circles around the injured soldier. The circles represent order of importance: 1st order = inner circle; 2nd order = middle circle; 3rd order = outer circle. Leadership is all-important for every attempt at intervention. The left quadrant is modifiable extrinsic risk factors and the right is modifiable intrinsic risk factors.

In a recent assessment of possible options to reduce the incidence of MSkI in the British Army [13], interventions were grouped into eight categories:

1) Physical training;
2) Chain of command;
3) Individual work capacity;
4) Life and culture;
5) Workplace provisions and equipment;
6) Psychological factors;
7) Nutrition and hydration; and,
8) Sleep.

Presenting more types of possible interventions than included in the previously cited systematic reviews may help to formulate prevention strategies that cover a wider variety of risk factors and provide a greater opportunity of success than those which focus on a single risk factor.

4.3.4 Prioritizing Interventions

If policymakers must prioritize among health problems that are competing for resources, this can be done based on a predetermined scoring system with the following five factors [14]:

1) Importance of the problem;
2) Effectiveness of the prevention strategy (preventability);
3) Feasibility of establishing the program;
4) Timeliness of implementation;
5) Potential for evaluation.

4.3.5 Essential Elements for Injury Prevention Efforts in the Military, Overcoming Barriers

Implementing injury prevention programs in the military is not simply introducing a policy change top-down. Education, surveillance, leadership support, and adequate resources for research and program evaluation are each considered essential elements for program success [2]. Education includes providing information on proven strategies for the prevention of injury to those who deliver training programs, and military instructors who are responsible for training soldiers at all levels. However, without adequate (standardized and regular) surveillance or tracking of MSkI rates, it is difficult to determine the magnitude of the MSkI problem in the military. Surveillance provides the critical foundation for identifying problem areas, informing improvement strategies and evaluation. Leadership focus at all levels of the organization, from the highest-level military commanders to the squad leader, has large influence on MSkI rates and may be crucial for injury prevention success [2]. Key to obtaining leadership support is aligning the mutual goal of injury prevention with the overall mission of military leaders (i.e., operational readiness). Finally, adequate resources for research and program evaluation are necessary to regularly report injury data through the chain of command [2].

Even if interventional programs have demonstrated efficacy in clinical studies, successful implementation of these programs on a community, state, or national scale is not certain [15]. Through the process of translating research into injury prevention practice, the following military potential barriers may be encountered:

1) At the corporate or strategic level (policy makers, senior officials, etc.);
2) At the organizational or operational level (medical treatment facilities, operational level units, etc.); and
3) At the individual or tactical level (health-care providers, service members, family members, tactical level units, etc.).

Detailed recommendations to overcome these barriers are available from Teyhen et al. [15]. Recommendations to overcome these barriers are also contained in Chapter 5 of this report. In summary, for each different component of the military, it is essential to modify the intervention and measure effectiveness in that particular environment.

4.3.6 Injury Prevention in the Military: Future Directions and Expert Opinion

In the discussion section of several recent review papers, the authors often take the opportunity to provide guidance for future research in the area of injury prevention in the military. Following is a summary of proposed research questions to address the gap in knowledge:

- **Cameron and Owens, 2014 [1]**
    - Can introducing the sports medicine model on base (an "open bay training room," with a multidisciplinary team of health-care providers) reduce MSkI risk and improve treatment?
    - Can embedded athletic trainers in the field environment at key training sites reduce MSkI?
    - Can more primary care sports medicine physicians on base reduce MSkI?
- **De la Motte and Oh, 2016 [2]**
    - Can biochemical markers provide early indicators of MSkI risk?
    - Can individuals at high risk for MSkI be identified by movement screening before the start of training?
    - Can increasing recruit fitness criteria reduce MSkIs? Pre-conditioning can be offered for interested applicants before the official entry into service.
- **Wardle and Greeves, 2017 [3]**
    - What are the best ways to influence leadership?
    - Should there be separate injury prevention interventions for men and women?
    - Single sex training: is it beneficial if women train in separate groups?
- **Dijksma et al., 2020 [12]**
    - Can a diagnosis specific prevention approach contribute to overall MSkI rate?
    - Can gait retraining contribute to reduction of MSkI rate?
    - Can agility and neuromuscular resistance training contribute to reduction of MSkI rate?

4.4 CONCLUSION

MSkIs in the military can be reduced using a systematic scientific approach, with input from sports medicine and occupational medicine approaches. Part 1 of this Chapter provided an introduction into the scientific foundation and current views on MSkI prevention in the military.

4.5 REFERENCES (PART 1)

[1] Cameron, K.L., Owens, B.D. (2014). The burden and management of sports-related musculoskeletal injuries and conditions within the US military. Clin Sports Med 33, 573-589.

[2] De la Motte, S.J., Oh, R. (2016). Successful injury prevention interventions (Chapter 15). In K.L. Cameron and B.D. Owens BD (Eds), Musculoskeletal Injuries in the Military. Springer Science + Business Media, New York.

[3] Wardle, S.L., Greeves, J.P. (2017). Mitigating the risk of musculoskeletal injury: A systematic review of the most effective injury prevention strategies for military personnel. Journal of Science and Medicine in Sport 20, S3-S10.

[4] Molloy, J.M., Pendergrass, T.L., Lee, I.E., Hauret, K.G., Chervak, M.C., Rhon, D.I. (2020). Musculoskeletal injuries and United States Army readiness. Part II: management challenges and risk mitigation initiatives. Mil Med Sep 18, 185(9-10):e1472-e1480.

[5] Van Mechelen, W., Hlobil, H., Kemper, H.C. (1992). Incidence, severity, etiology and prevention of sports injuries. A review of concepts. Sports Med 14, 2, 82-99.

[6] Van Tiggelen, D., Wickes, S., Stevens, V., Roosen, P., Witvrouw, E. (2008). Effective prevention of sports injuries: A model integrating efficacy, efficiency, compliance and risk taking behavior. Br J Sports Med 42, 648-652.

[7] Bittencourt, N.F.N., Meeuwisse, W.H., Mendonca, L.D., Nettel-Aguirre, A., Ocarino, J.M., Fonseca, S.T. (2016). Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition – narrative review and new concept. Br J Sports Med 50, 1309-1314.

[8] Schwartz, O., Libenson, T., Astman, N., Haim, L. (2014). Attrition due to orthopedic reasons during combat training: Rates, types of injuries, and comparison between infantry and noninfantry units. Mil Med 179, 8, 897-900.

[9] Van der Beek, A.J., Dennerlein, J.T., Huysmans, M.A., Mathiassen, S.E., Burdorf, A., van Mechelen, W. et al. (2017). A research framework for the development and implementation of interventions preventing work-related musculoskeletal disorders. Scand J Work Environ Health 43, 6, 526-539.

[10] Heagerty, R.D.H., Sharma, J. (2018). Musculoskeletal training injury in military recruit populations: An integrated prevention strategy-project OMEGA (Part 1). Int J Phys Med & Rehab 6, 1.

[11] Bullock, S.H., Jones, B.H., Gilchrist, J., Marshall, S.W. (2010). Prevention of physical training-related injuries. Am J Prev Med 38, 1S, S156-S181.

[12] Dijksma, I., Arslan, I.G., van Etten-Jamaludin, F.S., Elbers, R.G., Lucas, C., Stuiver, M.M. (2020). Exercise programs to reduce the risk of musculoskeletal injuries in military personnel: A systematic review and meta-analysis. PM&R Oct;12(10):1028-1037 doi: 10.1002/pmrj.12360. Epub 2020 Apr 22.

[13] Risius, D., McQueeney, S. (28 Feb 2018). Evidence-based options for reducing musculoskeletal injuries within the British Army. Unpublished report: DSTL/TR 106603.

[14] Canham-Chervak, M., Hooper, T.I., Brennan, F.H., Craig. S.C., Girasek, D.C., Schaefer, R.A. et al. (2010). A systematic process to prioritize prevention activities. Am J Prev Med 38, 1S, S11-S18.

[15] Teyhen, D.S., Goffar, S.L., Pendergrass, T.L., Shaffer, S.W., Butler, N. (2016). Overcoming barriers to injury prevention in the military (Chapter 16). In K.L. Cameron and B.D. (Eds), Musculoskeletal Injuries in the Military. Springer Science + Business Media, New York, 2016.

4.6 PART 2: INTERVENTIONS IN THE NATO MEMBER STATES CONTRIBUTING TO HFM-RTG-283: EXAMPLES OF SUCCESS, FAILURE, AND CURRENT DIRECTIONS

In Part 2, each NATO member state contributing to HFM-RTG-283 answered the following questions:

1) Please provide an example of an intervention implemented by your nation that was very successful in reducing musculo-skeletal injuries. Preference is for an intervention that was not published already (250 – 500 words);
2) Please provide an example of an intervention implemented by your nation that was not successful in reducing musculo-skeletal injuries or the results are still pending. Preference is for an intervention that was not published already (250 – 500 words);
3) Please describe the current direction your nation is taking with respect to the prevention of musculo-skeletal injuries. Please highlight if there is a difference between the scientific approach versus the applied approach (250 – 500 words).

4.6.1 Belgium

D. Van Tiggelen

Successful Intervention

The incidence of foot blisters and other overuse injuries of the lower limb is very high during Basic Military Training (BMT) and during military operations. One hundred and eighty-nine subjects were divided into two intervention groups wearing alternative sock systems and one control group. Overall, 57% of the 173 recruits who completed the training, developed foot blisters. Binary logistic regression revealed the type of sock, race, previous hiking or military experience, and known orthopedic foot conditions to be predictive variables for foot blisters. Fifty-three percent of the 173 recruits also developed another overuse injury of the lower limb (25.4% related to the knee joint). Previous military or hiking experience and the association of foot blisters revealed to be predictive for the overuse injuries of the knee joint. The results of the present study suggest associated foot blisters are also an important factor in the development of overuse injuries of the knee joint during BMT [1].

Unsuccessful Intervention

The Functional Movement Screen (FMS) has been used to screen 110 infantry recruits before Basic Military Training (BMT) of three months [2]. Besides the FMS anthropometrical data were collected as well as lifestyle data (smoking habits, injury history, and nutritional habits). Results found that 29% of the recruits sustained an overuse injury during BMT and over 50% of the encountered injuries were located in the foot and ankle. The FMS prior to BMT did not reveal to be different between the prospective injured and uninjured group. The mean value of the sum score of the FMS was 15.4 (+/- 2.01) for the injured group and 15.6 (+/- 2.48) for the uninjured group. And moreover, there is no prediction of injuries possible using the sum score of the FMS. The only factor remaining significant in the binary logistical regression was the score of the military physical fitness test which consists of a 2400 m run and the McGill side bridge test. The use of the FMS, which is rather time consuming, has been abandoned to screen recruits at entry [3]. The pre-entry general physical fitness level seems to be important and predictive for injuries in military recruits.

Description of Current Direction

The current and future research trends in musculo-skeletal injury prevention in the Belgian Defence is to monitor variables instead of performing pre-training screening. A pre-training screen is a temporary snapshot, whereas the variables measured in recruits are dynamic and therefore adaptive. The intention is to study performance fluctuations during training programs, using wearable devices such as IMU with or without a GPS-combination. The measurement of internal and external loads is widely used in professional sports. Measuring external load is important to understand the training program and the overall capacity of the recruits. The internal load is equally important to understand the imposed stress on the recruit, whether this stress is physiological or psychological. The combination of both types of loads is important in the monitoring of military training programs. Athletic or tactical performance of a soldier depends on physical fitness, mental resilience, rest and recovery as well as nutrition and hydration [4], [5]. All of these components are frequently challenged during entry training, which could lead to fatigue and potentially to injuries. A good balance should therefore be found to have optimal training programs for recruits where all variables are taken into account and sufficiently challenged in order to obtain a decent military training.

4.6.2 Canada

T. Karakolis

Successful Intervention

The most recent published comprehensive data set collected by the Canadian Armed Forces (CAF) on Musculo-Skeletal Injuries (MSkIs) is contained within the 2013/2014 CAF Health and Lifestyle Information Survey report [6]. In this report, there was a marked increase in the rates for reported Repetitive Strain Injuries (RSIs) across all body parts, when comparing the 2013/2014 survey results to the results of the 2008/2009 survey. The report also surveyed members of the CAF to determine which activities the members were engaging in that they attributed to causing their RSIs. The report found that Physical Training (PT), sports, and military training were the most common activities attributed to RSIs. As a result of these findings, the CAF has begun a pilot program to improve the strength and conditioning knowledge and practice received by new recruits during their basic military qualification course.

The pilot program was first initiated in 2019 with reservist recruits at Canadian Forces Base (CFB) Meaford. The program is not a unique training program created by the CAF, or specifically for the CAF. Instead, the program relies on well-published principles for training in a manner, with appropriately graded prescriptions that allow the trainees to build capacity within their musculo-skeletal tissues to withstand mechanical loading, without overloading the tissue to the point where injury will occur [7]. Many of the prescribed training exercises are described and illustrated in the *Practical guidelines for implementing a strength and training program for adults* [8].

Research on the effectiveness on the program is ongoing, with a multi-year longitudinal study currently taking place. The study is designed as a randomized control trial where one group is prescribed the novel training program, with the other group undergoing normal PT for the BMQ traditionally run for reservists at CFB

Meaford. Preliminary results are promising with self-reported cases of RSIs in the novel training group already being lower than the traditional group. Furthermore, additional dependent metrics are being collected to assess the potential performance benefits or drawbacks that may be associated with the novel training program. Preliminary results for the performance metrics are also promising with the novel training group showing improvements in strength, power, balance, and agility.

Although everyone in the study's research team concedes all results are still preliminary, and further research is still required, it does appear that the novel training program is beneficial. This preliminary evidence continues to support the idea that a holistic approach that includes well known best practices for strength and conditioning training can be successful in reducing the rate of RSIs in a military population. Further research is still required on the implementation of such programs to result in the maximum benefit that can be achieved.

Unsuccessful Intervention

In 2004, the Royal Canadian Air Force (RCAF) conducted a survey to determine the rate of musculo-skeletal pain and injury in the neck and back of rotary wing aircrew, including pilots and flight engineers [9]. This report revealed that 75 – 80 %of rotary wing aircrew that wore night vision goggles experienced some form of neck pain or injury during their careers. In 2014, the RCAF conducted a follow-up survey to assess the change in rate of neck pain or injury in the preceding 10 years [10]. Although a number of interventions were undertaken during the preceding years, surprisingly the rate of pain or injury remained stubbornly constant for aircrew, at a rate of 75 – 80 %. The following paragraphs will describe two interventions undertaken that were not able to reduce the incidences of neck pain or injury.

The first intervention taken was to replace the in-service helmet used by the aircrew for the CH-146 Griffon helicopter. A new helmet was procured that was considerably lighter than the in-service helmet used during and prior to the 2004 survey. The theory was that a lighter helmet would reduce loading the musculo-skeletal tissues of the neck and spine, resulting in a reduction in pain and injury rates. Unfortunately, the inertial properties for the new (lighter) helmet were not considered. The new lighter helmet had a weight distribution that was concentrated further from the neck joint center of the wearer. This resulted in a helmet system that could be considered as having a higher moment of inertia while being worn. Since rotary wing aircrew, both pilots and flight engineers, have relatively dynamic tasks when flying (ex. outside scanning, checking instruments, checking slung loads), the inertial properties of the helmet system become very important. The most likely reason the new lighter helmet did not reduce the incidences of pain and injury was the benefit of reducing neck joint loading caused by a lighter helmet was offset by the increase in neck joint loading caused by higher inertia during dynamic movements.

The second intervention taken between 2004 and 2014 was an exercise intervention, based on previously reported work in the scientific literature [11], with the goal of strengthening the musculo-skeletal tissue in the neck. Ultimately, this intervention also proved to be unsuccessful but the reasons are somewhat complex. Compliance proved to be the most glaring reason for lack of success. Although official results have not been published for this intervention, anecdotal evidence suggests that compliance to the exercise program was extremely low. One potential reason for low compliance was lack of instruction/coaching throughout the program. Again, based on anecdotes, the aircrew that participated in this program where given the program and equipment required at the onset, and then only followed up with periodically throughout the intervention. There was no consistent dialogue between the group prescribing the exercise/intervention and the aircrew being asked to comply. This can be one very important lesson taken from this intervention. Further to simply having a null effect caused by lack of compliance, an inadequate level of interaction between strength and conditioning trainers and military members (ex. aircrew) can potentially lead to further injuries. The goal of any strength and conditioning intervention must always be to increase the capacity of musculo-skeletal tissue, not necessarily to increase strength.

Description of Current Direction

Currently the Canadian Department of National Defence has a working group with the aim of preventing MSkIs in the CAF. One of the major goals of this group is to create a true injury surveillance system to better understand the context surrounding the most prevalent types of MSkIs.

Concurrently, and with the injury surveillance data that already exists, it is hoped that future CAF interventions will take a holistic approach to areas where MSkIs have been found to be most prevalent.

The goals of any future intervention should be to target one, two, or all three of the following areas:

1) Increase tissue capacity of musculo-skeletal system;
2) Where possible during training and operations, reduce the mechanical demands placed on biological tissues; and
3) Where possible, incorporate sufficient rest and recovery for the musculo-skeletal system.

4.6.3 Germany

S. Sammito

Successful Intervention

The number of MSkI during basic training in the German Armed Forces is comparable to other NATO Armed Forces. In 2018, the basic training of army recruits was changed. During a pilot phase, recruits were placed in training groups according to physical fitness level. Previously, high and low physical fitness candidates trained in one group. In addition, the number of physical training hours was increased from 70 hours to 110 hours, over the three months of basic training. Each training session was supervised by a physical fitness trainer and during the first six weeks of basic training, no physical activities in combat dress were performed but in sports clothes only. In comparison to a control group, who performed the traditional training regimen, the intervention group showed a larger increase in physical fitness and less duty days lost for medical reasons.

Intervention Pending

In the German Air Force, the high demands on pilots have been recognized for several years. Because of this, special groups for “Human Performance Optimization” with a physiotherapist and a sport science officer were established in each squadron, in close cooperation with the flight surgeon. This project will be evaluated with the aim to reduce chronic MSkI in military pilots and to increase the physical fitness of this specific group of military personnel.

Description of Current Direction

Focus will be on improving the physical fitness training and a special group of physical fitness instructors will be created to manage and to lead the physical fitness training in units with high physical requirements.

4.6.4 Latvia

A. Stepens

Overview

So far, no research has been done to assess the efficacy of any kind of intervention on musculo-skeletal injuries in the Latvian National Armed Forces (NAF). In general, physical fitness and sports activities are organized and directed with an emphasis on common group activities on a squad or platoon level. Grouping according to the individual's physical condition is infrequent, such training is organized in separate units only, where instructors have the appropriate education to provide physical training.

Description of Current Direction

Given that in the approximately 25% of newcomers who do not pass a basic training course, the main reason for leaving the forces is either a poor physical capacity or a medical issue (not analyzed in detail), in 2018 the "NAF physical readiness concept for 2018 – 2028" was developed. It stipulates that NAF units should create formal positions for sports instructors. Only individuals with an appropriate education are to be appointed. In collaboration with the Latvian Academy of Sport Education, the NAF organizes a specialized two month training course for soldiers /sports instructors, so they can obtain a category "C" coaching license.

In 2018, at the National Defense Academy (NDA) a Physical Training and Sports Study Course was created, attracting officers and instructors with a sports coach and implementing an educator-education strategy. Since then, physical exercises are organized by dividing cadets into smaller training groups according to the individual's physical fitness level. Following the basic principles of sports training theory, improvement in the physical fitness level of NDA cadets was observed, but the impact on musculo-skeletal injuries was not analyzed.

Since 2019, all NDA cadet candidates have had a 2-week entry training course at the NAF Infantry School, to help cadet candidates cope with the specific and increased physical activities in the military.

4.6.5 Slovenia

V. Hadžić

Slovenia joined NATO in 2004 and has a specific injury reporting system that registers only injuries that cause soldiers to miss three days from work or more. This means that time loss injuries, usually acute injuries, are properly registered, while there is a likelihood that overuse injuries are overlooked and underreported [12].

Successful Intervention

In 2017, a prevention program was introduced in Slovenia for the first time – "Prevention of Musculoskeletal Injuries in the Slovenian Armed Forces" (SAF), which was completed in 2018 [13].

The primary aim of the program was to lower the rate of ankle and knee injuries through implementation of a preventive exercise program. The program was designed as a prospective randomized controlled trial with two arms, experimental and control. The experimental group was training according to a specific 12-week functional training program (6 exercises, 2 times a week, progressive, functional), while the control group trained according to the standard SAF training routine. Standard SAF routine consists of five 1-h training sessions per week. In the experimental group only two of five training sessions were modified. Prior and following the intervention both groups underwent the Army Physical Fitness Test (APFT) and Functional Testing (FT) [14].

Preliminary results show that:

1) The intervention was successful in improving physical performance of soldiers;
2) That performing strength training had a positive effect on the performance of overweight soldiers, and
3) That even a basic strength training improves jumping capacity although the improvements were modest [15], [16].

However, the intervention did not reduce acute injuries. In the experimental group, injury incidence decreased from 3.2% to 1.6%, while in the control group injury incidence rate increased from 2.4% to 7.1%. This represented merely a positive trend, not a significant difference ($p>0.05$ for all within and between group comparisons).

There are several possible explanations for the lack of preventive effectiveness. First, the overall volume of preventive training that was implemented might have been too low in comparison with other studies that had positive findings (frequency and duration of each session). Second, as explained before, the registration of time loss injuries most likely under reported overuse injuries.

New studies are under way that address these limitations [17].

Prior to this prevention program there were no systematic interventions in the SAF directed toward the prevention of MSkI. So, this result could be an example of both a successful intervention, in regard to performance, as an unsuccessful intervention, in regard to injury reduction.

4.6.6 Spain

B. Sanz-Bustillo-Aguirre

Successful Intervention

Between November 2014 and January 2017, at one of Spain's military academies it was determined that wear out of the army walking boots was statistically significantly higher for light boots (81.7%) versus waterproof breathable Gore-Tex boots (18.3%). All reported cases of heel region skin abrasions were attributed to light boot's deterioration; none to Gore-Tex boots. After analysis carried out by the engineering team of the Quartermaster Corps, through the corresponding PRs, suppliers were requested to modify light boot's design and internal structure by improving the synthetic thermoplastic posterior buttress in terms of thickness (1.5 mm ± 0.2 mm), edge tapering and dimensions (minimum required to comply with its protective function) and not to interfere with the rest of the boot's components or with the user's comfort. No heel skin abrasions have been reported since these requirements were implemented, highlighting success of the intervention to reduce these MSkIs. This is a major landmark since light boots represent one of the most relevant parts of equipment used during military instruction and the pain evoked by heel skin lesions is known to alter lower limb biomechanics and may possibly lead to other MSkIs.

Unsuccessful Intervention

In February 2018, Achilles tendinopathy was diagnosed in 37.14% of Army recruits of three military companies following instruction (four 20-km topographic routes, and one 15-km and one 20-km marches). All cases were associated with the use of two types of army walking boots: light boots (56.4%) and waterproof breathable Gore-Tex boots (43.6%). These figures constitute a considerable rise compared to previous years and under similar environmental conditions. These MSkIs imply not only loss of training days but also negative effects on performance, motivation and fitness, both at the individual and at the collective level of the military unit. There is an ongoing process to implement preventive measures aimed at the boots' remodeling and at a more progressive usage of boots in order to facilitate recruits' adaptation. Data are still under analysis, but preliminary findings suggest that further investigation is needed to adequately address these MSkIs.

Description of Current Direction

The Spanish Army is considering a Dynamic Weight Distribution (DWD) system as a potentially useful tool for soldiers carrying out functions in static postures and/or performing long marches. The DWD system consists of a special belt with an attached telescopic flexible spine bar that can be extended or shortened in order to distribute the load being carried between the shoulders and the hips to suit the individual's proportions. The system is easily operated by simply pressing a button via the control unit. This exoskeleton provides comfort and allows natural movement of the body. Therefore, this equipment could be beneficial to reduce the impact of load carriage, especially on back and lower limb MSkIs.

4.6.7 The Netherlands

W.O. Zimmermann

Successful Intervention

Until 1998, recruits in the Netherlands were screened by physicians with a system focused on diagnosis and detection of diseases and infirmities [18]. Admission was determined on the basis of a predetermined list of medical conditions. This system bore no relation to actual military tasks. A new medical preemployment assessment system was developed with 43 job requirements. The new assessment system examined whether the medical anomalies caused restrictions in terms of job requirements. In a prospective, two year study, the two preemployment assessment systems were compared for their ability to predict fitness for duty in general and deployment in particular. The new preemployment assessment evaluation was a better predictor. In summary: A preemployment assessment system based on job requirements is a better predictor of fitness for duty and deployment than a system based on detection of diagnoses.

Unsuccessful Intervention (1)

In the Netherlands thousands of high school students participate each year in full-time pre-military training programs. The main goal is to provide a military-like preparation program to youngsters not old enough to apply for formal military training and employment (minimum age 17.5 years old). The program is 40 hours per week, during the academic year from September through May and offers daily classroom and field instructions, in alternation. In order to reduce exercise-related leg pain, Medial Tibial Stress Syndrome in particular, and drop out from the program, the head instructor of a single school proposed students wear sport compression stockings (European pressure class 2, 23 – 32 mm Hg) all day. In the intervention group (n = 19) all participants wore the stockings, in the control group (n = 17) none of the students wore the stockings. Both groups participated in a very similar training program, at the same school. Both groups developed symptoms of MTSS as diagnosed by a physician, the intervention group earlier in time, three students in the intervention group dropped out from the school. Four months into the study all but one student in the intervention group had decided to stop wearing the compressions stockings, mainly due to lack of comfort. In summary: Wearing sport compression stockings did not reduce the incidence of Medial Tibial Stress Syndrome during pre-military training. Mainly due to lack of comfort during prolonged wear, study participants gradually declined to wear the socks [19].

Unsuccessful Intervention (2)

One of the criteria to qualify for participation in Basic Military Training (BMT) of a special infantry unit in the Netherlands is the ability to run 2700 meters within 12'00". Sometimes several months pass between the testing days and the actual start of BMT and candidates lose fitness. It is estimated that 18% of all recruits that show up to this particular training course can no longer achieve this time standard for the 2700 m run at day one of BMT, they have become "low-fit" candidates. Since low aerobic fitness is associated with a larger risk of injury and drop out from BMT the goal of the intervention was to improve fitness of the low-fit candidates, before starting BMT. The intervention group, which included 26 low-fit candidates (average 2700 meter time 13'26"), were given a 7 – 12 week conditioning program. Twenty-three low-fit candidates, the control group (average 2700 meter time 13'16"), were admitted to BMT without extra training. The conditioning program increased the average 2700 meter time for the intervention group significantly to 11'34". Despite the extra conditioning, the passing rate of BMT in the intervention group was 8/26 (30.8%) and in the control group 8/23 (34.8%). The number of injuries and the number of training days lost was only slightly less in the intervention group. In summary: a pre-training conditioning program for low fitness infantry recruits was able to increase fitness above entry criteria. However, it did not reduce injuries and drop out from elite basic infantry training [20].

Description of Current Direction

It is difficult to hire enough young people for all job openings in the Netherlands Armed Forces (NAF). Obstacles to candidates willing to enter the armed forces, including medical testing with the goal of reducing MSkI, will be kept to a minimum. As of 01 January 2018, new pre-accession fitness tests have been introduced, among these: loaded road marching, lifting/carrying weights, a 12-minute run, a digging test, indoor physical skill tests (e.g., climbing, crawling, etc.). The intention of the tests is to be sex-neutral and to better predict occupational success in specific military occupational specialties than the previous set of pre-accession physical tests. Based on the results on these fitness tests, candidates will be grouped into six categories of fitness, where category 1 represents the light military specialties and category 6 special (fighting) forces.

Weekly monitoring state of mood of recruits, once they are in training, has been introduced. It is believed that imminent drop out from training can be predicted by decreasing mood scores on a simple weekly survey.

More effort will be put into increasing the quality of MSkI care (secondary prevention). Physicians and therapists are encouraged to raise their level of competency. Scholarships are available for individuals willing to pursue a master's degree, doctoral degree and research.

4.6.8 United States

Successful Intervention – US Army

S.P. Proctor

Intervention: Pre-enlistment physical test battery (Occupational Physical Assessment Test (OPAT)) requirement of standards to meet before entry into Army service.

The U.S. Army designed and implemented the Occupational Physical Assessment Test (OPAT) as a sex-neutral pre-enlistment physical test battery to match Soldiers with the appropriate military occupational specialty with the aim of reducing Musculo-Skeletal Injury (MSkI) and attrition during Initial Entry Training (IET). The OPAT consists of four fitness tests: the Seated Power Throw (SPT), Standing Long Jump (SLJ), Strength Deadlift (SDL), and Interval Aerobic Run (IAR) [21]. As of January 2017, the US Army requires all future Soldiers receive passing scores on all four OPAT tests before entering the Army and IET. Those persons not able to meet threshold performance criteria on all four tests are not permitted to enter IET. However, unlimited OPAT attempts are allowed, and further training until a successful OPAT score is attained allows recruits to enter IET with improved physical fitness. Prior to 2017, the US Army did not examine physical fitness performance prior to military service.

Because widespread implementation of the OPAT is relatively new, available data on efficacy of reducing MSkI and attrition rates are limited. The OPAT Longitudinal Validation Study conducted by the US Army Research Institute of Environmental Medicine was carried out to validate the 4-event OPAT as a predictor of high physical demand Soldier task performance [21]; the study also evaluated the relationship between OPAT performance and MSkI and attrition during IET in the study cohort (n = 1,182). The study found that lower OPAT scores at the start of IET were associated with more injuries during IET – in both males and females. In terms of specific test results, lower IAR scores were associated with higher injury prevalence, and in males, lower SDL and lower composite OPAT scores were associated with increased injury prevalence [22], [23]. In a 2-year follow-up of this cohort, Soldiers who scored lower on the SPT and IAR at the start of IET compared to those with better performance scores, were found to have higher attrition rates [24].

The U.S. Army continues to monitor the efficacy of the OPAT across the new Soldier population, since 2017, using MSkI and attrition data as outcome measures.

Summary: Research and practice within US Army cohorts studied supports that the introduction of the OPAT as an intervention has worked to reduce military MSkI.

Successful Intervention-US Marine Corps

K.R. Kelly

Intervention: Development of Military Specific Physical Screening (MSPS) and Force Fitness Readiness Center (FFRC).

The U.S. Marine Corps designed and implemented MSPS in 2016 as a tool to enhance physical screening and to provide reasonable assurance that Marines have the physical capacity to perform in physically demanding Military Occupational Specialties (MOS) which are identified as infantry, artillery and tank. This battery of tests was developed to test physical performance on critical skills required in combat arms position and to reduce injury via ensuring proper fitness to handle the repetitive physical load that is place on the body in these demanding occupations. The thrust of the effort was aimed at readiness; however, a sub-objective was to reduce injury and risk of injury in individuals that were not at a physical standard necessary for these demanding occupations. The results from these tasks are combine with data from the initial screening test (1.5 mile run, pull-ups and sit-ups) physical fitness test (3 mile run, pull-up, sit-ups) and combat fitness test CFT) which is a three part functional fitness assessment. The CFT is comprised of three events completed in succession: a Movement to Contact (880 yd run); ammo can lift (two minute repetitive lift of 30 lb. ammo can from shoulder to overhead); and Maneuver Under Fire (300 yd shuttle run that includes crawls, sprints, fireman's carry, simulated grenade throw, and ammo can carry). Marines must pass the MSPS in order to hold that particular MOS or they will be reclassified. Data from 2018 demonstrates that out of 30,244 students tested:30,224 only 150 had to be reclassified based upon these new standards. However, due to the recent implementation of these MSPS, data on injury prevention is not available. Data from Marine Corps Recruit Depot-San Diego suggest that there is a reduction in Musculo-Skeletal Injury (MSkI) from 2017 – 2019 [25] which coincides with the introduction of the MSPS (Figure 4-2). Data from this report also show that those that are more fit sustained fewer injuries with the strongest effects being elucidated from the CFT.

In addition to implementation of MSPA, the US Marine Corps stood up the Force Fitness Readiness Center which is aimed at developing a Marine Corps Force Fitness Program that is positive, holistic, and progressive. It utilizes structured contemporary exercise science in order to optimize mental and physical performance, reduce injuries, and maximize unit physical readiness [25]. One arm of the FFRC is the Force Fitness Instructor (FFI) MOS which provides an additional rating on a Marine as a fitness instructor. Marines with this MOS are educated on kinesiology, anatomy and physiology, recovery, nutrition, and development of group fitness exercise. FFIs are embedded into units to help physically train Marines in combat MOS as well as mentally prepare them for battle.

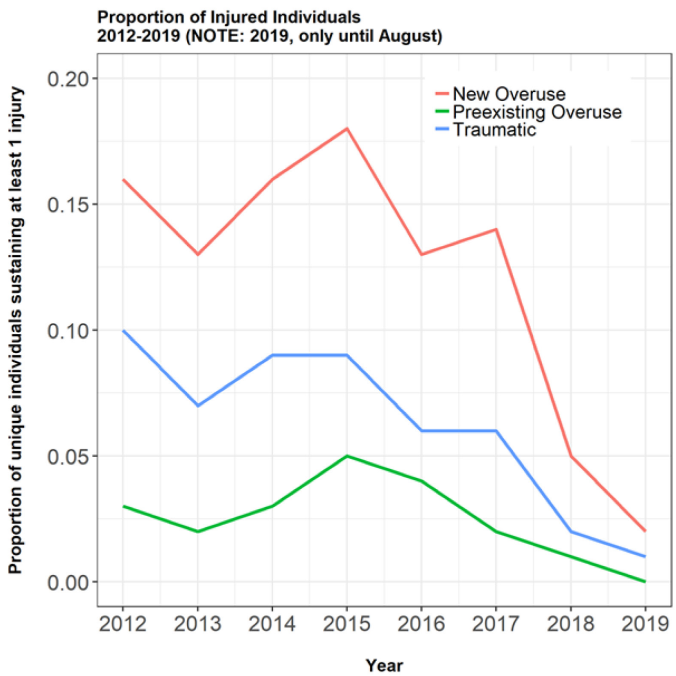

Figure 4-2: Proportion of Injured Individuals USMC Recruit Depot-San Diego from 2012 – 2019.

Intervention (Study Completion January 2022; Unpublished Findings): Holistic Monitoring of Musculoskeletal Injuries in US Marines – Implementation of Progressive Loaded Hike Program

This effort focused on implementation of a progressive loaded hike training program at Marine Corps Recruit Depot-San Diego which is one of two recruit training centers (boot-camp). Traditionally recruits engage in 5 training hikes over the course of 10-weeks; however, for this effort 6 hikes were substituted for physical training sessions starting week one of boot-camp. The intervention hikes were progressive in nature meaning they started with a 10kg load at week 1 and progressed up to 30 kg week during week 10. Three companies of recruits participated in the progressive hike program (n = 1133) and injury rates were compared to the same companies from the year prior (n = 2363). Control companies were selected in this manner to minimize potential influence of season and leadership. Preliminary analysis suggests that new overuse injuries were significantly reduced in the hike intervention ($p<0.001$) as well, strain ($p < .0001$), stress fracture ($p < .0001$). Sprains were reduced ($p = .059$), while not statistical the finding is clinically and operationally relevant. These early findings suggest that progressive overload hike training is a potential intervention for reduction of MSkI in military recruits.

Intervention Success Pending

Intervention: Introduction of a calcium and vitamin D fortified nutrition bar (PRB) into Army basic combat training

The Performance Readiness Bar (PRB) is a calcium and vitamin D fortified nutrition bar developed by the US Army to supplement Soldiers' nutrition, improve bone mineral density, and to potentially reduce Musculo-Skeletal Injuries (MSkI) such as stress fractures. The PRB contains approximately 1000 mg of calcium (Ca) and 2000 IU of vitamin D3 (Vit D) [26], micronutrients affecting bone health. The PRB is currently offered to recruits undergoing Army basic combat training (BCT), which is a time during which military personnel are more likely to sustain a stress fracture [27]. The PRB (one per day over the course of the 8 – 9 week training period) is provided under the close supervision of training staff. The premise for the development of the PRB originated from a randomized controlled trial in female Navy recruits who reported a nearly 20% reduction in stress fractures with 2000 mg Ca and 800 IU Vit D supplementation [28].

Whether and the extent to which the PRB reduces musculo-skeletal injuries, including stress fractures, in military recruits remains to be determined. Several studies to date have assessed the effects of Ca and Vit D supplementation on bone health endpoints in military recruits [26], [29] with a randomized double-blind, placebo-controlled trial reporting modest benefits in bone properties in Army recruits undergoing BCT, but these findings were not replicated in a similar study in Marine recruits undergoing initial military training. The inconsistencies reveal the need to further investigate the efficacy of the PRB and Ca and Vit D supplementation on bone health endpoints and, ultimately, stress fracture injury. Such research efforts are currently underway in a prospective field study of Army recruits that will identify whether the PRB, along with other modifiable factors, plays a role in injury reduction [30].

It is possible there is a subset of individuals who may benefit most from Ca and Vit D supplementation during training but given the multifactorial nature of military training and the numerous factors influencing Ca and Vit D metabolism, identifying this cohort is difficult. For example, there may be a genetic component to Ca and Vit D metabolism that influences an individual's ability to utilize Ca and Vit D [31]; however, it is not feasible at this time to genetically test all incoming recruits. Additionally, it is possible that there is seasonal variation in the response to Ca and Vit D supplementation [29], suggesting that recruits who train during different seasons may respond differently to the PRB. Baseline levels of Vit D and Ca (at the start of military training) may also impact the effect of Vit D and/or Ca supplementation on injury risk during this initial training period, as Marine recruits entering training with the lowest levels of 25OHD demonstrated the greatest changes in an index of bone strength at the tibia [29].

Summary: Further research is needed to determine the effects of PRB consumption on MSkI risk in military populations and if there are easily identifiable factors that may help determine which recruits are more likely to respond to the PRB intervention.

Description of Current Direction – US Army

The US Army is directing its focus to employ the Holistic Health and Fitness (H2F) System to define how it trains, develops, and cares for Soldiers. H2F is a comprehensive, integrated, and immersive health and fitness "System" of governance, personnel, equipment/facilities, programming, and education designed to generate lethal Soldiers who are physically fit and mentally tough to engage with and overmatch the enemy in multi-Domain Operations [32]. H2F will be the overarching framework that encompasses all aspects of human performance (physical and non-physical (sleep, nutritional, spiritual, and mental) readiness) to optimize Soldier personal readiness, reduce injury rates, improve rehabilitation after injury, and increase the overall effectiveness of the Total Army. For example, the first doctrinal product with be a transition to the Army Combat Fitness Test [33], [34]. And the Army's physical readiness training program is being re-written to incorporate evidence-based knowledge. The program will include best practices for physical, sleep, nutritional, mental, and spiritual programming, human performance teams of providers (such as Physical Therapist, Registered Dietitian, Occupational Therapist, Athletic Trainers Certified, Cognitive Performance Experts, and contracted Strength and Conditioning Coaches) and support brigade-sized elements and provide far-forward medical care and performance expertise. Additional unit physical and non-physical training equipment and facilities will be dedicated to providing holistic education, training and programs for Soldiers.

Description of Current Direction – US Marine Corps

In addition to the aforementioned efforts in "successful interventions," there is active research protocols in Marine Corps Recruit Depot (MCRD) aimed at nutritional interventions as well as proper pack fit. In conjunction with this research a targeted education program is being developed to provide to the drill instructors that include lectures and practical on overuse injury, recovery strategies, nutrition and hydration. Furthermore, research aimed at reporting of injuries and why recruits and young Marines do not seek treatment or barriers to treatment are being conducted at infantry schools. Additional efforts aimed at proper fit of personal protective equipment and back-packs is in discussion.

Conclusion: The US Marine Corps has taken pro-active measures to reduce MSkI through development and implementation of more precise combat arms physical assessments and development of the Force Fitness Instructor MOS. Further, the US Marine Corps supports independent research aimed at improving the health and readiness of the Marine Corp Force with the overall goal of reducing injury, improving recovery and increasing operational readiness and lethality through improved physicality.

4.7 REFERENCES (PART 2)

[1] Van Tiggelen, D., Wickes, S., Coorevits, P., Dumalin, M., Witvrouw, E. (2009). Sock systems to prevent foot blisters and the impact on overuse injuries of the knee joint. Mil Med, 174, 2, 183-9.

[2] Van Tiggelen, D., Bernard, E., Dewaelheyns, E. (2017, unpublished).The use of the Functional Movement Screen (FMS) to predict overuse injuries in military recruits.

[3] Warren, M., Lininger, M.R., Chimera, N.J., Smith, C.A. (2018). Utility of the FMS to understand injury incidence in sports: Current perspectives. Open Access J Sport Med, 9, 171-182.

[4] Jaspers, A., Kuyvenhoven, J., Staes, F., Frencken, W., Helsen, W., Brink, M. (2018). Examination of the external and internal load indicators' association with overuse injuries in professional soccer players. J Sci Med Sport, 21(6), 579-585.

[5] Weston, M., Siegler, J., Bahnert, A., McBrien, J., Lovell, R. (2015). The application of differential ratings of perceived exertion to Australian Football League matches. J Sci Med Sport 18(6), 704-708.

[6] Strauss, B., Theriault, F., Gabler, K., Naicker, K. (2016). Health and lifestyle information survey of Canadian forces personnel 2013/2014 – Regular Force Report. https://www.canada.ca/content/dam/dnd-mdn/documents/health/health-and-lifestyle-survey-2013-2014.pdf

[7] Gabbett, T.J. (2016). The training-injury prevention paradox: should athlete be training smarter or harder? B J Sports Med 50(5), 273-80.

[8] Baraki, A., Feigenbaum, J. (2019). Practical guidelines for implementing a strength training program for adults. https://www.uptodate.com/contents/practical-guidelines-for-implementing-a-strength-training-program-for-adults#!

[9] Adam, J. (2004). Results of NVG-induced neck strain questionnaire study in CH-146 Griffon aircrew. Technical Report DRDC Toronto TR 2004-153, Defence Research and Development Canada Toronto Research Centre.

[10] Chafe, G., Farrell, P.S.E. (2016). Royal Canadian Air Force CH-146 griffon aircrew 2014 spinal musculoskeletal trouble survey. Scientific Report DRDC Toronto TR 2016-179, Defence Research and Development Canada Toronto Research Centre.

[11] Salmon, D.M., Harrison, M.F., Neary, J.P. (2011). Neck pain in military helicopter aircrew and the role of exercise therapy. Aviation Space and Environmental Medicine 82(10), 978-987.

[12] Kovčan, B., Vodičar, J., Šimenko, J., Videmšek, M., Pori, P., Hadžić, V. (2019). Retrospective and cross-sectional analysis of physical training-related musculoskeletal injuries in Slovenian Armed Forces. Mil Med 184(1-2):e195-e9.

[13] Hadžić, V. (2018). Prevention of musculoskeletal injuries in Slovenian Armed Forces. University of Ljubljana. ClinicalTrials.gov NCT03415464 Https://clinicaltrials.gov/show/nct03415464

[14] Šimenko, J., Kovčan, B., Pori, P., Vodičar, J., Vodičar, M., Hadžić, V. (2019). The relationship between army physical fitness and functional capacities in infantry members of the Slovenian Armed Forces. J Strength Cond Res.

[15] Vodičar, M., Kovčan, B., Pori, P., Vodičar, J., Šimenko, J., Karpljuk, D. et al. (2020). Regular strength training and baseline fitness in overweight infantry members of Slovenian Armed Forces. BMJ Mil Health 168(2), 141-145.

[16] Kozinc, Ž., Šarabon, N., Kovčan, B., Simenko, J., Pori, P., Vodičar, J., Hadžić, V. (2021). Effects of 12-week full body resistance exercise on vertical jumping with and without military equipment in Slovenian Armed Forces. BMJ Mil Health. 2021 Sep 7:e001899. doi: 10.1136/bmjmilitary-2021-001899. Epub ahead of print.

[17] Paravli, A. (2022). Enhancement of physical and combat preparedness of SAF members (EPCPSAF-2021). University of Ljubljana. ClinicalTrials.gov NCT05216146. https://clinicaltrials.gov/ct2/show/NCT05216146

[18] De Raad, J., Nijhuis, F.J.N., Willems, J.H.B.M. (2005). Difference in fitness for duty among soldiers on a mission: Can these be explained by a difference in the preemployment assessment? Mil Med 170, 9, 728-734.

[19] Moen, M.H., Holtslag, L., Bakker, E., Barten, C., Weir, A., Tol, J.L., Backx, F. (2012). The treatment of medial tibial stress syndrome in athletes; a randomized clinical trial. Sports Med Arthrosc Rehabil Ther Technol. 4(12).

[20] Dijksma, I., Zimmermann, W.O., Bovens, D., Lucas, C., Stuiver, M.M. (2020). Despite an improved aerobic endurance post-conditioning, still high attrition rates in low-fit recruits – results of a randomised controlled trial. Contemp Clin Trial Comm, 20, 100679, https://doi.org/10.1016/j.conctc.2020.100679

[21] Sharp, M.A., Foulis, S.A., Redmond, J.E., Canino, M.C., Cohen, B.S., Hauret, K. (2018). Longitudinal validation of the Occupational Physical Assessment Test (OPAT). Report No. T18-05, 105 USARIEM.

[22] Hauret, K.G., Steelman, R., Pierce, J.R., Alemany, J.A. (2018). Association of performance on the Occupational Physical Assessment Test (OPAT), Injuries, and Attrition during Initial Entry Training – OPAT Phase I. Report No. S.0047229-18b, DTIC#:AD1061860.

[23] Hauret, K.G., Steelman, R., Sharp, M.A., Canino, M. (2020, unpublished). Association of occupational physical assessment test performance with risks of injury during U.S. Army initial entry training. Submitted to 5th International Congress on Soldier Physical Performance (ICSPP) 2020, Quebec City.

[24] Sharp, M.A., Canino, M., Redmond, J., Cohen, B.S. (2020, unpublished). Relationship between the Occupational Physical Assessment Test (OPAT) and 2-year attrition from the U.S. Army. Submitted to 5th International Congress on Soldier Physical Performance (ICSPP) 2020, Quebec City.

[25] Jensen, A., Laird, M., Jameson, J.T., Kelly, K.R. (2019). Fitness and Body Composition as Predictors of Musculoskeletal Injury Risk (FITRISK), Mil Med Mar 1;184(Suppl 1), 511-520.

[26] Gaffney-Stomberg, E., Lutz, L.J., Rood, J.C., Cable, S.J., Pasiakos, S.M., Young, A.J., McClung, J.P. (2014). Calcium and vitamin D supplementation maintains parathyroid hormone and improves bone density during initial military training: A randomized, double-blind, placebo controlled trial. Bone 68, 46-56.

[27] Lee, D. (2011). Stress fractures, active component, U.S. Armed Forces, 2004 – 2010. MSMR 18, 8-11.

[28] Lappe, J.M, Cullen, D., Haynatzki, G., Reicker, R., Ahlf, R., Thompson, K. (2008). Calcium and vitamin D supplementation decreases incidence of stress fractures in female navy recruits. J Bone Miner Res 23(5), 741-749, doi:10.1359/jbmr.080102.

[29] Gaffney-Stomberg, E., Nakayamaab, A.T., Guerrierea, K.I., Lutza, L.J., Walker, L.A., Staab, J.S., Scott, J.M., Gasier, H.G., McClung, J.P. (2019). Calcium and vitamin D supplementation and bone health in Marine recruits: Effect of season. Bone 123, 224-233.

[30] Hughes, J.M., Foulis, S.A., Taylor, K.M., Guerriere, K.I., Walker, L.A., Hand, A.F. et al. (2019). A prospective field study of U.S. Army trainees to identify the physiological bases and key factors influencing musculoskeletal injuries: a study protocol. BMC Musculoskelet Disord 20, 1-7, doi:10.1186/s12891-019-2634-9.

[31] Gaffney-Stomberg, E., Lutz, L.J., Shcherbina, A., Ricke, D.O., Petrovick, M., Cropper, T.L., Cable, S.J., McClung, J.P. (2017). Association between single gene polymorphisms and bone biomarkers and response to calcium and vitamin D supplementation in young adults undergoing military training. Journal of Bone and Mineral Research 32, 498-507.

[32] Molloy, J.M., Pendergrass, T.L., Lee, I.E., Hauret, K.G. Chervak, M.C., Rhon, D.I. (2020). Musculoskeletal Injuries and United States Army Readiness. Part II: Management Challenges and Risk Mitigation Initiatives. Mil Med 185 e1472-e1480.

[33] Center for Initial Military Training (2019). Army Combat Fitness Test: Initial Operation Capability (1 Oct 2019 to 30 Sep 2020). Prepper Press.

[34] Bigelman, K.A., East, W.B., Thomas, D.M., Turner, D., Hertling, M. (2019). The new Army Combat Fitness Test: An opportunity to improve recruitment and retainment. Obesity 27(1):1772-1175.

Chapter 5 – A MULTINATIONAL CONSENSUS ON RECOMMENDATIONS GIVEN TO STAKEHOLDERS TO PREVENT INJURIES DURING MILITARY TRAINING

D. van Tiggelen, B. Sanz-Bustillo-Aguirre, T. Karakolis, V. Hadžić, K.R. Kelly, S.P. Proctor, S. Sammito, A. Stepens, G. White and W.O. Zimmermann

5.1 SUMMARY

The goal of this chapter is to address the following key points with the aim of providing recommendations for reducing injuries during military training:

- The recommendation to consider military training as a learning environment composed of three subsystems: the organism (service member), the environment and the tasks.
- The recommendation to address the three interrelated subsystems to promote successful strategies to reduce musculo-skeletal injuries in the military personnel.

The recommendation that military leadership, military instructors, health care providers, and scientists and researchers, working together, take the guidelines provided in this NATO report into consideration.

5.2 CHAPTER OUTLINE

1) Introduction
2) Military Training: the interaction between organism, environment and tasks
3) Information and recommendations for leadership and policy makers
4) Information and recommendations for military instructors and health care providers
5) Information and recommendations for scientists and researchers
6) References

5.3 INTRODUCTION

Recruits are combat athletes that need to learn new skills, new tasks and perform unaccustomed physical activities with novel equipment in a new environment. Further military training will always be focused on new tasks or tasks performed in a different environment (e.g., tropic, jungle, mountain, Arctic).

To optimize the military learning environment, modern theories of learning must be considered, such as the learner-centered approach of skill acquisition based on the Dynamic Systems Theory (DST) and the constraints-led learning theory. The DST considers three continuously interacting and changing subsystems: the *organism*, the *environment*, and the *task* as defined by Newell (1986) [1], [2] (Figure 5-1). The model is designed to explain the learning environment of an individual. The *organism* in this case is the service member(s) with his or her physical capacity to perform a mission. The *task* in this case is the mission, occupation or exercise the service member(s) perform. Lastly, the *environment* is not only the climatological conditions, but also the equipment, the instructors and so on.

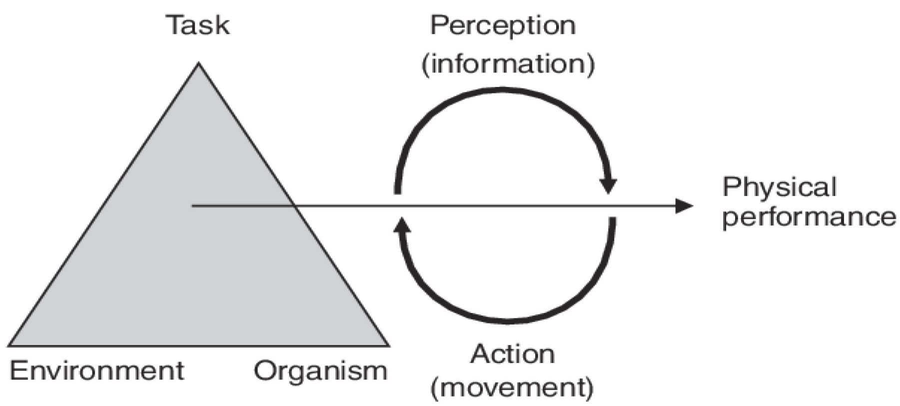

Figure 5-1: Newell's Triangle (Environment –Task – Organism) [2].

In order to be successful, there must be an interaction between the three subsystems. If the organism, which can be an individual or a group, does/cannot adapt adequately to the task and environment, successful completion of the task will not be achieved.

Basic Military Training (BMT) typically presents so many new environments and tasks to the unaccustomed recruits that it could be classified as a suboptimal learning situation. If the recruit is not resilient enough, both mentally and physically, the training will not be successful and the number of graduates will be low. Although it is the earliest level military training, there is an abundance of scientific reports on the incidence of overuse injuries during BMT. This means the tasks and/or environments are not in balance with the capacity of the recruit. The service member's operational lifecycle as is described by Billing and Drain (2017) is the illustration of the adaptation of the service member to different tasks (operations) and environments [3]. As described in the model of Newell (Newell's Triangle; 1986), the service member must be very compliant and adaptable if the tasks and/or environment are very demanding and variable. A recovery period after strenuous training or operation is required [3].

In Figure 5-2, we adapted the service member lifecycle where each stage (triangles) consists of an interplay between the organism, task and environment. In this model, the fluctuations in the curve represent the modifications in the individual performance level.

For leadership and policymakers: It is important to recognize that there are two goals of training:

1) To train the soldiers, aircrew, and sailors, and
2) To provide experience for selection for specialist roles.

For example, the goal of BMT is to train as many candidates as possible to the level of graduation, preferably a high percentage of all starters. In contrast, Commando or Special Forces Qualification type courses, aim to select those candidates that are able to meet the highest standards of performance for a particular job. A low passing rate is not uncommon because in those situations the tasks and environment are more demanding. In the case of training, leadership and instructors should take tasks and environment into account to prevent injuries; whereas in selection, the service member (organism) has to adapt to the imposed tasks and environment. The different levels of the chain of command and management should know how to design the appropriate learning context from recruits' level to Special Forces operators' level, in order to produce the required number of competent service members. High levels of overuse injuries are one of the potential undesired outcomes of an inappropriately designed learning environment.

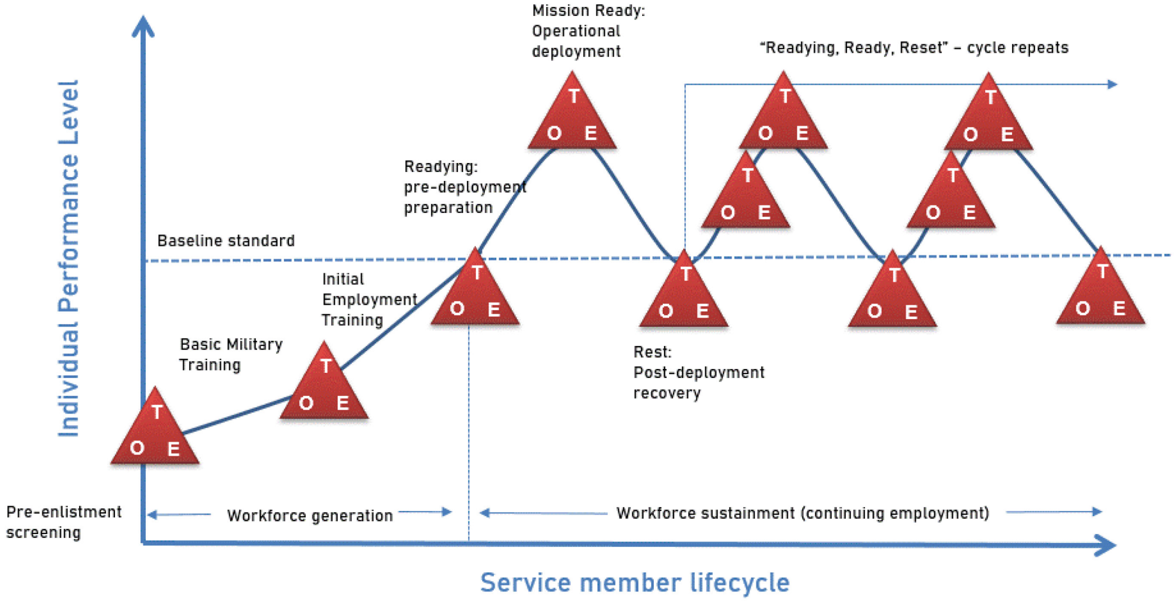

Figure 5-2: The Service Member Lifecycle Adapted from by Billing and Drain [3]. Each stage consists of an interplay between Organism (O), Tasks (T) and Environment (E).

For military instructors and healthcare providers: These professionals are the key persons able to implement the learning environment and help the recruits succeed. Military instructors use the environment and impose progressively more complex tasks to the trainee, whereas the healthcare providers monitor the balance between load and the loading capacity. One key element to reduce injuries is to prevent a mismatch between training load and the ability of the individual to cope with this load.

For scientists and researchers: These professionals must gather the information that is necessary to provide valid evidence that supports developed policies aiming to increase the success rate of military training. It is important that data are collected using uniform definitions across nations and communicated convincingly with all levels of military leadership.

5.3.1 Examples of Basic Military Training (BMT): The Interaction Between Organism, Environment, and Tasks

The BMT environment is new for the recruit: barracks, strict time constraints, different and new fellow recruits, outdoor activities, different food, weather conditions, equipment, etc. The tasks are new: loaded marches in boots and with backpacks, shooting practice, sports, etc. and the organisms (the recruits) are not necessarily adapted to the applied physical load, mental load, fatigue and limited adaptation period. In summary, BMT presents a mix of physical, psychological, social, environmental, cognitive and emotional constraints to the individual recruit.

When regarding the physical load in military training, each recruit has individual characteristics like body shape, physical fitness level, psychological coping strategies, cognitive abilities, decision-making skills, recovery capabilities, fatigue resistance, etc., which can turn out to be risk factors for injury. It is important to understand that some risk factors for injury are modifiable (e.g., bodyweight can be altered), but some are not (e.g., injury history cannot be altered). Each recruit possesses a unique and variable set of talents and resources which will lead to individual adaptations and strategies. Examples are experience in sports and exercise and variability in movement patterns and task execution.

Therefore, the BMT environment provides both physical and social challenges to the recruits. Physical challenges may include the weather, the terrain, day or nighttime, the barracks and the facilities. Social challenges may be the platoon members, the instructors and their style and attitude. Not all challenges of BMT can be alleviated, for a recruit the military training environment will always present new experiences. However, many aspects of training can be optimized to promote learning and success (graduation). Progressive training load, progression in distance to be marched or weight to be carried may be the adjustments military instructors can introduce to prevent overload and injury and such approach has already proven effective in military settings (e.g., IDF).

5.4 INFORMATION AND RECOMMENDATIONS FOR LEADERSHIP AND POLICY MAKERS

As dropout and attrition are a major concern due to both costs and inefficient outcome of training, military leadership should be aware that reduction of training injuries is possible and has been accomplished in many interventions over the past decades (see Chapter 4). For military leadership, it is paramount not only to take the potential effective and efficient preventative measures into account, but also to assess the overall effectiveness. When introducing a protective measure, leadership should consider whether it might induce in service members a modification in their risk-taking behavior that may negate the benefit of the implemented intervention or protective measure [4]. For example, if a protective measure is introduced (e.g., providing kneepads), a false sense of safety may be created, and cause a negative behavior modification that offsets the protective effect (e.g., soldiers may be more reckless as they adopt a kneeling posture). Leadership should therefore take this risk into account when introducing preventative measures.

Regardless of the training goals, some overuse injuries may be inevitable, but leadership should be aware of the fact that injuries in the military tend to recur, and injuries sustained early on may remain an issue for the rest of a member's military career [4]. Therefore, well periodized smart training programs need to be designed, that take physical and mental load into account, but also rest, recovery, hydration and nutrition [5]. It is important to recognize that as in formal sports, training military activities such as backpack marching, shooting drills and parade drills, also present physical loading. The proper choice of procurement and use of equipment is paramount. Progressive exposure to new equipment like boots and other new loads is important to accommodate progressive adaptation [6]. Education on lifestyle choices, such as nutrition, rest, recovery and different training methods should be included in BMT to be able to implement further during the service member life cycle.

Understanding Figure 5-1 will surely lead to a closer look and analysis of the specific and new learning environment and tasks recruits encounter. As the coach is accountable for the team in sports, so is the drill instructor for the platoon in military training. Making instructors and leadership personally accountable for the number of graduates in military training, has been shown to induce an adaptation of the "environment" in the model, which has shown great results in the Israeli Defense Forces (IDF).[1]

[1] Yan Ranovich, Presentation to NATO-HFM-RTG 283 Meeting #2 – Dstl Porton Down, UK, May 2017.

One end goal of military training is to reach a predefined level of physical and mental fitness and military and tactical skills (Figure 5-2). As the entry level of all these skills will differ among the recruits at the start of BMT, a retroactive, flexible design with a fixed endpoint of required competency could be used. Therefore, the training programs could have a different duration depending on the entry level of the recruits. Historically, for example, BMT has a fixed duration, during which all required competencies are expected to be reached. Therefore, the BMT programs do not suit the least fit recruits, who get injured more often, nor do they stimulate the best candidates, who already possess many of the required skills.

5.4.1 Recommendations for Leadership and Policy Makers

1) Understand that any learning situation has three components: the organism (service member), the environment and the tasks.

2) Take responsibility: you are in a key position to personally contribute to a reduction in training injuries in the armed forces.

3) Recognize that there can be two different goals during military training courses: 1) Training = learning skills to pre-selected candidates, a high graduation percentage is expected; and/or 2) Selection course = selection of the best service members for a specific job.

4) The best strategy to reduce injuries is to prevent a mismatch between training load and the ability of the individual to cope with this load; consider the development of individual training programs towards a common training goal.

5.5 INFORMATION AND RECOMMENDATIONS FOR MILITARY INSTRUCTORS AND HEALTHCARE PROVIDERS

Both military instructors and healthcare providers are in direct contact with service members on a regular basis and are therefore well-positioned stakeholders to make adjustments at the organism, environment and tasks levels. These professionals must be aware that they can each contribute to the prevention of Musculo-Skeletal Injuries (MSkIs). In this section, military instructors encompass different professionals such as: drill instructors, strength and conditioning coaches or physical training instructors. An enlarged healthcare team might include among others: physicians, nurses, physiotherapists, occupational therapists, registered dietitians, psychologists or cognitive enhancement specialists. Communication and active collaboration between these professionals is essential, so is communication with military leaders and scientists and researchers. In addition, knowledge exchange between military and civilian MSkI-care stakeholders both at the occupational and sports spheres is valuable.

Considering the prevalence of MSkIs among service members (Chapter 2) and their impact on the armed forces readiness and combat capability (Chapter 1), it seems necessary to analyze the risk factors that can lead to MSkIs in this population, in order to give recommendations on how to address them. Chapter 3 describes in detail the risk factors for overuse injuries in the military. It is noteworthy to highlight that overall, the causal relationship between each injury risk factor has a weak to moderate evidence in this population (Chapter 3). Risk factors can be intrinsic or extrinsic in nature. Intrinsic refers to risk factors within the body of the service member (organism), while extrinsic risk factors are from outside the body of the service member (environment and tasks). As previously stated, all risk factors are either modifiable or non-modifiable.

Examples of modifiable intrinsic risk factors for MSkIs in the military population include (Chapter 3; Molloy et al. Part I 2020) [7]: obesity, over- and underweight, high percentage of body fat, low physical fitness, low muscular strength, bone tissue geometry, bone mineralization, smoking and low vitamin D level. During the pre-participation medical screening, some of these factors could be recorded to start their tracking and control during the early stages of the military career. Categorization of soldiers into groups (e.g., for physical training, instruction or participation in a prevention and health promotion campaign) based on risk factors such as physical fitness or body composition, could be explored. When trying to reduce body weight and fat percentage, both the environment (through caloric intake restriction in nutrition) and tasks (through an increase in the cumulative physical exertion of all individual activities performed) subsystems could be adjusted. The goal would be a controlled negative energy balance. Increase in physical activity should be conducted gradually and progressively, towards a minimum of 250 minutes of moderate (40% – 60% Heart Rate Reserve (HRR)) to vigorous (>60% HRR) weekly aerobic exercise [8]. Moderate and vigorous physical activity can be accumulated in multiple daily bouts, with a minimum of 10 minutes duration [8]. In addressing both the underweight and low muscular strength risk factors, emphasis could be placed on a steady increase in resistance training. Regarding low vitamin D level, bone tissue geometry, and bone mineralization, the effectiveness of either calcium and vitamin D (Chapter 4) [9] or Multi-Vitamin with Iron (MVI) [9] supplementation to reduce MSkI risk is currently unclear, but initial reports seem promising.

Examples of non-modifiable intrinsic risk factors for MSkIs are unfavorable anatomic characteristics (foot geometry, ankle mobility, and thigh length), and previous MSkIs (Chapter 3). To tackle the former, adjustments to footwear or the prescription of foot orthotics should further be researched before recommendations can be made.

Extrinsic risk factors for overuse injuries are outside of the organism and therefore by definition part of the environment or task. Examples of modifiable extrinsic risk factors in the military are: load carriage (Chapter 3) [10], equipment ergonomics and direct access to physiotherapists within the unit medical team [7]. Examples of non-modifiable extrinsic risk factors are military occupational specialty/branch, season of the year and previous deployment (Chapter 3).

Load carriage is an example of a risk factor for MSkIs, that can be altered, preferably reduced, in many different ways. Parameters such as load weight, speed of march, grade and type of terrain, other military duties or overall number of load carriage activities on the same day, can be adjusted to comply with a gradual volume and intensity progression of training [10]. For instance, in planning training progression, the weight of the load can be kept constant, while another factor is altered, such as the speed of the march, the grade of the terrain (up- or downhill), the firmness of the surface or the addition of features of mental stressors. In general, load carriage training should include one load carriage session every 10 to 14 days, combined with aerobic and resistance training [10].

Another important opportunity to reduce the occurrence of MSkIs is the ergonomic improvement of military equipment. Examples include reducing the weight of helmets, adapting the ballistic vests to the female anatomy and modifying the materials and components of military boots. While these advancements evolve, military instructors can provide relevant feedback to service members on how to properly use the equipment. Examples of preventative feedback are teaching the right way to carry a backpack, by adjusting the shoulder straps to ensure adequate positioning of the backpack at the level of the individual’s pelvis; teaching correct load lifting procedures, by the use of the body weight and maintenance of neutral spine curves; teaching the correct shoulder and arm movement patterns when throwing a grenade.

The season of the year and the climate conditions are examples of non-modifiable extrinsic risk factors for injury (e.g., trainees nor the staff can alter the weather conditions). Again, educating the service members may contribute to a reduction of injuries. Topics for lessons may include:

1) **The organism (service member) –** hydration, sweating, body temperature, heart rate and respiratory rate, body composition;
2) **The tasks –** running speed, training frequency and duration, recovery warm-up procedures, stretching exercises; and
3) **The environment –** clothing, equipment, solar radiation protection, atmosphere temperature and humidity. In recent years, much improvement has been accomplished in the prevention and treatment of heat illness in the military by measures like hydration (through oral fluid intake), stretching, recovery periods and dietary sodium chloride intake [8].

Moreover, it should be noted that an individual training in hot or humid conditions – until heat acclimatization occurs – will achieve their desired training heart rate with a lower running speed compared to training under cold temperatures [8].

Previous deployment is known to elicit mental stress on military personnel [11] and is considered an extrinsic risk factor for future MSkIs. Despite its non-modifiable nature, increasing the soldiers' adherence to regular physical activity and stress-reducing skills, from the moment they join the armed forces, may prove beneficial for long-term health outcomes.

As mentioned previously, during BMT, recruits are faced with physical demands and tasks that are unfamiliar; therefore, they are at risk of sustaining a musculo-skeletal injury. Indeed, high amounts of training volume during unit training (Chapter 3) and duties performed [7] are consistently described as risk factors for MSkIs among military personnel. High levels of physical fitness (aerobic fitness and muscle strength) are required to successfully perform military tasks [12]. Therefore, training of recruits, who are often in low physical condition, must be planned carefully. The training plan should include components of aerobic, strength, power, coordination and flexibility training. Special attention should be placed on providing adequate periods for recovery.

Gradual progression in training load, variation in training modes and division of training components into stages/blocks (periodization) may provide optimal training adaptations. This can be performed by modulating the training's frequency, volume (distance, number of repetitions and duration) and intensity (load, power and speed) [12]. To achieve optimal individual progression, it is advised to make training groups according to physical fitness level. Trainees with a lower fitness level may benefit from a preparatory physical training course, before BMT. Training should encompass aerobic, strength, flexibility and motor skills training. Improving fitness before BMT may lead to a decreased risk of MSkIs.

High Intensity Interval Training (HIIT) seems to improve aerobic capacity and neuromuscular performance with less time expenditure, in comparison with other training modalities. According to Molloy et al. [7], the physical exercise program can be standardized by incorporating minimum two weekly sessions of strength/mobility and endurance/mobility, with emphasis on interval, hill repeat and shuttle runs. This enables aerobic and anaerobic development with less distance covered and training frequency. Moreover, this training methodology seems to provide gradual volume training progression, strength, endurance and mobility development as well as sufficient preparation and recovery periods. Additionally, the standardized exercise program has proven safe and effective in reducing injury rates among service members while ensuring their maintenance or improvement of overall physical fitness. Its effectiveness is thought to be (partially) due to commanders' advocacy to a correct performance of the training program [9].

Finally, healthcare professionals can accomplish activities within their expertise aimed at [9]: early MSkI reporting, early and complete healing of injuries, prevention of re-injuries, primary prevention of injuries by eliminating or mitigating known risk factors, facilitation of appropriate transition from clinical rehabilitation to military task-specific training, contribution to adequate physical activity programming – with safe execution of exercise techniques and attention for exercise load and recovery. After injury, special attention should be placed on restoring proprioception, strength, pain perception and adequate biomechanical patterns [9].

5.5.1 Recommendations for Military Instructors and Healthcare Providers

1) Understand that any learning situation has three components: the organism (service member), the environment and the tasks.
2) Take responsibility: as direct-contact professionals, you are in a key position to reduce training injuries in the armed forces.
3) In order to reduce musculo-skeletal injuries, it is essential to understand the risk factors that can lead to those injuries and to actively collaborate with all stakeholders with responsibilities in their mitigation.
4) Military instructors are well-positioned to adjust parameters on the organism, environment and tasks with the aim of reducing MSkIs in the personnel under training. Examples of measures include creation of training groups based on risk factors (e.g., physical fitness level), feedback on adequate equipment positioning and handling, adjustments on the training plan (periodization, gradual progression in training load, variation in training modalities, recovery periods), advocacy for a correct performance of techniques within training.
5) The role of healthcare providers is focused more predominantly on the organism subsystem of the learning situation, taking into account the environment and tasks the personnel is faced with. Examples of interventions include screening for intrinsic risk factors, categorization of trainees based on risk factors (e.g., weight disturbances) for prevention and health promotion campaigns, formative actions on healthy lifestyle choices and on the physiological responses of the organism towards the environment and tasks, early intervention towards complete restoration after injury, appropriate transition from clinical rehabilitation to military-specific training and return to full duty.

5.6 INFORMATION AND RECOMMENDATIONS FOR SCIENTISTS AND RESEARCHERS

In this section, three important questions will be addressed:

1) How can researchers better understand injury mechanisms?
2) What types of interventions or strategies can be used to prevent injuries?
3) What are the barriers to converting science-based interventions and strategies to implementable solutions?

5.6.1 How Can Researchers Better Understand Injury Mechanisms?

To understand training injuries in the military it is important to have adequate information, based on surveillance. Unfortunately, adequate information is not often available due to the following two reasons: 1) injuries are not categorized and described correctly; and 2) the context of the injuries is not well described. This problem is not limited to the military; standardizing definitions in the science of injury treatment and prevention in civilian sports is also still in a beginning phase.

In a first step towards simplifying and creating consensus among definitions related to injury surveillance in the military context, a Glossary to this document is provided (Annex A). This list of definitions is not comprehensive, but it is believed that it can be a good starting point for further discussion, simplification, and consensus.

The military training environment is well suited for research. In contrast to the world of civilian sports, military leadership and instructors have the ability to control the lives and activities of the trainees to a large extent (24/7), for the duration of the course. So preventive measures can be implemented relatively easily for all participants. However, the military is also traditional in nature, with an emphasis on providing the same environment to every recruit (e.g., discipline, equipment, food and sleep), which is far from optimal. As discussed in Chapter 3 of this document, the number of potential risk factors for injury is very large. In a comprehensive review completed by Sammito et al. in 2021 (Chapter 3), it was clear that the evidence linking the majority of the risk factors to injury causation is still only weak to moderate. Therefore, continued research is necessary to better understand the interaction between risk factors and injury. It is essential to collect reliable data on the number of injuries and the context of the injuries. Specifically, context of injury is not always collected or recorded. Furthermore, data must be easily obtainable for those researchers that can analyze, interpret, and provide conclusions based upon the data. Unless clear evidence exists, researchers should remain cautious with any advice and recommendations that are made to healthcare providers and instructors.

Although the environment and tasks are mainly under control in military training, the complex and individually variable interaction between the many intrinsic and extrinsic risk factors does not let the researcher apply relatively simple models to predict injuries [13]. Current methodology allows for individual risk profiles to be created, but further development of validated multifactorial predictive modeling is warranted.

5.6.2 What Types of Interventions or Strategies Can be Used to Prevent Injuries?

Although much remains to be learned about injury mechanisms in the military, a great body of literature on military injuries is already available. In addition, even more information is available on injury causes and prevention in civilian sports. Therefore, research from the military and civilian sports can be used to create effective intervention strategies.

Chapter 4 of this document has presented examples of successful and unsuccessful injury intervention efforts in the military. It is obvious that a sound scientific analysis must be the basis of the intervention. However, no intervention will be successful without the full support of military leadership, military instructors and military healthcare providers.

For example, selection or screening tools can potentially be used to prevent injuries in a military setting, although they are not always effective. Part of the complexity with using selection or screening tools in a military setting is the performance outcomes for military tasks are not as objectively defined, when compared to sports and athletics. Success in a military context is not solely measured as how fast you can complete a task or how far you can throw an object. This leads to the requirement of developing surrogate, objective measures for performance to be used as selection or screening tools. The challenge then becomes to develop surrogates that can be objectively measured but are also still directly relevant to the real life military setting performance outcomes that they are trying to represent. This may be why so few screening tools have been demonstrated to be effective, and why more research is required in this area.

5.6.3 What are the Barriers to Converting Science-Based Interventions and Strategies to Implementable Solutions?

The military is a unique environment with a strong hierarchical structure, chain of command and discipline. This environment provides unique opportunities for implementation of injury prevention, but only if full engagement of all leadership is obtained: policy makers, instructors and healthcare providers and the participants (service members) themselves. Research in the area of influencing leadership may be equally important as research on injury prevention [14].

It is not always easy to convince leadership to start an intervention, when proposing strategies developed in a laboratory and measured with medical statistics. Specific challenges exit when trying to translate laboratory findings to field interventions. Research results may take years to be available, and interpretation of the results may be ambiguous. Often, questions can arise such as, was the noticed decrease or increase in certain types of injury caused by the intervention or caused by other incidental changes over time: such as different groups of military personnel coming in, or new equipment.

Therefore, it is proposed to use "return to duty" as one of the most important outcomes of interventions. Readiness for action is the most important outcome for the military after injury. Again, a precise description of return to duty is important. Return to duty does not necessarily mean return to the exact same level of physical work.

5.6.4 Recommendations for Scientists and Researchers

1) Understand that any learning situation has three components: the organism (service member), the environment and the tasks.
2) Researchers need to engage with leadership to translate the efficacy of a preventative measure into real world effectiveness.
3) Record and analyze injuries using internationally-agreed-upon definitions and terminology.
4) Research should take the "return to duty" as outcome measure of interventional studies into account
5) Communicate injury prevention science to military leadership, instructors and healthcare providers.

5.7 REFERENCES

[1] Newell, K. (1986). Constraints on the development of coordination. In: M.G. Wade, H.T.A. Whiting, (Eds.). Motor Development in Children: Aspects of Coordination and Control. Dordrecht/ Boston/Lancaster: Martinus Nijhoff Publishers, 341-60.

[2] Davids, K., Glazier, P., Araujo, D., Bartlett, R. (2003). Movement systems as dynamical systems – The functional role of variability and its implications for sports medicine. Sports Med. 33(4), 245-60.

[3] Billing, D.C., Drain, J.R. (2017). International Congress on Soldiers' Physical Performance 2017: Research priorities across the service members operational lifecycle. J Sci Med Sport 20 Suppl 2:S1-S3.

[4] Van Tiggelen, D., Wittevrongel, Y., Bernard, E. (2020). The long-term impact of injuries encountered during basic military training. 5th International Congress on Soldiers' physical performance; Feb 2020; Quebec, Canada.

[5] Mullie, P., Maes, P., van Veelen, L., Van Tiggelen, D., Clarys, P. (2021). Energy balance and energy availability during a selection course for Belgian paratroopers. Mil Med Nov 2, 186(11-12), 1176-1182.

[6] Finestone, A., Shlamkovitch, N., Eldad, A., Karp, A., Milgrom, C. (1992). A prospective-study of the effect of the appropriateness of foot-shoe fit and training shoe type on the incidence of overuse injuries among infantry recruits. Mil Med 57(9), 489-90.

[7] Molloy, J.M., Pendergrass, T.L., Lee, I.E., Chervak, M.C., Hauret, K.G., Rhon, D.I. (2020). Musculoskeletal injuries and United States Army readiness. Part I: Overview of injuries and their strategic impact. Mil Med 185(9/10):e1461-e1471.

[8] American College of Sports Medicine (2017). ACSM Guidelines for Exercise Testing and Prescription. 10th ed. London: Wolters Kluwer, 389.

[9] Molloy, J.M., Pendergrass, T.L., Lee, I.E., Hauret, K.G., Chervak, M.C., Rhon, D.I. (2020). Musculoskeletal injuries and United States Army readiness. Part II: Management challenges and risk mitigation initiatives. Mil Med 185(9/10): e1472-e1480.

[10] Orr, R., Pope, R., Lopes, T.J.A., Leyk, D., Blacker, S., Bustillo-Aguirre, B.S., Knapik, J.J. (2021). Soldier load carriage, injuries, rehabilitation and physical conditioning: An international approach. Int J Environ Res Public Health Apr 11;18(8), 4010.

[11] Lazar, S.G. (2014). The mental health needs of military service members and veterans. Psychodyn Psychiatry Sep;42(3, 459-478.

[12] Kyröläinen, H., Pihlainen, K., Vaara, J.P., Ojanen, T., Santtila, M. (2018). Optimising training adaptations and performance in military environment. Journal for Science and Medicine in Sport, 21(11), 1131-1138.

[13] Bittencourt, N.F., Meeuwisse, W.H., Mendonça, L.D., Nettel-Aguirre, A., Ocarino, J.M., Fonseca, S.T. (2016). Complex systems approach for sports injuries: Moving from risk factor identification to injury pattern recognition – narrative review and new concept. British Journal of Sports Medicine 50(21), 1309-1314.

[14] Van Tiggelen, D., Wickes, S., Stevens, V., Roosen, P., Witvrouw, E. (2008). Effective prevention of sports injuries: A model integrating efficacy, efficiency, compliance and risk-taking behaviour. British Journal of Sports Medicine Aug 1; 42(8), 648-52.

Annex A – GLOSSARY

Specific definitions regarding MSkIs in a military context.

Acute Injury	An injury that results from a single event.
Attrition	Not successfully completing a training course or maintaining the requirements for being in an occupation or trade. If a member cannot successfully maintain the requirements for being in the military, attrition can ultimately result in leaving military service.
Basic Training	Generally, the first 8 – 16 weeks of service (depending on country; exceptions are possible for reserves or special forces). It occurs as soon as a member joins the armed forces, and prior to occupational or trade training.
Chronic Injury	An injury that persists for an extended period of time (e.g., 6 weeks). This can result from acute, traumatic, overuse, or recurrent injury.
Commander	Commander is a generic term for an officer commanding any armed forces unit. More specifically, in the Navy (CA, UK, US), Commander is a rank generally equivalent to Lieutenant Colonel.
Discomfort	An unpleasant sensory or emotional experience not necessarily associated with tissue damage.
Downgrading	Permanently assigning a less demanding physical occupation or trade. (e.g., infantry to cook).
Entry Training	Basic training plus occupational or trade training.
Green Training or Military Physical Training	Individual or group training performed in military clothing and equipment (e.g., road march, obstacle course).
Incidence	Occurrence of new injuries in a population within a specified period of time.
Light Duties	Temporarily being required to complete only the less physically demanding tasks associated with an occupation.
Limited Duties	Temporarily not being able to complete any physically demanding duties (e.g., desk job assignment).
Loss Time	The amount of time lost as a result of a time loss injury.
Manning	Target number of people required in a military unit.
Medical Discharge	Leaving military service due to not being able to meet minimum military service medical requirements.

Musculo-Skeletal Injury	A physical disruption to musculo-skeletal tissue that results in pain, discomfort, or performance decrement. For the purposes of this report, "injury" will be used as an abbreviation for "musculo-skeletal injury."
Occupational Specialty Codes	The military specialty or occupation (e.g., Infantry, Artillery, Pilot, etc.). The United States Armed Forces uses different acronyms depending on the Service. (e.g., the US Army and Marines use MOS – Military Occupational Specialty whereas the US Air Force uses AFSC – Air Force Specialty Code).
Occupational, Trade, or Secondary Training	Individual or group training specific to the skills or proficiencies required to complete their job functions or tasks (e.g., loading ammo, marksmanship, driving a tank, advance to contact/objective).
Off-Duty Training	Individual or group training not required by the military (e.g., recreational sports, strength and conditioning, or leisure time activities).
On Profile	Medical code that determines a service member's medical limitations.
Overuse Injury	Injury that results from repetitive or recurring tissue loading (stress/strain) greater than the body's ability to repair.
Pain	An unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage. An adverse sensory and emotional experience typically caused by, or resembling that caused by, actual or potential tissue injury.
Permanent or Temporary Profiles	The CA, NL, UK and US definitions are all different for these terms. No agreed upon standard definition.
Physical Training	On-duty individual or group training in athletic clothing in a sport or gym facility, or sport field.
Pre-deployment Training	Specified training in preparation for a deployment.
Prevalence	Actual number of cases of injury per population studied at a given time point (point prevalence) or over a period of time (period prevalence).
Recruit or Trainees	An individual participating in basic training.
Recurrent Injury	An injury that occurs to the same site as an initial injury after the soldier has returned to full duty.
Remedial Unit Group (Ex. Platoon)	Unit consisting of officially transferred trainees out of the training course. Not performing regular training, allowed to rest or recover, will re-enter regular training at a future point in time. Building up their capacity or capabilities. Does not count to completing their official training course.

Soldier	Generally, in CA, UK, and US armed forces, soldier is a generic term used for a member of a ground/land combat force. In many other countries' armed forces, the equivalent of the word soldier is the initial military rank.
Time Loss Injury	An injury that results in missing a duty/activity or an inability to perform all regular duties/activities. Some nations have a minimum amount of time lost to be considered a time loss injury (e.g., Slovenia – 3 days). A time loss injury can be acute or chronic.
Trade	The military specialty or occupation (e.g., Infantry, Artillery, Pilot, etc.).
Training Hours	The time spent developing technical and tactical capabilities and proficiencies.
Traumatic Injury	An injury that results from a severe unexpected external force.
Workup Training	Can be used as synonym for pre-deployment training. May also be used to describe the training of a ship's crew prior to entering the operational cycle.

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	STO-TR-HFM-283 AC/323(HFM-283)TP/1107	ISBN 978-92-837-2424-7	PUBLIC RELEASE

5. Originator	
	Science and Technology Organization North Atlantic Treaty Organization BP 25, F-92201 Neuilly-sur-Seine Cedex, France

6. Title

Reducing Musculo-Skeletal Injuries

7. Presented at/Sponsored by

Final report of Task Group RTG-283.

8. Author(s)/Editor(s)	9. Date
Multiple	August 2023

10. Author's/Editor's Address	11. Pages
Multiple	176

12. Distribution Statement	
	There are no restrictions on the distribution of this document. Information about the availability of this and other STO unclassified publications is given on the back cover.

13. Keywords/Descriptors

Health; Injury prevention; Injury risk factors; Musculo-skeletal injury; Prevention of injury

14. Abstract

The high prevalence (20 to 40 %) of Musculoskeletal Injuries (MSkIs) places considerable burden on soldiers throughout their military career, impacts operational readiness, and remains a concern to the NATO military community. The frequency and quality of injury reporting by clinicians and patients varies: reported data tend to focus on injuries that lead to medical discharge or downgrading. Better data on the incidence and causes of MSkI are required to determine the effectiveness of preventative measures.

A literature review was conducted on the prevalence, risk factors, and interventions for MSkI in the military to form recommendations on preventive strategies to Commanders. An expert panel prioritized risk factors and a new model was developed, which can guide the planning and implementation of intervention strategies.

Recommendations for a successful MSkI preventative program include: prevention strategies based on a multidisciplinary approach; leadership (at all levels of the organization); education of personnel, trainers and leaders; surveillance; adequate resources for program evaluation; and research. Prioritization of preventive measures should take into account the following five elements: importance of the problem; likely effectiveness of the prevention strategy; feasibility of establishing the measure; timeliness of the implementation; and potential for evaluation of its effectiveness.

NORTH ATLANTIC TREATY ORGANIZATION

BP 25
F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE
Télécopie 0(1)55.61.22.99 • E-mail mailbox@cso.nato.int

SCIENCE AND TECHNOLOGY ORGANIZATION

DIFFUSION DES PUBLICATIONS
STO NON CLASSIFIEES

Les publications de l'AGARD, de la RTO et de la STO peuvent parfois être obtenues auprès des centres nationaux de distribution indiqués ci-dessous. Si vous souhaitez recevoir toutes les publications de la STO, ou simplement celles qui concernent certains Panels, vous pouvez demander d'être inclus soit à titre personnel, soit au nom de votre organisation, sur la liste d'envoi.

Les publications de la STO, de la RTO et de l'AGARD sont également en vente auprès des agences de vente indiquées ci-dessous.

Les demandes de documents STO, RTO ou AGARD doivent comporter la dénomination « STO », « RTO » ou « AGARD » selon le cas, suivi du numéro de série. Des informations analogues, telles que le titre est la date de publication sont souhaitables.

Si vous souhaitez recevoir une notification électronique de la disponibilité des rapports de la STO au fur et à mesure de leur publication, vous pouvez consulter notre site Web (http://www.sto.nato.int/) et vous abonner à ce service.

CENTRES DE DIFFUSION NATIONAUX

ALLEMAGNE
Streitkräfteamt / Abteilung III
Fachinformationszentrum der Bundeswehr (FIZBw)
Gorch-Fock-Straße 7, D-53229 Bonn

BELGIQUE
Royal High Institute for Defence – KHID/IRSD/RHID
Management of Scientific & Technological Research for Defence, National STO Coordinator
Royal Military Academy – Campus Renaissance
Renaissancelaan 30, 1000 Bruxelles

BULGARIE
Ministry of Defence
Defence Institute "Prof. Tsvetan Lazarov"
"Tsvetan Lazarov" bul no.2
1592 Sofia

CANADA
DGSIST 2
Recherche et développement pour la défense Canada
60 Moodie Drive (7N-1-F20)
Ottawa, Ontario K1A 0K2

DANEMARK
Danish Acquisition and Logistics Organization (DALO)
Lautrupbjerg 1-5
2750 Ballerup

ESPAGNE
Área de Cooperación Internacional en I+D
SDGPLATIN (DGAM)
C/ Arturo Soria 289
28033 Madrid

ESTONIE
Estonian National Defence College
Centre for Applied Research
Riia str 12
Tartu 51013

ETATS-UNIS
Defense Technical Information Center
8725 John J. Kingman Road
Fort Belvoir, VA 22060-6218

FRANCE
O.N.E.R.A. (ISP)
29, Avenue de la Division Leclerc
BP 72
92322 Châtillon Cedex

GRECE (Correspondant)
Defence Industry & Research General Directorate, Research Directorate
Fakinos Base Camp, S.T.G. 1020
Holargos, Athens

HONGRIE
Hungarian Ministry of Defence
Development and Logistics Agency
P.O.B. 25
H-1885 Budapest

ITALIE
Ten Col Renato NARO
Capo servizio Gestione della Conoscenza
F. Baracca Military Airport "Comparto A"
Via di Centocelle, 301
00175, Rome

LUXEMBOURG
Voir Belgique

NORVEGE
Norwegian Defence Research Establishment
Attn: Biblioteket
P.O. Box 25
NO-2007 Kjeller

PAYS-BAS
Royal Netherlands Military Academy Library
P.O. Box 90.002
4800 PA Breda

POLOGNE
Centralna Biblioteka Wojskowa
ul. Ostrobramska 109
04-041 Warszawa

PORTUGAL
Estado Maior da Força Aérea
SDFA – Centro de Documentação
Alfragide
P-2720 Amadora

REPUBLIQUE TCHEQUE
Vojenský technický ústav s.p.
CZ Distribution Information Centre
Mladoboleslavská 944
PO Box 18
197 06 Praha 9

ROUMANIE
Romanian National Distribution Centre
Armaments Department
9-11, Drumul Taberei Street
Sector 6
061353 Bucharest

ROYAUME-UNI
Dstl Records Centre
Rm G02, ISAT F, Building 5
Dstl Porton Down
Salisbury SP4 0JQ

SLOVAQUIE
Akadémia ozbrojených síl gen. M.R. Štefánika, Distribučné a informačné stredisko STO
Demänová 393
031 01 Liptovský Mikuláš 1

SLOVENIE
Ministry of Defence
Central Registry for EU & NATO
Vojkova 55
1000 Ljubljana

TURQUIE
Milli Savunma Bakanlığı (MSB)
ARGE ve Teknoloji Dairesi Başkanlığı
06650 Bakanliklar – Ankara

AGENCES DE VENTE

The British Library Document Supply Centre
Boston Spa, Wetherby
West Yorkshire LS23 7BQ
ROYAUME-UNI

Canada Institute for Scientific and Technical Information (CISTI)
National Research Council Acquisitions
Montreal Road, Building M-55
Ottawa, Ontario K1A 0S2
CANADA

Les demandes de documents STO, RTO ou AGARD doivent comporter la dénomination « STO », « RTO » ou « AGARD » selon le cas, suivie du numéro de série (par exemple AGARD-AG-315). Des informations analogues, telles que le titre et la date de publication sont souhaitables. Des références bibliographiques complètes ainsi que des résumés des publications STO, RTO et AGARD figurent dans le « NTIS Publications Database » (http://www.ntis.gov).

NORTH ATLANTIC TREATY ORGANIZATION

BP 25
F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE
Télécopie 0(1)55.61.22.99 • E-mail mailbox@cso.nato.int

SCIENCE AND TECHNOLOGY ORGANIZATION

DISTRIBUTION OF UNCLASSIFIED STO PUBLICATIONS

AGARD, RTO & STO publications are sometimes available from the National Distribution Centres listed below. If you wish to receive all STO reports, or just those relating to one or more specific STO Panels, they may be willing to include you (or your Organisation) in their distribution.

STO, RTO and AGARD reports may also be purchased from the Sales Agencies listed below.

Requests for STO, RTO or AGARD documents should include the word 'STO', 'RTO' or 'AGARD', as appropriate, followed by the serial number. Collateral information such as title and publication date is desirable.

If you wish to receive electronic notification of STO reports as they are published, please visit our website (http://www.sto.nato.int/) from where you can register for this service.

NATIONAL DISTRIBUTION CENTRES

BELGIUM
Royal High Institute for Defence – KHID/IRSD/RHID
Management of Scientific & Technological Research for Defence, National STO Coordinator
Royal Military Academy – Campus Renaissance
Renaissancelaan 30
1000 Brussels

BULGARIA
Ministry of Defence
Defence Institute "Prof. Tsvetan Lazarov"
"Tsvetan Lazarov" bul no.2
1592 Sofia

CANADA
DSTKIM 2
Defence Research and Development Canada
60 Moodie Drive (7N-1-F20)
Ottawa, Ontario K1A 0K2

CZECH REPUBLIC
Vojenský technický ústav s.p.
CZ Distribution Information Centre
Mladoboleslavská 944
PO Box 18
197 06 Praha 9

DENMARK
Danish Acquisition and Logistics Organization (DALO)
Lautrupbjerg 1-5
2750 Ballerup

ESTONIA
Estonian National Defence College
Centre for Applied Research
Riia str 12
Tartu 51013

FRANCE
O.N.E.R.A. (ISP)
29, Avenue de la Division Leclerc – BP 72
92322 Châtillon Cedex

GERMANY
Streitkräfteamt / Abteilung III
Fachinformationszentrum der Bundeswehr (FIZBw)
Gorch-Fock-Straße 7
D-53229 Bonn

GREECE (Point of Contact)
Defence Industry & Research General Directorate, Research Directorate
Fakinos Base Camp, S.T.G. 1020
Holargos, Athens

HUNGARY
Hungarian Ministry of Defence
Development and Logistics Agency
P.O.B. 25
H-1885 Budapest

ITALY
Ten Col Renato NARO
Capo servizio Gestione della Conoscenza
F. Baracca Military Airport "Comparto A"
Via di Centocelle, 301
00175, Rome

LUXEMBOURG
See Belgium

NETHERLANDS
Royal Netherlands Military Academy Library
P.O. Box 90.002
4800 PA Breda

NORWAY
Norwegian Defence Research Establishment, Attn: Biblioteket
P.O. Box 25
NO-2007 Kjeller

POLAND
Centralna Biblioteka Wojskowa
ul. Ostrobramska 109
04-041 Warszawa

PORTUGAL
Estado Maior da Força Aérea
SDFA – Centro de Documentação
Alfragide
P-2720 Amadora

ROMANIA
Romanian National Distribution Centre
Armaments Department
9-11, Drumul Taberei Street
Sector 6
061353 Bucharest

SLOVAKIA
Akadémia ozbrojených síl gen M.R. Štefánika, Distribučné a informačné stredisko STO
Demänová 393
031 01 Liptovský Mikuláš 1

SLOVENIA
Ministry of Defence
Central Registry for EU & NATO
Vojkova 55
1000 Ljubljana

SPAIN
Área de Cooperación Internacional en I+D
SDGPLATIN (DGAM)
C/ Arturo Soria 289
28033 Madrid

TURKEY
Milli Savunma Bakanlığı (MSB)
ARGE ve Teknoloji Dairesi Başkanlığı
06650 Bakanliklar – Ankara

UNITED KINGDOM
Dstl Records Centre
Rm G02, ISAT F, Building 5
Dstl Porton Down, Salisbury SP4 0JQ

UNITED STATES
Defense Technical Information Center
8725 John J. Kingman Road
Fort Belvoir, VA 22060-6218

SALES AGENCIES

The British Library Document Supply Centre
Boston Spa, Wetherby
West Yorkshire LS23 7BQ
UNITED KINGDOM

Canada Institute for Scientific and Technical Information (CISTI)
National Research Council Acquisitions
Montreal Road, Building M-55
Ottawa, Ontario K1A 0S2
CANADA

Requests for STO, RTO or AGARD documents should include the word 'STO', 'RTO' or 'AGARD', as appropriate, followed by the serial number (for example AGARD-AG-315). Collateral information such as title and publication date is desirable. Full bibliographical references and abstracts of STO, RTO and AGARD publications are given in "NTIS Publications Database" (http://www.ntis.gov).

ISBN 978-92-837-2424-7