The Use of Movement-Based Tests for the Prediction of Non-Contact Low Back Injuries in Uninjured Military Personnel: A six-month prospective cohort study.

by

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Abstract

Background

Low back pain (LBP) is the most reported musculoskeletal complaint in the Canadian Armed Forces (CAF). By identifying low-tech movement-based tests that predict risk of future non-contact low back injury (LBI), we could create an easy to administer screening test. It may then be possible to target intervention to high-risk individuals to affect the prevalence of future LBIs.

The objective of this prospective cohort study was to (1) determine which personal characteristics, medical history, and movement-based test variables could predict non-contact LBI in a six-month follow-up in military personnel without LBI at baseline.

Methods

Volunteers without LBI for at least three months at baseline were recruited via multiple recruitment presentations to CAF personnel. At baseline, a standardized questionnaire was used to collect predictors variables and participants completed 19 movement-based tests including; the Functional Movement Screen (FMS), Lower and Upper Quarter Y-Balance Tests (LQYBT and UQYBT), LBP provocation tests, ankle dorsiflexion mobility, low back extensor endurance, side planks, and four spinal mobility tests. LBI was tracked for 6 months using monthly online surveys. An LBI was defined as a non-contact sudden onset or overuse injury to the spine, hip or pelvis causing ≥2/10 pain for at least three days, limiting ability to work/exercise for >24 hours, with self-reported function of ≤90%, and resulting in medical care. Independent t-tests for continuous variables and Chi-square tests for categorical variables were used to identify variables presenting univariate associations with LBI. Receiver operator characteristic (ROC)

curves were used to dichotomize promising continuous variables. Dichotomous predictors with an odds ratio of 2.0 or more and with $p<0.2$ were used to develop a logistic regression model to predict future LBI. A clinical prediction rule was developed by examining the accuracy for presenting any number of predictors retained in the regression.

Results

Four hundred ninety-four personnel were enrolled. Data were available on 455 participants (92%): one withdrew, four retired, and 36 had incomplete data. Nineteen participants reported an LBI over the 6-month follow-up.

The following seven dichotomized movement-based continuous variables presented significant univariate associations with future LBI: UQYBT inferolateral asymmetry ≥1.5cm, worst LQYBT anterior reach ≤55cm, LQYBT composite worst score ≤100%, fingertip-to-floor distance ≥16cm, side plank time asymmetry ≥8s, Modified Sorensen duration ≤86.0 seconds and Trunk Stability Push Up score ≤5.

Three demographic and medical history categorical variables presented significant univariate associations with future LBI: smoker, more than one LBI episode in the last five years; and perceived low back baseline function score <90%.

Five pain provocation tests predicted future LBI: side plank, ankle dorsiflexion, trunk stability push up, extension clearance and passive lumbar extension.

A logistic regression prediction model for LBI was identified by combining five modifiable predictors: baseline perceived lumbar/hip function ≤90%, pain with extension clearance, UQYBT inferolateral asymmetry ≥1.5cm, side plank time asymmetry ≥8s and LQYBT composite worst score ≤100%. Using this model, 89.9% of the participants were correctly classified as injured/not injured during the 6-month follow-up.

Participants with three or more predictors were 6.8 (CI 4.2-11.1) times more likely to have an LBI with 57.9% sensitivity, 91.5% specificity and 90.1% accuracy. Using three or more variables accurately predicted 11 of 19 cases.

Conclusion

History of LBI, current level of function, pain provocation and movement testing contributed to predict first episode or recurrent episode of LBI in CAF personnel without LBP at baseline at risk for future LBI. The proposed prediction rule is a moderately sensitive and highly specific test cluster to effectively identify people at higher risk of non-contact LBI. Presenting three or more of the five predictors represents a greater risk of LBI with a high specificity (91.5%). Such cases may benefit from a preventive training program. With two or fewer predictors, specificity decreased (59.8%), it may be impractical to offer preventative programming to the larger number of personnel thus identified. The benefits of early identification of "LBI risk" are potential for decreased costs, use of medical assets, and lost days. Modifying risk, if possible, may increase deployability of military personnel.

Preface

This thesis is an original work by Daniel Crumback. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "The Use of Movement-Based Clinical Tests to Predict Low Back Pain in Canadian Armed Forces Personnel", No. Pro00065519, July 13 2016.

Chapter 3 of this thesis will be submitted for publication as D.J. Crumback, E.C. Parent, and J.S. Hebert, "*The Use of Movement-Based Tests for the Prediction of Non-contact Low Back Injuries in Military Personnel: A six-month prospective cohort study*", to Spine. E.C. Parent was the supervisory author, involved in developing the study plan, data analysis and contributed to manuscript composition. J.S. Hebert assisted with developing the study plan and manuscript edits.

Dedication

This research is dedicated to the men and women of the Canadian Armed Forces who volunteer to protect our country. It was an honour to serve with you.

“The value of an idea lies in the using of it.”

Thomas Edison

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I would also express my appreciation to my wife, Jessica Crumback-Nyahoe, who recognised the importance of this research and provided undying support throughout this process.

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List of Abbreviations

CAF: Canadian Armed Forces

CFHS: Canadian Forces Health Service

FMS: Functional Movement Screen

ICC: Intraclass Correlation Coefficient

LBI: Low back injury

LBP: Low back pain

MEL: Medical employment limitations

MMST: Modified-Modified Schober Test

MSK: Musculoskeletal

NLR: Negative likelihood ratio

NPV: Negative predictive value

OR: Odds ratio

PLE: Passive lumbar extension

PES: Physical Exercise Specialist

PT: Physiotherapist

PTA: Physiotherapy assistants

PLR: Positive likelihood ratio

PPV: Positive predictive value

PIT: Prone Instability Test

ROM: Range of motion

ROC: Receiver operator characteristic

RSI: Repetitive stress injury

SANE – Single Analogue Numerical Evaluation

SFMA: Selective Functional Movement Assessment

DN: Dysfunctional Non-painful

DP: Dysfunctional Painful

FN: Functional and Non-painful

FP: Functional Painful

TCAT: Temporary category

YBT: Y Balance Test

LQYBT: Lower Quarter Y-Balance Test

UQYBT: Upper Quarter Y-Balance Test

RSI: Repetitive stress injury

Chapter One: Thesis Overview

Low back pain is a common global problem. The point prevalence of low back pain (LBP) in 2017 was estimated to be 7.5% of the global population, or around 577 million people.[1] LBP has been the leading cause of years lived with disability (YLDs) since 1990[1] and remains a significant global public health concern. Although less than 28% of people with LBP have severe disability, they account for 77% of all disability caused by low back pain.[2]

The societal impact of early retirement in terms of direct health-care costs and indirect costs (i.e., work absenteeism or productivity loss) is enormous. Studies in European countries indicate that the total costs associated with low back pain varies between 0.1-2% of the gross domestic product.[3,4]

The incidence of musculoskeletal injuries and the associated morbidity is also high among Canadian Armed Forces (CAF) personnel. Almost half of all medical visits (45%) and medical releases (43%) are the result of a musculoskeletal (MSK) injury.[5] The CAF is not immune to this high incidence of LBI. According to the 2013/2014 Health and Lifestyle Information Survey,[5] 32.3% of all Regular Force personnel reported having sustained a repetitive stress injury (RSI) serious enough to limit their normal activities in the previous year. The percentage was not different between categories of sex, rank, service element, smoking status, or physical activity level. Low back injury (LBI) was the most reported musculoskeletal (MSK) RSI complaint affecting 12.3% of CAF personnel.[5]

The prevalence of LBI is even higher in the operational environment. Workload measures from Afghanistan indicate that an average of 37.6% of personnel treated in physiotherapy during deployment were referred secondary to spine pain.[6] Of this group, 70.7% were for thoracic or lumbar referrals.[6] This contrasts with an average of 18% referred for LBI each year while in garrison (non-operational).[7] A potential reason for the increase in back related referrals was the increased loads carried by CAF members in Afghanistan as well as the potential effects of increased stress and anxiety associated with being in a combat environment. Low back injuries increase lost time, health care utilization, and disability costs, generating a substantial economic burden.[8]

1.1 Statement of the Problem

In 2013, a CAF Expert Panel for the creation of a Spinal Pathway for LBP met in Ottawa, Ontario. CAF experts from all areas of medicine met to create an assessment and treatment pathway due to the high prevalence of LBP in the CAF. As part of this pathway, the panel agreed as part of the Injury Prevention Statement that "primary prevention must be a priority" and that "the creation of a low back specific fitness program may help prevent the occurrence (or recurrence) of low back injury."[9]

The goal in primary prevention is to reduce the number of incident cases of LBP experienced by a population.[10] In order to apply a preventative strategy to the appropriate audience, a screening tool must be developed that could identify those at an increased risk of LBI. This would allow targeting the most at-risk candidates with prevention interventions, thereby improving effectiveness of the program, and limiting intervention implementation costs.

In 2015, Teyhen et al.[11] examined the ability of baseline measures of self-report and physical performance to identify future musculoskeletal injury risk in currently uninjured Army Rangers in the United States. Smoking, prior surgery, recurrent prior musculoskeletal injury, limited-duty days in the prior year for musculoskeletal injury, asymmetrical ankle dorsiflexion, pain with Functional Movement Screen clearing tests, and decreased performance on the 2-mile run and 2-minute sit-up tests were associated with increased injury risk. This important study, however, did not isolate the specific area of injury which was predicted; it aimed only for predicting the risk of any MSK injury. Due to their ability to challenge a specific region, we hypothesized that a subset of movement-based screening tests may perform better when predicting a specific MSK injury type than a broad range of MSK injuries. Further, our focus on movement-based testing was justified by our understanding that the screening must be able to be employed on many personnel in stark conditions, including during deployments, without relying on highly technical tests (e.g., MRI, CT, EMG) due to their limited availability and high cost.

The literature identifies several movement-based clinical tests that may predict LBI in currently uninjured populations. The Modified Schober (excessive lumbar mobility) and the Modified Sorensen (decreased lumbar extensor endurance) have been shown to predict LBI in an adolescent population.[12,13] Another test indicating promise in predicting LBI includes the side plank.[14] Movement-based screening techniques such as Functional Movement Screen (FMS) have also shown promise to predict risk of MSK injuries in military populations, but this assessment and results were not specific to LBI.[11,15,16]

Psychosocial factors have been found to play an important role in the perception of severity and chronicity as well as the prognosis of LBP.[17] Bigos et al.[18] prospectively evaluated 3020 volunteers of the Boeing-Everett plant to assess risk factors that predispose workers to file industrial back injury claims. They looked at physical variables such as anthropometry, results of a back examination, and physical capacities including flexibility and isometric strength as well as nonphysical variables such as demographics, medical history, workplace factors, job perception and psychological factors. During four years of follow-up observation, more than 279 subjects reported acute back problems. Personnel with recent LBIs were not excluded. Back pain with straight leg raise, previous chiropractic treatment, number of doctor visits, Minnesota

Multiphasic Personality Inventory (MMPI) scale 3, health locus of control item 3 and modified work as captured by The Modified Work Adaptation, Partnership, Growth, Affection, and Resolve (APGAR) survey summary score were the significant results included in their final predictive multivariate model. They found the most predictive individual factors were (1) job task dissatisfaction and (2) distress as reported on Scale 3 of the MMPI. They surmise that this perhaps explains why the focus on purely physical and injury-related factors has met with little success in predicting future LBI. But, as the authors state, "distress and job dissatisfaction are not markers or labels for individuals; they are dynamic and could possibly be influenced through a humane approach to the problem."[19] Claims may not indicate a true LBI but an issue with potential gain where the employees may have been filing a claim (indicating a new LBI) but saw the opportunity to gain financially.

Currie et al.[20] only looked at major depression as an antecedent risk factor for first onset of chronic back pain. They followed 9909 pain-free individuals 15 years and older for up to 24 months with no history of back problems. The rate of new cases of chronic LBP in persons who were depressed was 3.6% compared to 1.1% in non-depressed persons. After controlling for other factors, pain-free individuals diagnosed as majorly depressed were almost three times more likely (OR 2.9, 95% CI 1.2–7.0) to develop chronic LBP. They found that consistent with other longitudinal studies,[21] major depression increases the risk of developing future chronic pain. The causal mechanism linking these conditions is unknown however depression may represent a modifiable risk factor in the development of chronic LBP.

These studies indicate that psychosocial factors may influence risk of future LBI and should be considered in future studies. In the study by Teyhen et al.[11,16] in military personnel, they included a psychosocial component in their study which included a survey of biopsychosocial questions related to job/life satisfaction, depression, anxiety, frustration, anger, and fear by integrating both the Biopsychosocial Summary Score and the Patient Health Questionnaire (PHQ-9). The Biopsychosocial Summary Score is a composite score from 5 questions associated with depression, anxiety, frustration, anger, and fear (0% to 100% for each rating, where 0% = "none" and 100% = "most severe imaginable"). The PHQ-9 is a 9-item symptoms self-report checklist that is a valid and reliable measure of depression severity. There were significant univariate relationships between the baseline data and time loss injury for both the Biopsychosocial Summary Score ($p<0.01$; OR 3.06) and the PHQ-9 ($p<0.01$; OR 3.01). These variables, however, did not make it into their final model which consisted of previous history, perceived level of function, pain provocation and movement-based tests. In our study, we were interested in identifying movement-based predictors specific to LBI, therefore we did not include psychosocial factors in order to keep the number of variables to a manageable level.

1.2 Purpose of the thesis

The objectives of this study were:

(1) to determine which self-reported personal characteristics, medical history, and clinical variables can predict first episode or recurrent LBI in a six-month follow-up in military personnel initially not currently experiencing LBI; and

(2) to determine which combination of predictor variables would best predict low LBI risk in CAF personnel.

If a test cluster could be identified, the tests could then be used to inform the development of exercise interventions which may decrease risk of future LBI or recurrence of LBI in previously injured personnel. If an effective targeted preventative strategy could be designed, the potential benefit of early identification of "at risk" personnel and the application of an effective exercise program could decrease costs, use of medical assets, lost days, and loss of trained and experienced personnel to medical release as well as increase the deployability of military personnel. This thesis focuses on the initial step of developing a prediction strategy.

1.3 Outline of the thesis

This thesis document is organised as follows. The current chapter, Chapter 1, provides an outline of the rationale for the thesis and an orientation to the context and structure of the thesis. Chapter 2 presents a general review of the literature associated with LBI prediction beginning with a review of the global prevalence and cost of LBI, and specifically, in the CAF population. Chapter 2 also outlines the rationale for prediction of MSK injuries, and more specifically, prediction of LBI. Chapter 2 concludes with a review of the requirements of a predictive model for LBI, summary of the literature on prediction of MSK injuries and LBI and offers a rationale for the investigation of movement-based predictors of LBI.

Chapter 3 presents a manuscript prepared for *The Spine Journal* summarizing the experimental research conducted for this thesis. The objective of this study was to: (1) determine which personal characteristics, medical history, current level of function, pain provocation and movement-based test variables could predict non-contact LBI in a six-month follow-up in military personnel without LBI at baseline; and (2) to determine which combination of variables would best predict non-contact LBI risk in non-injured CAF personnel at baseline. This work is justified by the high prevalence, the ramifications of LBIs in the CAF, a brief review of the current literature specific to the potential to achieve success with LBI prediction, and the fact that developing a prediction model for LBI is a stated priority by the CAF. The study recruited 494 military personnel not affected by LBI during the three months preceding baseline. At baseline, they completed self-reported medical history and inventory of their personal characteristics and also completed a battery of simple-movement based tests. They later completed monthly LBI surveys for 6 months. This paper summarizes which tests could predict LBI and presents the best combination of predictors which could be used as a screening battery to investigate the effectiveness of prevention programs in targeted personnel at higher risk of LBI.

Finally, Chapter 4 is a general discussion of the thesis comparing our results with the literature, outlining the take home messages, presenting future avenues for research while acknowledging the strengths and limitations of the thesis work. The conclusion of the chapter includes the take home message and clinical implications.

1.4 Anticipated significance of the thesis

After many years of treating the soldiers over and over for the same condition, it was clear that if the CAF hoped to make a significant difference in the prevalence of LBI, they had three things to consider:

1) What is it about some soldiers that results in high levels of recidivism of LBI but not for others,

2) Can we identify those at risk for LBI or re-injury using movement-based tests,

3) Would decreasing their risk profile via an individualized limitation-specific training program result in decreased LBI and re-injury rates?

The general application of a low back specific training program without identifying the at-risk population is not respectful of those with low risk and would likely not yield the same results as one applied to the medium or high-risk group. Further, it may be cost prohibitive to implement a prevention program without targeting at-risk personnel. This study was the first step in identifying risk of first episode or recurrent episode of LBI in CAF personnel without LBP at baseline. Results of this thesis could help inform the design of an LBI-specific movement-based training approach purposely targeting those at risk to then determine if by correcting the movement deficit, we can decrease first episode or recurrent non-contact LBI rates in personnel without LBP at baseline. It may also be possible to target those who are currently injured with a similar program aiming to reduce their risk level for reinjury or perhaps, a different prediction scheme is needed in those recovering from injury at baseline.

This research study is significant as currently, the CAF does not use any predictive tests to predict LBI. If we were able to identify the at-risk military population for LBI with our simple and deployable screening tests, we may have the opportunity to mitigate the risk via exercise and education. The goal of this study was to gain a deeper understanding of the predictive value of a variety of clinical tests on military personnel. The results may support the implementation of risk-specific exercise programming, which would potentially have a large effect on the disability related to LBI in the CAF. As the rates of LBI are similar between the civilian and military population, and the military population demographics affected by LBI are similar to the civilian demographics, it is reasonable to argue that despite the specificity of this study, its results may be applicable to a work population at large.

Chapter Two: Literature Review

2.1 LBP is an important problem

LBP is an extremely common symptom experienced by people of all ages. According to Hartvigsen et al.[2] in 2015, the global point prevalence of activity-limiting LBP was 7.3%, inferring that 540 million people were affected at any one time. LBP is now the number one cause of disability globally. Worldwide, disability from LBP is highest in working age groups.[2] LBI has been the leading cause of years lived with disability since 1990[1] and remains a significant global public health concern. Although less than 28% of people with LBP have severe disability, they account for 77% of all disability costs caused by LBP.[1]

The societal impact of early retirement in terms of direct health-care costs and indirect costs (i.e., work absenteeism or productivity loss) is enormous. Studies in European countries indicate the total costs associated with LBP varies between 0.1-2% of gross domestic product.[3,4] According to Wu et al.[1] "globally, LBP remains the leading global cause of years lived with disability, yet it continues to be inadequately recognized as a disease burden in the population." In his 2004 paper, Mirolla[22] found that MSK disorders were the most prevalent of all chronic diseases accounting for the highest disability costs in Canada. MSK disorders were the single largest cost category associated with any chronic disease. MSK was the second costliest category of any illness (19.7B) after circulatory disease (24.8B) and ahead of cancer (17.1B).[5]

According to Nindl et al.[8] musculoskeletal (MSK) injuries also represent a major threat to the health and fitness of US military personnel. This affects both financial (such as the economic burden from medical, healthcare, and disability costs) and human manpower resources (soldiers medically unable to optimally perform their duties and to deploy). In 2012, MSK injuries represented the leading cause of medical care visits across all US military services resulting in almost 2 200 000 medical encounters and resulted in more disability discharges than any other health condition. Disabilities from MSK injuries in the US military increased over time disproportionately to other medical treatment rates. From 1982 to 2002, the disability discharge rates for MSK injuries increased from less than 15/10 000 for both men and women to 140/10 000 for females (a 9-fold increase) and to 81/10 000 for males (a 5-fold increase).[8] The cost due to time loss is staggering. Estimates of limited duty days in the US military in 2004 were more than 25 million days annually resulting from MSK injuries, an equivalent of 68 000 service members a year on limited duty.[23] The healthcare costs alone ascribed to those 68 000 service members are over $700 million a year. The cost of salaries of service members who cannot deploy is just over $3 billion annually. The costs to the Army for medical care and salaries of soldiers on limited duty can be conservatively estimated to be about $1.5 billion per year.

The incidence of musculoskeletal injuries and the associated morbidity is also high among CAF personnel. Almost half of all visits to CAF medical facilities (45%) and medical releases (43%) are the result of an MSK injury.[5] The CAF is not immune to this high incidence of LBI. According to the 2013/2014 Health and Lifestyle Information Survey,[5] 32.3% of all Regular Force personnel reported having sustained a repetitive stress injury (RSI), which includes some LBI, serious enough to limit their normal activities in the previous year. The percentage was not different between categories of sex, rank, service element, smoking status, or physical activity level.[5] LBI was the most reported MSK RSI complaint affecting 12.3% of CAF personnel.[5]

The prevalence of LBI is even higher in the operational environment. Workload measures from Afghanistan indicate that an average of 37.6% of personnel treated in physiotherapy were referred secondary to spine pain. Of this group, the vast majority (70.7%) were for thoracic or lumbar referrals.[6] This contrasts with an average of 18% referred for LBI each year while in garrison (non-operational).[7] This may be due the additional loads carried while deployed on operations.

MSK injuries also place a large financial burden on the CAF, as well as a major resource draw on the Canadian Forces Health Service (CFHS). In 2012, CAF Physiotherapy (PT) clinics registered 28 484 referrals from a population base of approximately 68 000 personnel.[24] Based upon in-garrison data, approximately 5 100 LBI related PT referrals were written in 2012. CF PT clinics outsource an average of 24% of all patients as referrals exceed our CAF PT staff capacity to assess and treat.[24] The CAF, therefore, outsourced approximately 1 500 LBI PT referrals to providers in 2012. According to Blue Cross data (personal communication from Blue Cross Canada representative), the average number of treatments for outsourced LBI is 11 visits. At that time, with the average cost of $65 per visit, the CAF spent over one million dollars annually in outsourced PT costs for LBI alone. Many of these referrals are for members who have repeatedly sought care for similar complaints at CAF PT clinics. Unfortunately, no data on recurrence rates are available for members in the CAF.

The CAF loses many well-trained and experienced members each year to LBI. Despite ready access to quality care, musculoskeletal complaints continue to be the primary cause of medical releases for members of the CAF. In 2010, 55% of all medical releases were secondary to MSK complaints.[24] From within the MSK grouping, LBP accounted for 16% of medical releases. These numbers have been consistent for over eight years.[24]

2.2 Rationale for prediction of future LBI

In 2013, a CAF Expert Panel for the creation of a Spinal Pathway for LBI met in Ottawa, Ontario. CAF experts from all areas of medicine met to discuss the problem of LBI in the CAF. In the Injury Prevention Statement, the panel agreed that "maintaining physical fitness […] and following a core strength fitness program may prevent the occurrence (or recurrence) of LBI."[9]

Recent review articles suggest that future research related to prevention of LBI should focus on exercise programs, as they may offer the greatest potential for reducing disability from LBP.[25–27] Linton and van Tulder[25] stated, "Only exercises provided sufficient evidence to conclude that they are an effective preventive intervention," but core stabilization programming alone has not been found to be successful in preventing LBI in comparison to standard exercise approaches in a military population.[17] Sowah et al.[27] found that generally, aerobic exercises and resistance training were reported to be effective. Perhaps the issue is that we currently have no movement-based assessment or screening method that can accurately predict LBI and therefore we cannot determine the appropriate exercise programming specific to the deficits identified through screening. According to Covalschi et al.[28] focusing on one area of fitness may not be appropriate, but a multimodal prevention training program integrating major physical activity contents (muscular endurance, strength, stretching and aerobic fitness) may be best.

The goal in primary prevention is to reduce the overall number of LBI episodes experienced by a population.[29] In order to properly prescribe a preventative program, a screening tool must be created that can accurately identify the at-risk population for developing LBI. Research by Lehr et al. established that field-expedient screening and an injury prediction algorithm helped identify collegiate athletes at increased risk of noncontact lower extremity injuries.[30] Those athletes classified as high risk by the algorithm were 3.4 times more likely to sustain a noncontact lower extremity MSK injuries. This study demonstrated that an algorithm was able to stratify athletes into meaningful categories based on multiple risk factors and that screening can be completed in a field-expedient manner with limited time and equipment. This approach could be utilized to individualize injury prevention programs and appropriately distribute resources to those at greatest risk of injury. It is important to note that contact injuries were excluded from this study. Contact MSK injuries, in theory, cannot be predicted based upon movement and therefore should be excluded from any MSK prediction analysis.

However, a need still exists for a population-specific, multifactorial, field-expedient test and algorithm that are predictive of LBI risk among military personnel. Identifying military personnel at risk for LBI RSIs could provide a foundation for personalized injury prevention and risk mitigation programs.

The purpose of this study was to determine whether a multifactorial injury screening protocol and specific predictors can accurately identify military members at risk for non-contact LBI. The hypothesis was that because of the multifactorial nature of LBIs, multiple risk factors would provide a useful method of categorizing military personnel based on injury risk, similar to screening protocols that have been implemented in college athletics.

2.3 Requirements of a predictive model for LBI in the CAF

The CAF employs over 68 000 regular force members who are distributed over more than 20 locations across Canada in addition to supporting foreign operations. A majority of CAF locations provide direct access to full medical services and well-equipped physical training facilities employing qualified fitness instructors. Even on remote operations, CAF military personnel have access to medical care and training centres. Many of the physiotherapists and fitness trainers who work with CAF personnel have access to the equipment and training required to complete movement screening in order to complete movement-based testing. As the intent is to identify personnel at risk of future LBI within an organization who employs a large number of personnel over many locations, we must identify an injury prediction method that requires minimal time to complete, is cost efficient, and requires basic equipment and training that is available at most locations. According to Teyhen et al.,[16] the "challenge with injury prediction and prevention programs is the ability for the program to be feasible, acceptable, and sustainable when applied in scale across the entire military population."

Therefore, the predictive tests included as candidates in this study did not include advanced testing techniques such as electromyography (EMG) or diagnostic imaging (e.g., CT or MRI) as these tests are neither simple, efficient, nor of low cost or available at all testing locations.

A prevention training program cannot practically be designed to be applied to all CAF personnel as the extremely demanding annual training schedule of CAF units precludes its members from completing extraneous and unnecessary training. Offering a prevention training program to all members would also likely be too costly and burdensome. Considering these assumptions, it is logical to first develop a simple and efficient means to identify CAF personnel at risk for LBI or low back reinjury such that an appropriate exercise-based training program could then be applied and evaluated for its ability to mitigate that risk on a smaller targeted subgroup from the CAF population.

2.4 Previous research on prediction of MSK injuries support the value of movement-based tests.

Movement can be defined as a combination of mobility and stability[31–33] which is made up of components of range of motion, flexibility, strength, endurance, proprioception, and balance. Movement is also a large part of being a functioning human being.[31,32] Movement is often affected by injury or dysfunction. Some promise has been shown with the ability of movement-based screening techniques such as Functional Movement Screen (FMS) to predict risk of MSK injuries in military populations, but this assessment and results were not specific to LBI.[11,15,16] The Functional Movement Screen (FMS) combines multiple movement-based functional tests as a screen to predict injury risk in athletes.[32] The FMS includes the following seven tests: squatting, lunging, step-over, active straight leg raise, shoulder mobility, trunk stability push up, and rotational stability tests; and three pain provocation tests including flexion clearance, extension clearance, and shoulder impingement tests. In our study, we used the 100-point scoring method recommended for research.[34] The Functional Movement Screen has good inter-rater (ICC = 0.74) and intra-rater (ICC = 0.76) reliability with trained raters in military populations.[35] The FMS has been researched using US military personnel and has been proven to be effective at predicting MSK injury within this population.[11,15,16] In a meta-analysis looking at whether FMS composite score predicts future MSK injury, Moran et al.[36] reported that in male military personnel, there was "strong" evidence that the strength of association between FMS composite score (cut-point ≤14/21) and subsequent injury was significant but "small" (pooled risk ratio=1.47, 95% CI 1.22 to 1.77, p<0.0001, I^2=57%).

Lisman et al.[15] found that low fitness scores and lower FMS scores could predict injury risk in Marine Corps Officer Candidates undergoing basic training.[15] Slower run times (≥20.5 minutes) on the 3-mile run test yielded injury odds ratios of 1.72 (95% CI 1.29-2.32) and low FMS scores (≤ 14/21) yielded a higher injury odds ratio (OR) of 2.04 (1.32-3.15) for any MSK injury (overuse or traumatic). Candidates with both a low FMS score and slow run time were 4.19 (OR) times more likely (95% CI = 2.33-7.53) to suffer an injury (overuse or traumatic). Due to the substantial evidence supporting the FMS to predict future non-contact MSK injuries, we included the FMS using the 100-point research scoring in our study.[34]

Several studies have looked at the ability of the YBT (upper or lower quadrant) to predict MSK injuries. Smith et al.[37] studied collegiate athletes using the LQ-YBT and determined an asymmetry of >4 cm on the anterior reach predicted non-contact MSK injuries over the athletic season (OR 2.33, 1.15–4.76). A study by Cosio-Lima et al.[38] of coast guard members attending 2 months of intense training found that limited UQ-YBT composite scores predicted MSK injury. Composite left score of 81.8-89.3% and right score of 77.0-88.9% presented a risk ratio of 5.40 (linear trend $p = 0.03$ vs higher scores). The YBT showed good inter-rater test–retest reliability with multiple raters screening a military population with the inter-rater test-retest reliability of the maximal reach (ICC 2,1 of 0.80-0.85) and of the average reach of 3 trials (ICC 2,3 of 0.85-0,93).[39] While the research on YBT to predict LBI is not available, there is some promise as it has been shown to predict MSK injury, therefore we included the YBT in our research for this reason.

One movement-based assessment system that has never been examined for its ability to predict MSK injury or LBI is the Selective Functional Movement Assessment (SFMA). The SFMA is a clinical assessment system designed to identify musculoskeletal dysfunction by evaluation of fundamental movements for limitations or symptom provocation.[40] The SFMA is a system developed for clinicians to identify movement dysfunction in a population with known musculoskeletal injury.[33] The SFMA consists of ten movements: 1) Cervical Flexion, 2) Cervical Extension, 3) Cervical Rotation, 4) Upper Extremity Pattern One (behind the back internal rotation), 5) Upper Extremity Pattern Two (behind the back external rotation), 6) Multi-segmental Flexion, 7) Multi-segmental Extension, 8) Multi-segmental Rotation, 9) Single Leg Balance, and 10) Overhead Deep Squat. The scoring for each movement is based upon combining a score for function (F- functional, D – dysfunctional) and pain (N – non-painful, P – painful). Therefore, each functional movement could be rated as either FN, FP, DN or FP. The intra-rater reliability for an experienced rater (>100 hours) is (ICC 3,1 = 0.86 (0.74-0.93) while inter-rater reliability is poor (ICC 2,1 = 0.43 (0.12-0.67).[40] Glaws et al.[40] therefore, recommended scoring to be completed by a single experienced rater. Considering many of the SFMA movements are similar to the FMS tests - Upper Extremity Pattern One and Two (SFMA) and Shoulder Mobility (FMS), Single Leg Balance (SFMA) and Stepping Over (FMS), and Overhead Deep Squat (SFMA) and Squatting (FMS) – we could eliminate these SFMA movements and capture the movements using the FMS tests. We, therefore, included multi-segmental flexion, extension, and rotation from the SFMA in our LBI study as these movements related to movement and pain with movement of the thoracolumbar spine, pelvis, and hip. We ensured that we used one experienced rater throughout our baseline data testing.

In the Teyhen et al.[11] study with US Army Rangers, they reported that the following predictors were associated with increased MSK injury risk: smoking history (odds ratio = 5.0, 95% CI, 1.3-18.3), prior surgery (3.5, 0.9-13.5), recurrent prior MSK injury (≥3.5prior injuries 5.5,1.5-20.1), limited-duty days in the prior year for MSK injury by one day or more (2.1, 0.8-5.0), asymmetrical ankle dorsiflexion of ≥6.5° (4.1, 1.4-11.7), pain during any of the FMS clearance tests (2.3, 0.7-7.2), and decreased performance on the 2-mile run with ≥773.5 seconds (1.4, 0.8-2.6). Once again, combining risk factors improved predictive ability. Presenting with one or fewer predictors resulted in a sensitivity of 0.90 (95%CI, 0.83– 0.95), and having three or more predictors resulted in a specificity of 0.98 (95% CI, 0.93–0.99). The combined factors that contributed to the final multivariable logistic regression equation yielded an odds ratio of 4.3 (95% CI, 2.0–9.2), relative risk of 1.9 (95% CI, 1.4–2.6), and an area under the curve of 0.64.

In the Teyhen et al.[16] MSK prediction study from 2020 with US military personnel, they found female sex, previous profile for MSK injury, perceived recovery from prior injury, prior injury, pain on movement tests, and slower 2-mile run times had the greatest impact on increasing likelihood of future non-contact MSK injury. In addition to these variables, they found that age, dorsiflexion asymmetry, LQ-YBT anterior reach distance, UQ-YBT superolateral reach distance, and UQ-YBT inferolateral reach asymmetry were also associated with increased likelihood of future injury. Their prediction model accurately identified 88% of non-injured and 46% of injured participants. The specificity of the model was maximized (1.0) when at least 9 of the 11 predictors were present (OR, 9.6; 95% CI, 1.2-80.1) and specificity reached greater than 0.90 once the participant had 7 or more variables present. When only 2 or more predictors were present, the sensitivity was 0.89 (95% CI, 0.84-0.90).

The Teyhen studies support our hypothesis that a multifactorial prediction model that includes past medical history, current perceived level of function, pain provocation, limited movement, and movement asymmetry would likely best predict future non-contact LBI. Respecting these findings, we added several low back specific tests (modified Schober, modified Sorensen, Side Plank, Fingertip to Floor and Multi-segmental Flexion, Rotation and Extension) and pain provocation tests including the Prone Instability Test (PIT) and Passive Lumbar Extension (PLE) to ensure we applied the theory most specifically to the low back area.

2.5 Rationale for further investigation of movement-based predictors of LBI

Because the goal of identifying the population at risk of LBI is to then apply and explore the effects of an exercise-based mitigation strategy to reduce this risk, our review of the LBI prediction research focused on movement-based clinical tests. These clinical tests are currently evaluated clinically at all CAF locations by physiotherapists and physical training staff; thereby, meeting the aforementioned logistical requirements. Another reason that movement-based clinical tests were considered in priority was that they are highly influenced by limitation specific exercise programming, therefore making them ideal variables to measure as modifiable risk factor which could be targeted in future exercise-based LBI risk mitigation strategies.

In a study of professional American football players (62) by Kiesel et al.[41] to determine if an off-season intervention program was effective in improving FMS scores, pre- and post-intervention FMS scores were obtained after completing an individualized limitation specific seven-week off-season intervention program. The intervention program consisted of an individual specific training program, based on their FMS score, designed to correct the identified movement deficits. This program consisted of stretching, self-administered trigger point treatment, and corrective exercises specific to their limitations. At the end of the intervention, a greater number of players exhibited a score that improved to above the injury threshold (≤14/21) compared with before the intervention ($X^2 = 164.9$, $p<0.01$). Thirty-nine subjects exhibited a score that exceeded the injury risk threshold at the end of the program compared with seven that exhibited a score >14 at baseline.

In a study with firefighters (n=524) in 2020, Jafari et al.[42] studied the distribution of FMS scores in firefighters and examined whether an 8-week corrective exercise program could improve their scores compared to a control group. Those who obtained a score of 14 or less, a sign of movement dysfunction, and volunteered to continue their participation were randomly assigned to either an experimental (n = 51) or a control (n = 45) group. Both groups participated in an 8-week training program. The control group used their own usual training routine (endurance and resistive training), but the experimental group used the specific protocol designed with the aim of correcting the functional movement patterns. Repeated-measures analysis of variance revealed a significant interaction for FMS scores between the groups over time (F 1.94 = 165, P < .001). The experimental group showed a 69% improvement from pretest (10.6) to post test (17.8), whereas the control group showed only a 3% improvement from pretest (11.8) to post-test (12.1).

These studies demonstrate the ability to improve movement-based deficits through the application of an individualized training plan specific to their movement deficits, as represented by their change in FMS scores, potentially decreasing their risk of future MSK injury. This supports the concept that LBI prevention should be based upon identification of LBI risk factors and a movement specific exercise program to decrease movement deficits applied to those at high risk of non-contact LBIs. Unfortunately, no known studies exist demonstrating an actual decrease in MSK injuries when attempting to reduce risk by treating movement deficits (FMS or YBT) scores but this should be a focus of future research.

No known research could be found to support exercise as a primary prevention of LBI. In a systematic review on exercise for the prevention of non-specific chronic LBP, Covalschi et al.[28] concluded physical activity is significantly better for reducing recurrence and a multimodal prevention training program aimed at adjusting the deficits or imbalance by integrating major physical activity contents (muscular endurance, strength, stretching, and aerobic fitness) can be beneficial in the prevention of non-specific chronic LBP. If we can affect recurrence rates in chronic LBI through exercise, it is possible that we can use exercise to decrease a person's risk of an initial LBI.

2.6 Previous research on prediction of LBI

The literature identifies several movement-based clinical tests that may predict LBI in currently uninjured populations. The modified Schober (excessive lumbar mobility) and the modified Sorensen (decreased lumbar extensor endurance) have been shown to predict LBI in adolescent[12] and adult populations.[13,43] Biering-Sorensen[44] reported fair predictive value with the Modified Schober test indicating that excessive lumbar flexion mobility may be a predictor of new onset LBP over a one year period in men only. According to Alaranta,[45] good low back extensor endurance may prevent first-time occurrences of LBP in men. Participants with poor low back endurance (>85 seconds) were 3.4 times more likely to develop LBI in the next year (95% CI, 1.2-10.0) than those who had a medium or good performance.

McGill et al.[14] study of 53 elite police officers who were followed over five years found through logistic regression analysis ($p < 0.001$, $x^2 = 26.561$, $R^2 = 0.581$) seven variables best predicted those who would suffer a back injury with 64% sensitivity and 95% specificity for an overall concordance of 87%. These variables were: abdominal endurance (sit up posture), low back extensor endurance (Sorensen), ratio of abdominal to extensor endurance, side plank duration, hip extension with knee flexed, and hip extension with knee extended. This study further supports the need to include movement-based tests in any LBI prediction study.

Pain provocation has also been determined to be a predictor of future MSK injury[19,20] in military[11,16] and athletic populations.[46,47] Teyhen et al.[16] included several pain provocation tests (pain with Flexion Clearance, Extension Clearance, and Impingement tests from FMS) as well as tracked pain during movement and performance tests. They categorized them together as pain on movement testing and it proved to be a strong predictor (OR 2.2 (1.7-3.0), RR 11.6 (1.3-1.9)) making it into the final logistic regression model. The evidence that pain provocation can predict future MSK injuries is clear; therefore, we included this component in our study and added two low back specific pain provocation tests (PIT and PLE) and recorded pain responses to many other movement tests which have not been evaluated for their ability to predict LBI.

In systematic literature reviews of studies on preventing LBP episodes, they found strong, consistent evidence to guide prevention of LBP episodes in working-age adults. The reviews found exercise interventions effective and other interventions not effective, including education (psychosocial) without an exercise component.[27,48] Psychosocial factors have been found to play an important role in the perception of severity and chronicity as well as the prognosis of LBP.[17] Bigos et al.[18] prospectively evaluated 3020 volunteers of the Boeing-Everett plant to assess risk factors that predispose workers to file industrial back injury claims. They looked at physical variables such as anthropometry, results of a back examination, and physical capacities including flexibility and isometric strength as well as nonphysical variables such as demographics, medical history, workplace factors, job perception and psychological factors. During four years of follow-up observation, more than 279 subjects reported acute back problems. Personnel with recent LBIs were not excluded. Back pain with straight leg raise, previous chiropractic treatment, number of doctor visits, Minnesota Multiphasic Personality Inventory (MMPI) scale 3, health locus of control item 3 and modified work detected using The Modified Work Adaptation, Partnership, Growth, Affection, and Resolve (APGAR) survey summary score were the significant results included in their final predictive multivariate model. They found the most predictive individual factors were (1) job task dissatisfaction and (2) distress as reported on Scale 3 of the MMPI. They surmise that this perhaps explains why the focus on purely physical and injury-related factors has met with little success in predicting future LBI. But, as the authors state, "distress and job dissatisfaction are not markers or labels for individuals; they are dynamic and could possibly be influenced through a humane approach to the problem."[19] Claims may not indicate a true LBI but an issue with potential gain where the employees may have been filing a claim (indicating a new LBI) but saw the opportunity to gain financially.

In a study by Currie et al.[20] they only looked at major depression as an antecedent risk factor for first onset of chronic back pain. They followed 9909 pain-free individuals 15 years and older for up to 24 months with no history of back problems. The incidence of new cases of chronic LBP in persons who were depressed was 3.6% compared to 1.1% in non-depressed persons. After controlling for other factors, pain-free individuals diagnosed as majorly depressed were almost three times more likely (OR 2.9, 95% CI 1.2–7.0) to develop chronic LBP. They found that consistent with other longitudinal studies,[21] major depression increases the risk of developing future chronic pain. The causal mechanism linking these conditions is unknown however depression may represent a modifiable risk factor in the development of chronic LBP.

These studies indicate that psychosocial factors may influence risk of future LBI and should be considered in future studies. In the study by Teyhen et al.[11,16] in military personnel, they included a psychosocial component in their study which included a survey of biopsychosocial questions related to job/life satisfaction, depression, anxiety, frustration, anger, and fear by integrating both the Biopsychosocial Summary Score and the Patient Health Questionnaire (PHQ-9). The Biopsychosocial Summary Score is a composite score from 5 questions associated with depression, anxiety, frustration, anger, and fear (0% to 100% for each rating, where 0% = "none" and 100% = "most severe imaginable"). The PHQ-9 is a 9-item symptoms self-report checklist that is a valid and reliable measure of depression severity. There were significant univariate relationships between the baseline data and time loss injury for both the Biopsychosocial Summary Score ($p<0.01$; OR 3.06) and the PHQ-9 ($p<0.01$; OR 3.01). These variables did not make it into their final model which consisted of previous history, perceived level of function, pain provocation and movement-based tests. In our study, we were interested in identifying movement-based predictors specific to LBI, therefore we did not include psychosocial factors in order to keep the number of variables to a management level.

Considering there is some evidence supporting the ability of psychosocial variables such as job satisfaction and depression to predict future LBI[19–21] and MSK[16] injuries it may be beneficial to include a psychosocial component in a MSK or LBI prediction model. Nevertheless, as a strong majority of the literature supports exercise as the method of preventing future LBI and to ensure we had sufficient power, we focused our prediction model development specifically on movement-based testing.

2.7 Why predict LBI over a 6-month duration in the military?

Recently, the average duration of an operational tour in the CAF has been six months. It is costlier, logistically challenging, and potentially perilous to remove a military member from a deployment due to an MSK injury. We selected this 6-month follow-up period as we wanted to be able to determine risk of MSK injury in the next 6-12 months. If a commander knows that they have a member at a high risk of injury while on deployment, they have the ability to select another candidate while allowing the high-risk member the time and means to potentially decrease his/her risk through the appropriate application of exercise.

2.8 Conclusion

This general literature review suggests that prediction of LBI injuries is possible and identified several candidate prediction variables among personal characteristics, medical history, and simple movement-based tests. All these tests may be usable in the many settings where CAF personnel are called to work even when advanced testing technologies may not be available. Research with tactical athletes and military populations indicate smoking history, related MSK medical history, fitness test results, the Functional Movement Screen (FMS), ankle mobility, and pain provocation have been found to predict future MSK injuries and should be investigated for their ability to specifically predict LBI. The Modified Schober and the modified Sorensen have already been shown to be predictive of LBI and may perform better in combination with the other tests just mentioned.

The SFMA, specifically the lumbar multi-segmental movements and lumbar provocation tests (PLE and PIT), have not been investigated for ability to predict LBI, but in theory, present the potential to be useful as argued earlier and should be tested in a prospective study.

Based upon this review, we intend to evaluate the predictive ability of the aforementioned tests and combine them as a screening cluster to assess their ability to predict future LBI in a military population. This is a preliminary step necessary before testing the effectiveness of feasible prevention programs by targeting personnel identified as at risk of future LBI by the prediction tool.

Chapter Three: The Use of Movement-Based Tests for the Prediction of Non-contact Low Back Injuries in Military Personnel: A six-month prospective cohort study

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ABSTRACT

Study Design: Prospective cohort study.

Objective: To identify personal characteristics and movement-based tests that predict first episode or recurrent episode of non-contact low back injuries (LBI) in military personnel without LBP at baseline over a six-month follow-up.

Setting: Canadian Armed Forces base in Alberta, Canada.

Summary of background data: Identifying personnel at risk of LBI would help target candidates which could be offered prevention programs.

Methods: Participants (n=494; 91.9% male) met the following inclusion criteria: age 18-50 years, English fluency, and active military member. Exclusion criteria were: MSK or abdominal surgery within 12 months, MSK pain in last three months or injections within three months, prescription pain medication, current medical employment limitations or temporary medical category due to MSK injury, medical or mental health conditions, history of fractures, or pregnancy. Ninety two percent completed all follow-ups. LBI self-reported on monthly questionnaires was defined as a non-contact MSK injury in the spine, hip, or pelvis causing ≥2/10 pain for ≥3 days, limiting ability to work/exercise for >24 hours, with self-reported function ≤90% using the Single Assessment Numeric Evaluation (SANE) scale, and requiring medical care or MELs. Baseline predictors were: Upper and Lower Quadrant Y-Balance Tests (UQ, LQYBT), Functional Movement Screen (FMS), Selective Functional Movement Assessment (SFMA), Lumbar Multi-segmental Mobility, Modified-Modified Schober, Side Plank, Ankle Mobility, Modified Sorensen, Passive Lumbar Extension, and Prone Instability Test.

Results: Among 455 participants who completed the study (age 28.6±6.8 years), 19 members reported an LBI during follow-up. Univariate associations ($p<0.05$) existed with three demographic or medical history, five pain-related, and seven movement-based variables. Pain with Extension Clearance Test, LQYBT composite score of ≤100%, Lumbar Function score ≤90%, Side Plank asymmetry ≥8 seconds and UQYBT inferolateral asymmetry ≥1.5cm predicted an LBI in the logistic regression.

Presenting three or more predictors resulted in 91.5% specificity (Odds ratio=6.8), 57.9% sensitivity with 90.1% accuracy. Presenting with two or less predictors accurately identified no LBI with a sensitivity of 84.2%.

Conclusion: A combination of past medical history, perceived level of function, pain provocation, and movement-based tests predicted LBI. Combining three or more predictors had good specificity for future LBI.

Key words: low back injury, military personnel, prediction, musculoskeletal disease, movement, range of motion, physical endurance, muscle strength, motor control

3.1 Introduction

According to the 2013/2014 Health and Lifestyle Information Survey,[5] 32.3% of Regular Force personnel reported having sustained a repetitive stress injury (RSI) serious enough to limit normal activities in the previous year. The percentage was not different between categories of sex, rank, service element, smoking status, or physical activity level. Low back injury (LBI) was the most reported musculoskeletal (MSK) complaint affecting 12.3% of CAF personnel. The prevalence of LBI is even higher in the operational environment (37.6% of physiotherapy cases in Afghanistan with 70.7% as thoracic or lumbar referrals).[6] This contrasts with 18% referred for LBI each year while in garrison (non-operational).[7] LBIs increase lost time, health care utilization, and disability costs, generating substantial economic burden.[8]

The goal in primary prevention is to reduce the number of non-contact LBI episodes experienced by a population.[10] In order to properly prescribe a preventative program, a predictive strategy is needed to accurately identify the at-risk population for developing LBI. Tests found to identify deficits which predict LBI, could be used to inform the development of interventions to mitigate this risk with the goal of reducing LBI occurrence.

Previous studies have identified several predictors for future MSK injuries. Lisman et al.[15] found that 3-mile run times ≥20.5 mins (Odds ratio 1.72, 95% CI 1.29-2.32) and FMS scores ≤ 14/21) (2.04, 1.32-3.15) predicted overuse or traumatic MSK injury in Marine Corps Officer Candidates undergoing basic training.[15] Candidates with both predictors were 4.19 times more likely to suffer an injury.

Pain provocation has been determined to be a predictor of future MSK injury in military[11,16] and athletic populations.[46,47] Teyhen et al.[16] included pain provocation with Flexion Clearance, Extension Clearance and Impingement tests from FMS with tracked pain during movement and performance tests. This combined pain on movement testing variable was a strong predictor (OR 2.2 (1.7-3.0), RR 11.6 (1.3-1.9)) entering the final logistic regression model. Two low back specific pain provocation tests, the Prone Instability Test (PIT)[49,50] and Passive Lumbar Extension (PLE)[49,51] test, have not yet been evaluated for their ability to predict LBI.

Several studies used the upper or lower extremity Y-Balance Test (UQ- or LQYBT) to predict MSK injuries. Smith et al.[37] determined that an asymmetry of >4 cm on the LQYBT anterior reach predicted non-contact MSK injuries over the collegiate athletic season (OR 2.33, 1.15–4.76). Cosio-Lima et al.[38] found that limited UQYBT composite scores predicted MSK injury in coast guard members attending 2 months of intense training (Trend $p = 0.03$).

In 2015, Teyhen et al.[11] could predict future non-contact MSK injury risk in currently uninjured Army Rangers in a regression model including smoking history (odds ratio = 5.0, 95% CI, 1.3-18.3), prior surgery (3.5, 0.9-13.5), recurrent prior MSK injury (≥3.5prior injuries 5.5, 1.5-20.1), limited-duty days in the prior year for MSK injury by one day or more (2.1, 0.8-5.0), asymmetrical ankle dorsiflexion of ≥6.5º (4.1, 1.4-11.7), pain during any of the FMS clearance tests (2.3, 0.7-7.2), and decreased performance on the 2-mile run with ≥773.5 seconds (1.4, 0.8-2.6).[11] Presenting with one or fewer predictors resulted in a sensitivity of 0.90 (95%CI, 0.83–0.95), and having three or more predictors resulted in a specificity of 0.98 (95% CI, 0.93–0.99).

In a follow-up study with US military personnel, Teyhen et al.[16] found that female sex, previous profile for MSK injuries, perceived recovery from prior injury, prior injury, pain on movement tests, and slower 2-mile run times best predicted future non-contact MSK injury. Variables presenting univariate associations with future injuries also included age, dorsiflexion asymmetry, LQYBT anterior reach distance, UQYBT superolateral reach distance, and UQYBT inferolateral reach asymmetry. Their prediction model accurately identified 88% of non-injured and 46% of injured participants. The specificity reached greater than 0.90 once the participant had 7 or more variables present. When only 2 or more predictors were present, the sensitivity was 0.89 (95% CI, 0.84-0.90).

The literature identifies several movement-based clinical tests that may predict LBI. Lumbar mobility (modified Schober) and endurance (modified Sorensen) predicted LBI in adolescent[12] and adult populations.[13,43] According to Alaranta,[45] participants with poor low back endurance (>85 seconds) were 3.4 times more likely to develop LBI in the next year (95% CI, 1.2-10.0).

McGill et al.[14] followed 53 elite police officers over five years and found through logistic regression analysis ($p <0.001, x^2 = 26.561, R^2 = 0.581$) seven variables best predicted back injury with 64% sensitivity and 95% specificity for an overall concordance of 87%. These variables were: abdominal endurance (sit up posture), extensor endurance (Sorensen), ratio of abdominal to extensor endurance, side plank duration, hip extension with knee flexed, and with knee extended. This study further supports the need to include movement-based tests in any LBI prediction study.

Prior studies showed promising results predicting any MSK injury in military or police context but there were limited efforts to predict LBI specifically. Better prediction performance may be possible by focusing only on LBI and using candidate predictors more reflecting of deficits related to the low back. For example, the Selective Functional Movement Assessment (SFMA) is a movement-based assessment system that has never been examined for its ability to predict MSK injury or LBI. The SFMA is a clinical assessment system designed to identify musculoskeletal dysfunction by evaluation of fundamental movements for limitations or symptom provocation.[40] Prone Instability Test (PIT)[49,50,52], and Passive Lumbar Extension (PLE)[49,51], have not yet been investigated for their ability to predict LBI but may be valuable in predicting LBI due to their being low back specific pain provocation tests.

3.2 Objectives

The objectives of this study were to: (1) to determine which personal characteristics, medical history, and clinical tests could predict first episode or recurrent LBI in a six-month follow-up in military personnel initially not currently experiencing LBI; and (2) to determine which combination of variables would best predict LBI risk in CAF personnel. A six-month period was selected as a majority of military deployments are of that duration and therefore would be able to assess LBI risk prior to deployment. Our hypothesis was that a combination of past LBI history, current perceived level of function, pain provocation and movement deficits would predict first episode or recurrent episode of non-contact LBI in a military population without LBP at baseline.

3.3 Methods

3.3.1 Study design

This was a six-month prospective observational cohort study. A total of 494 volunteer participants were recruited from seven units which were part of 1 Canadian Mechanized Brigade Group located at CFB Edmonton in Alberta. The potential recruitment group consisted of approximately 2850 personnel. Several units were unavailable to participate due to operational requirements. Research staff introduced the study via regimental briefings (N=11) to all potential participants between July 2016 and January 2017. (Appendix A: Study information presentation) Cluster testing took place at the Garrison Fitness Facility, CFB Edmonton during eighteen test sessions from August 2016 to February 2017. From this group, only military members wishing to participate and self-determining their eligibility did volunteer.

Participants were 18 to 50 years of age and fluent in English. Individuals with current or ongoing MSK pain were excluded. Being MSK pain-free was operationalized as: 1) being free of MSK pain on the testing day (0/10 NPRS) and <2/10 on NPRS for the three months prior to screening and 2) not having had an episode of MSK pain that limited work or activity that caused the participant to seek healthcare in the last three months. Participants were excluded if they were currently seeking medical care for an MSK condition; currently using medication for MSK pain, had had any surgeries or recent injections (e.g., cortisone) that would affect their ability to complete the tests (< 3 months), were on medical employment limitations (MELs) or on a temporary category (TCAT) that restricted their ability to participate in unit exercise due to other MSK injury, mental health or medical conditions, had a history of fractures (stress or traumatic); were pregnant; or if they were to be deployed or on course outside the area during the planned follow-up.

Supervisors were not informed of which personnel provided signed informed consent to volunteer in the study in order to ensure there was no pressure to participate by the chain of command. (Appendix B: Informed consent documents) The study was approved by the Health Research Ethics Board at University of Alberta (Pro00065519) and by the CAF Surgeon General's office (Appendix C: Ethics approval letter.).

Data collection was divided into three phases detailed in the following sections:

1. **Background information**: Eligible interested candidates self-reported baseline information at the time of recruitment that included age, gender, trade, years in CAF, smoking history, previous history of MSK injuries in the last five years, date of the last episode of LBP in the last five years resulting in MELs, and date of last visit to Canadian

Forces Health Service (CFHS) clinician(s) for LBP. (Appendix D: Baseline information questionnaire)

2. **Movement based testing**: Testing consisted of 13 stations where 19 clinical tests were completed in a set order (Appendix E: Station testing order and instructions for assessors) designed to allow rest after physically stressful tests and to distribute the tests between spinal, upper, and lower extremity challenges. (Appendix F: Data Collection sheet for testers) Lumbar provocation tests were placed last to avoid exacerbations prior to the other tests.
3. **Monthly questionnaires monitoring incidence of LBP** over the last reporting period were sent electronically via RedCap for a six-month period. (Appendix G: Monthly injury data survey.)

3.3.2 Screening team

The test team consisted of two SFMA-certified licensed physiotherapists (PT), six licensed PTs, two physiotherapy assistants (PTA), and eight fitness and sport instructors and an advanced physical trainer - Physical Exercise Specialist (PES) - all certified in Functional Movement Screening (FMS) and Y Balance testing (YBT) at the Physical Rehabilitation Department at Canadian Forces Base (CFB) Edmonton.

3.3.3 Testing protocol

A half-day education session involving all testers took place in July 2016. Trials of the testing procedure were completed in May and June 2016. The order of the tests was then adjusted prior to initiating baseline testing for the present study, and additional staff (n=4) were added to improve testing efficiency and ensure adequate rest time between stations.

3.4 Movement-based clinical tests

3.4.1 Upper Quarter Y-Balance Test (UQYBT)

The UQYBT assesses thoracic and shoulder stability and mobility.[9] It is performed in a single arm push up position as the participant reaches as far as they can in three planes (medial, superolateral, and inferolateral) with the other arm. This test requires shoulder girdle and core stability, as well as adequate mobility. It correlates well with shoulder stability and core strength measures in a military population. The maximum reach in each direction was normalized to the upper limb length measured from C7 to the tip of the middle finger with the arm abducted to 90°.[53] Two practice trials of all three reach directions on each arm were performed using a tape version of the YBT kit (three-rulers connected in a Y shape with sliders) prior to recording three trials for each side. The UQYBT demonstrated good test-retest reliability (ICC 0.80-0.99) and excellent interrater reliability (ICC – 1.00) with the general population[53] and high between-day reliability (ICC=0.88–0.99)[54] with military populations.[39]

3.4.2 Lower Quarter Y-Balance Test (LQYBT)

The LQYBT assesses lower quarter flexibility, core control, proprioception, and dynamic balance at the limits of stability. It is performed in single leg stance reaching as far as possible with the opposite limb in the anterior, posterior medial, and posterolateral directions. The maximum reach in each direction was normalized to the leg length measured from the anterior inferior iliac spine to the distal tip of the medial malleolus. Three practice trials in each direction were followed by measuring three test trials using a YBT kit.[39] In a previous study, interrater test–retest reliability for the LQYBT was demonstrated with an ICC of 0.80 to 0.85 with an acceptable level of measurement error among multiple raters screening active-duty service members.[39]

3.4.3 Ankle mobility

Ankle dorsiflexion was tested in a split kneel position after completing two 30-sec calf stretches on each leg. An iPhone inclinometer was placed with the top aligned 15 cm distal to the tibial tuberosity on the anterior tibia. The second toe and the center of the heel had to remain aligned with a taped line perpendicular to the wall with the heel touching the ground as the participant moved into maximal ankle dorsiflexion. Three measurements were obtained, and the best score was recorded for each side. Criterion validity comparing the inclinometer to the smartphone application was excellent (r>0.99).[55] This measurement was previously demonstrated to have excellent intra-tester (ICC 0.97) and inter-tester reliability of ICC 0.76.[55]

3.4.4 Modified-Modified Schober Test

The Modified-Modified Schober test uses a measuring tape to measure lumbar spine flexion and extension ranges of motion as the distance between a mark at the base of the lumbar spine (L5-S1) and 15 cm above this mark in neutral standing. To assess spinal flexion, we measured the difference in the distance between marks between standing with shoulders over the hips and after bending forward as far as possible. Similarly, for extension, we measured the difference between standing and after bending backwards. Increasing spinal extension motion resulted in the marks becoming closer. The Modified-Modified Schober Test (MMST) has been shown to have excellent intra-tester (ICC 0.95) and inter-tester (ICC=0.91) reliability.[56]

3.4.5 Functional Movement Screen (FMS)

The FMS identifies movement limitations and asymmetries and was designed for MSK injury prediction.[31] The FMS consists of seven tests including the deep overhead squat, in-line lunge, hurdle step, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability and three pain provocation tests including flexion clearance, extension clearance and shoulder impingement tests. All testing was completed by FMS-certified testers. Overall performance was scored using the 100-point scoring method for improved reliability.[34] In addition, we recorded pain provoked for each test. All tests except shoulder mobility were examined for their ability to predict LBP. Trained raters in military populations have achieved good inter-rater (ICC = 0.74) and intra-rater (ICC = 0.76) reliability with the FMS.[35,57,58]

3.4.6 Selective Functional Movement Assessment (SFMA)

The SFMA was designed as a diagnostic system consisting of movements of the whole body graded as Functional and Non-painful (FN), Functional Painful (FP), Dysfunctional Non-painful (DN), and Dysfunctional Painful (DP). The tests are: Lumbar multi-segmental flexion, extension, and rotation; Cervical multi-segmental flexion, extension, and flexion/rotation; Shoulder mobility; Single leg stance; and Overhead squat. As some overlap exists with the FMS, we only completed the lumbar specific tests associated with lumbar mobility. All tests were completed by a PT certified in SFMA. Criterion scoring previously demonstrated substantial to perfect intra- and inter-rater reliability (.83 and .91 for raters with >100 hours of experience and .78 and .88 with raters with >25 hours of experience).[40]

3.4.7 Modified Sorensen/Lumbar Extensor Endurance Test

The Modified Sorensen test assessed back extensor muscle endurance. The participants were strapped in a prone position on a therapy table with the upper body unsupported. Straps were placed above the buttocks, over the hamstrings and over the calves. The hands were touching the ears, with the elbows held level with the trunk, and the head in a neutral position. Participants were asked to maintain their upper body unsupported in a horizontal position until no longer able to overcome gravity. Reminders to maintain position were given a maximum of two times and the endurance time was recorded. The test was stopped once the participant was unable to maintain position despite warnings or if exceeding three minutes. Two physiotherapists administered the tests.[59–61]

3.4.8 Side planks

The Side Plank Test[62] required participants to lay on their side with the heel of their top leg touching the toes of the bottom leg and propped up on their bottom elbow bent to 90 degrees. They then lifted their hips off the mat while propped up on their bent elbow in order to maintain a straight line over their full body. The top arm rested along their side. They were instructed to remain in the plank position for as long as possible. Reminders to maintain the correct position (no sagging or rolling) were given a maximum of two times and the endurance time was recorded. The test was stopped once the participant was unable to maintain the correct plank position despite warnings or if exceeding three minutes. The test was completed on each side starting with the left side. A reliability study with the five subjects found that the repeated tests, on 5 consecutive days, produced excellent reliability coefficients of .99 on the left and right sides.[62] The reliability remained excellent over a period of 8 weeks. A minimum of five minutes of rest was provided between testing each side to ensure recovery. Using a coronal plane lumbar-specific endurance test allowed us to determine if an endurance-based asymmetry is predictive of future LBI. Pain provocation was also recorded.

3.4.9 Prone Instability Test (PIT)

For the PIT, subjects are asked to adopt a position with the body supported on a manual therapy table and their legs over the edge with their feet resting on the floor. With the trunk muscles relaxed, the examiner applies posterior to anterior pressure to each individual spinous process of the lumbar spine from T12 to L5. If any pain is provoked, the patient lifts the legs off the floor while holding the table thereby engaging their active stabilizers and compressions are applied again to the painful spinous processes detected previously while the trunk musculature is contracted. The test is positive if pain is present in the resting position but not in the second position, suggesting lumbo-pelvic instability.[63] In previous research, the PIT demonstrated fair to moderate sensitivity and specificity [sensitivity = 0.71 (95% CI: 0.51 - 0.83), specificity = 0.57 (95% CI: 039 - 0.78)]. The inter-rater reliability of the PIT ranged from slight (k = 0.10 and 0.04), to good (k = 0.87).[49,50,52] No intra-rater reliability studies are available and only one rater was used for our testing.

3.4.10 Passive Lumbar Extension (PLE) Test

For the PLE test, the participant lays in a prone position while the tester lifts the participant's lower extremities concurrently to 30 cm above the bed while maintaining the knees extended and gently pulling the legs. A positive test corresponds to the reporting of strong lumbar pain during elevation, disappearing when returning to the start position. The PLE demonstrated high sensitivity (0.84) and high specificity (0.90) and good reliability (k = 0.76).[49]

3.4.11 Outcome Survey for Low Back Pain during the 6-month follow-up.

A monthly self-administered questionnaire was used during the six-month follow-up to capture LBP episodes over the last month (Appendix G). Email invitations were sent using Research Electronic Data Capture (RedCap) Survey. Participants were asked if they had any injury that resulted in pain or decreased function lasting more than 48 hours or resulting in medical care. Participants reported the injured area(s) on a body diagram. For each area selected, participants reported the date of onset, if they received treatment and/or medical employment limitations secondary to the injury in the last month, whether related to trauma or overuse, the cause of the injury, and a self-rating of function. The Single Assessment Numeric Evaluation

(SANE) scale was used to record self-reported function with a single question on a scale of 0-100 with 100 representing full function (or function prior to injury).[16]

An LBI was defined as a self-reported non-traumatic injury affecting the low back or hip region with >2/10 pain, lasting >72 hours and limiting function for >24 hours that required treatment or MELs, and associated with greater than 10% loss of function. Traumatic injuries were excluded as they are unlikely to be predictable by baseline function (sudden onset contact injury = unpredictable event requiring an external force; e.g car accident or hit into the boards in hockey). Self-reported hip injuries were included in this LBI definition because LBIs often refer pain to the buttock or hip area.[64]

3.5 Data Analysis

Published Monte Carlo simulations showed that, to consider 24 promising candidate predictor variables in a logistic regression (6 subjective, 9 pain, and 9 movement-based tests), we required a sample of 240 participants.[65] Simulations suggested that ten participants were required for each candidate variable when developing the prediction model. Such a sample size is sufficient when using an alpha 0.05 to obtain a power of 0.80 to detect a medium effect size (odd ratio = 2.0) using a one-tailed test to build the multivariate regression model with the candidate variables identified as promising during the univariate exploratory stage. A total of 500 participants were sought in order to provide sufficient power, boost precision and allow losses to follow-up as we allow the model to predict serious LBI requiring treatment thereby decreasing incidence.

Mean and standard deviations for continuous variables and frequencies for each option of categorical variables were reported as descriptive statistics for the overall group and those with and without an LBI during the follow-up. The initial step was to determine which baseline candidate predictors presented univariate associations with LBI during the follow-up. We calculated independent t-tests to compare means for continuous variables of the group with and without LBI.[66] Continuous variables with p-value <0.20 were retained for further analysis as per the research by Teyhen et al.[11] This more liberal cut-off p-value was used to protect against Type II error at this early state of analysis. Receiver operator characteristic (ROC) curves were then used to identify the cut points for the continuous variables identified as promising with the t-tests.[66] The cut points with coordinates near the top-left corner of the ROC curve (best sensitivity and specificity) were used to dichotomize the predictor.

Dichotomous and dichotomized predictors that exhibited an odds ratio equal to or greater than 2.0 and a Chi-Square test using Pearson[66] (or Fisher's exact test if assumptions were not met)[67] with p<0.2 were retained for developing the regression model. Variables with high collinearity with another predictor but lower association with the outcome were removed.
To develop the logistic regression model, the variables were entered using a forward stepwise strategy. A significance of p<.05 was required to enter, and p>.20 was used to remove a variable from the equation. Once the predictor variables were identified, a clinical prediction rule was developed by examining the accuracy, sensitivity, specificity, positive and negative likelihood ratios for LBI, for cases presenting one or more compared to no target predictor, cases with two or more compared to less than two, cases with three or more compared to less than three, cased with four or more compared to less than four and cases with five or more or less than five target predictors retained in the logistic regression model.

3.6 Results

3.6.1 Sample Description

Of the 494 CAF personnel tested with a mean age of 28.6 ± 6.8 (Table 2), 415 were male (91.9%) and 40 were female (8.1%) (Table 1). There were 416 junior non-commissioned officers (84.2%) and 78 senior non-commissioned officers and officers (15.8%) (Table 1). Two hundred fifteen were from the combat arms (43.5%) and 279 from support trades (56.5%). Most (390) had less than ten years of service (78.9%), 81 had completed between 10 and 20 years (16.4%) and 23 had served longer than 20 years (4.6%). (Table 1)

In the last five years, a total of 127 participants (25.7%) had reported a prior MSK injury resulting in MELs and 129 (26.1%) had reported an LBI requiring medical care. (Table 3) Within this group, 21 (16.4%) reported a sudden onset contact LBI, 62 (48.4%) a sudden onset non-contact LBI, and 45 (35.2%) reported a repetitive or overuse LBI. When considering recidivism in relation to the 129 personnel with LBIs, 33 (25.6%) had a single prior episode, 47 (36.4%) had 2-3 previous episodes, 19 (14.7%) had 4-5 previous episodes, 10 (7.8%) had 6-10 previous episodes, and 20 (15.5%) had greater than 10 episodes of LBP. (Table 1)

There were 455 participants with complete follow-up data. Of the 39 participants not completing the study, one participant requested to withdraw, four retired and the remaining 36 had incomplete data. (Figure 1) As determined a priori, only sex, smoking, history of LBI and baseline SANE were used as possible predictors of future LBI from this group of variables.

3.6.1.1 Frequency of LBIs

Thirty-seven participants reported low back or hip injuries over the 6-month follow-up. Only one of those participants reported more than one injury. Of these 37 low back and hip injuries, 18 sudden onset contact injuries were excluded as planned a priori as contact injuries were hypothesized to not be predictable with movement-based tests, leaving 19 with sudden onset non-contact or overuse injuries used as outcomes to be predicted.

3.6.1.2 Summary of Continuous Predictors – Movement-Based Tests (Table 2)

The following movement-based continuous variables presented associations ($p<0.2$ and OR>2.0) with future LBI:

UQYBT inferior-lateral asymmetry (t-test p=0.06, AUC 0.63, p=0.06), LQYBT anterior worst (t-test p=0.12, AUC 0.62, p=0.08), LQYBT composite worst (t-test p=0.06, AUC 0.57, p=0.06), LQYBT composite asymmetry (t-test p<0.01, AUC 0.65, p=0.03), fingertip to floor (t-test p=0.09, AUC 0.58, p=0.24), side plank asymmetry (t-test p=0.11, AUC 0.57, p=0.06), Modified Sorensen (t-test p=0.12, AUC 0.63, p=0.06), Hurdle Step asymmetry (t-test p<0.01, AUC 0.60, p=0.13), Active Straight Leg Raise asymmetry (t-test p<0.01, AUC 0.57, p=0.30),trunk stability push-up (t-test p<0.01, AUC 0.68, p<0.01), rotary stability worst (t-test p=0.06, AUC 0.59, p=0.21) and FMS total score (t-test p<0.01, AUC 0.67, p=0.01). Variable where less asymmetry was associated with future LBI (LQYBT composite, hurdle step and active straight leg raise) were not investigated further.

3.6.1.3 Summary of Dichotomized Continuous Predictors – Movement-Based Tests (Table 3)

The following dichotomized movement-based continuous variables presented univariate associations with future LBI: UQYBT inferolateral asymmetry of ≥1.5cm (OR, 3.65, Chi^2=7.44, p=0.014), LQYBT anterior worst ≤55cm (OR, 3.52, Chi^2=6.98, p=0.017), LQYBT composite worst ≤100% (OR 3.69 exact p=0.011), fingertip to floor of ≥16cm (OR, 4.19, Chi^2=8.26, p=0.013), Sorensen ≤86.0 seconds (OR, 3.97, exact p=0.005), Side Plank asymmetry ≥8sec (OR 2.70, Chi^2 4.597, p=0.071), FMS total score ≤52 (OR, 2.38, Chi^2=3.625, p=0.052), Trunk Stability push-up ≤5 (OR 3.32, Chi^2 6.365, p=0.017), baseline SANE ≤90% (OR, 6.06, Chi^2=16.81, p=0.001) and Rotary Stability Worst <2 (OR 2.97, Chi^2 3.957, p=0.062).

3.6.1.4 Summary of Categorical Predictors – Demographic and Past Medical History (Table 3)

The following demographic and past medical history categorical variables presented univariate associations with future LBI: These include smoking status (OR, 2.59, Chi^2=4.39, p=0.033), previous LBI in the last five years (OR, 2.38, Chi^2=3.65, p=0.052), LBI with a frequency over once in the last five years (OR, 3.19, Chi^2=6.591, p=0.015), and LBI lasting greater than eight weeks in the last five years (OR, 2.50, Chi^2=exact, p=0.137). No females developed LBI during the follow-up (OR 3.98 for male sex, exact p=0.168).

3.6.1.5 Summary of Categorical Predictors – Pain with Movement-Based Tests (Table 3)

Ten potential pain provocation tests were found to predict future LBI. They include pain with: multi-segmental flexion (SFMA, OR=23.5, exact p=0.08), multi-segmental rotation (SFMA, OR=7.79, exact p=0.19), side plank (OR=3.74, exact p=0.05), deep overhead squat (FMS, OR=3.88, exact p=0.16), ankle dorsiflexion (OR= 70.78, exact p=.04), trunk stability push up (FMS, OR=9.29, Chi^2 p<0.01), extension clearance (FMS, OR=12.2, Chi^2 p<0.01), flexion clearance (FMS, OR=10.04, exact p=0.02), passive lumbar extension (OR=8.14, exact p=0.05) and positive prone instability test (OR=2.98, exact p=0.09).

3.6.1.6 Summary of Categorical Predictors – Movement-Based Tests (Table 3)

None of the categorical movement-based test variables met the threshold criteria for univariate association with LBI set for consideration in our logistic regression.

3.6.1.7 Summary of Final Logistic Regression Model (Table 4)

A forward stepwise logistic regression retained five modifiable predictors: baseline perceived lumbar/hip function ≤90% (SANE), pain with the extension clearance test (FMS), UQYBT inferior-lateral asymmetry ≥1.5cm, side plank time asymmetry ≥8s and LQYBT composite worst score of ≤100%. Using this model, 89.9% of the participants were correctly classified as injured/not injured during the 6-month follow-up. It is important to note that the having a SANE score indicates that the participant had a history of an LBI in the last five years as those without a previous injury did not complete a SANE and were assigned a value of 100% function at baseline.

3.6.1.8 Summary of the Prediction Rule Analysis (Table 5)

A predictive rule was developed determining the prediction value of having an increasing number of the predicting factors from the logistic model above (Table 5). Overall, 367 members had one or more predictors, 191 had two or more, 48 had three or more, five had four or more and only one had all five predictors. Combining three or more predictors from our multivariate models is associated with a greater risk of LBI (OR 6.8) with high specificity (91.5%) and having two or less predictors have high sensitivity (84.2%) for remaining uninjured.

3.7 Discussion

3.7.1 Prediction Model

The summation of the number from five modifiable risk factors (baseline perceived lumbar/hip function ≤90% (SANE), pain with extension clearance test (FMS), UQ-YBT inferolateral asymmetry ≥1.5cm, side plank time asymmetry ≥8s and LQ-YBT composite worst score of ≤100cm) produced a moderately sensitive and highly specific test cluster, which can be used to identify people at higher risk of LBI. Those with three or more of the five predictors (11 injured out of 48 with 3+ predictors in our study) had a greater risk of LBI (6.8, 95% CI 4.2-11.1) in the next six months with a high specificity (91.5% CI 88.5-93.9). When two or less predictors were present, our model was highly sensitive (84.2% CI 60.4, 96.6) for remaining uninjured.

When comparing our results with the prediction model from Teyhen et al.[16] for MSK injury (not LBI specific), the Teyhen et al. model included more variables (n=11) including age, sex, injury history, perceived full recovery from prior injury, pain, and performance on movement tests (UQ and LQ-YBT metrics). They found that presenting with seven or more risk factors yielded high specificity (94% CI 89-95%), whereas 2 or fewer risk factors was highly sensitive (89% CI84-91%) for remaining uninjured. Our model demonstrates similar specificity and sensitivity with only five rather than 11 variables and it demonstrates the ability to predict specifically future LBI rather than any MSK injury in a healthy population. The prediction rule developed in this thesis offers clear prediction with those who present with three or more predictors being classified as "at risk" and "at very low risk of LBI" in those with two or less predictors. With our prediction rule, there is a minimal number of participants in the grey zone where classification would be unclear.

Comparatively, in the five-year study by McGill et al.[13] with elite police officers (n=53), he assessed four subsets of grouped variables: fitness, hip ROM, movement competency, and FMS movement competency. Through regression analysis, he found seven variables best predicted those who would suffer a back injury with 64% sensitivity and 95% specificity for an overall concordance of 87%. These variables were: abdominal endurance (sit up posture), low back extensor endurance (Sorensen), ratio of abdominal to extensor endurance, side plank duration, hip extension with knee flexed, and hip extension with knee extended. McGill suggested that because the ability to rule out back injury was not as high as desired (sensitivity = 64%), there was more complexity to this relationship than was explained with the variables he studied. McGill did not take the extra step of reporting the predictive ability of combining a different number of predictors retained in his model in the form of a prediction rule. McGill only reported the regression results and may have had power issues trying to predict 14 injuries over five years while considering over 45 variables with 53 participants. Nevertheless, McGill et al.'s findings were consistent with our study by finding that the Modified Sorensen and side plank tests help predict future LBI.

3.7.1 Univariate Results

Smoking has been found predictive of future MSK injury[11] and this was further supported in its ability to predict LBI in our study. History of previous injury and subjective reported level of function have been found to be predictive of future MSK injury in military populations.[11,16] Consistent with these results, we also found recurrence of greater than one episode, and perceived level of function <90% predicted LBI. The previous history of LBI is represented by their SANE scores as only those with a history of LBI in the last five years completed a baseline SANE. Participants without a LBI history were assigned a function score of 100% at baseline.

Low scores on the FMS[68] or components of the FMS[69] or pain during FMS[11,13,16] tests have been found to be predictive of MSK injury in tactical athlete populations as supported in our study. We did find several of the FMS tests to be predictive of LBI including LBP on extension clearance and the Trunk Stability Push up as well as a score on the Trunk Stability Push Up of <5. Low back pain on the Side Plank was found to be predictive of LBI. In several other prediction studies, pain provocation with movement-based testing has also been found to be a predictor of future non-contact MSK injury.[11,16,47]

Movement limitations and asymmetry has been discussed as a potential indicator of increased injury risk.[70] Low scores and asymmetries in the YBT tests have been found to be predictive of MSK injury in previous military studies.[11,16] As in other studies[11,16], movement limitations in LQYBT anterior reach and composite scores were also found to be predictive of

LBI in our study. The Fingertip to Floor test was also found to be predictive. We found that Side Plank and UQYBT inferior-lateral reach asymmetries were also predictive as in other studies.[13,16] We found one asymmetry metric actually supported having a smaller asymmetry may predict LBI: LQYBT composite score asymmetry (<2.5cm). This result was in part due to poor performance bilaterally in participants at risk.

The Modified Sorensen and Side Planks tests were found to be predictive of LBI[13,60] with the working population and law enforcement personnel and this was further supported in our study. To our knowledge, no research has been completed to determine if low back specific instability tests are predictive of future LBP. As we hypothesized, one of the spine specific pain provocation tests (PLE) was found to be predictive but to our knowledge these factors has not been previously tested specific to prediction. Overall, our results supported our hypothesis that a combination of past medical history, movement asymmetry, or limitation and pain provocation could predict future LBI.

3.7.2 Clinical Implication/Application

This research supports the utilization of demographic and movement-based tests to predict first episode or recurrent LBI in a population without LBP at baseline. By screening, we may be able to identify people who are at greater risk of injury or re-injury and then prescribe exercise programming to affect changes in their risk, thereby possibly decreasing the costs associated with LBI. Future, research should investigate the cost-effectiveness of such a strategy. Potentially, since most of our sample had experienced previous injuries, this screen could also be used to determine if those with a recent LBI are at a low risk of reinjury before returning to function in order to decrease recidivism rates of LBI.

3.7.3 Value of the prediction rule, future research.

The summation of the number of risk factors produced a moderately sensitive and highly specific (91.5%) test cluster, which can be used to effectively identify people at higher risk of LBI. Those with three or more of the five predictors (11 of the 19 injuries detected out of 48 presenting 3 or more predictors in our analysis) had a greater risk of LBI and may benefit from a preventive training program. When two or less predictors were present, the model lacked specificity (59.8%) and it may be too costly and burdensome to offer the prevention interventions to this larger number of candidates (n=191) in hoping to prevent 16 injuries. The potential benefits of early identification of "at risk" people, if an effective intervention could be provided to reduce the risk, would be decreased costs, decreased use of medical assets, decreased lost days, and increased deployability of military personnel.

3.7.4 Study Limitations

There was a low frequency of participants meeting our serious LBIs definition over the relatively short 6-month period (n=19) (>2/10 for >72 hours with >10% functional limitations for >24 hours and seeking medical care or receiving MELs). The self-reported method of identifying injuries may have missed injuries that were unreported by participants. The anonymous self-reporting strategy can be considered a strength of the study in that it allowed participants to report LBI without fear of workplace restrictions which has been documented in the military.[71] Our survey specifically sought injuries resulting in functional limitations. However, the identification of injuries was based solely on self-reported surveys which may have resulted in recall and response bias. We attempted to avoid response bias by specifically defining what constituted an injury in simple language. We attempted to avoid recall bias by surveying for injury at monthly intervals. The study involved military personnel only; therefore, results may not apply to the general population, although the demographics of CAF members mimics those of the working Canadian population.

Other limitations include the number of study participants in relation to the number of candidate predictors. Further, the number of testers was high which could lead to inter-rater reliability issues however, all the tests chosen had demonstrated good to excellent reliabilities and extensive education was provided pre-study. The follow-up duration (six months) was limited but this duration corresponds to the duration of most CAF deployments. The number of subjects lost to follow-up was 9.9%, while not negligible, can be considered a very low dropout rate. It is possible that other tests may have been able to predict LBI (e.g., more complex tests) but good prediction results were observed, nonetheless. Very few women completed the study, and none reported an LBI (n=40) and therefore the results may be less reliable for this group.

The inclusion of pelvis and hip injuries within LBI may have affected our results, although these are common areas of referral with LBI. Our definition of an LBI may also have resulted in missing minor LBI. Our relying on self-reported injuries without medical diagnosis verifications may have led to misclassifying pathologies referring in the low back but that were not LBIs. Further, the exclusion of contact LBI may have affected our ability to predict LBI but this is a strength as well, as people with low risk are likely still susceptible to contact injuries.

Future research should confirm the extent to which the identified test cluster can predict LBI in non-military populations. A practical application of this research is to determine if we decrease the deficits identified by the predictors of high-risk subjects through an appropriate low back exercise program, whether this may, in turn, lead to decreased LBI rates.

3.8 Conclusion

We developed a novel multivariable predictive model that can identify military personnel at risk of future LBI. Participants with three or more predictors have a greater risk of LBI with a high specificity (91.5%). This combination produced a specific model that may be valuable for informing a screening strategy to predict LBI that can be completed in any environment with minimal resources. Utilizing the predictive model to identify military personnel at risk for LBI could facilitate the development of an injury prevention program to address the identified deficits, reduce the risk of LBI, and thereby reduce military costs and improve combat readiness.

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Table 1. Sample Description

Descriptive Variable	Category	Frequency (%)
Sex	Male	415 (91.2)
	Female	40 (8.8)
Smoking	Smoker	182 (40.1)
	Non-Smoker	272 (59.9)
Rank	Junior Non-Commissioned Officer	416 (84.2)
	Senior Non-Commissioned Officer	40 (8.1)
	Officer	38 (7.7)
Time in Military	< 1 year	15 (3.0)
	1 - <5 years	203 (41.1)
	5 - <10 years	172 (34.8)
	10 - <20 years	81 (16.4)
	>20 years	23 (4.6)
Trades	Combat	215 (43.5)
	Support	279 (56.5)
Percent time spent with physical demands	0-25% of Work Time/week	148 (30)
	25-50%	193 (39.1)
	50-75%	107 (21.7)
	75-100%	45 (9.1)
Load carried most of the time during your last deployment or training exercise?	I do not participate in activities that require me to wear equipment	14 (2.8)
	Weapon (≈4.5 kg)	13 (2.6)
	Load bearing vest, weapon, helmet (≈ 9 kg)	118 (24)
	Helmet, weapon, body armour, basic load (≈ 20 kg)	248 (50,4)
	Helmet, weapon, body armour, basic load, ruck (≈ 36 kg)	52 (10.6)
	Helmet, weapon, body armour, basic load, heavy ruck, or section weapon (≈ 45 kg)	26 (5.3)
	Helmet, weapon, body armour, basic load, heavy ruck, other (≈ 54 kg)	21 (4.3)
How often did you wear the above equipment in a typical duty day?	I do not participate in activities that require me to wear equipment	13 (2.6)
	0-25% of time	99 (20.1)
	26-50% of time	148 (30.1)
	51-75% of time	172 (35)
	76-100% of time	60(12.2)

Deployments (>2months in the last 5 years)	Yes	92 (18.7)
	No	401 (81.3)
If you were on MELs for an MSK issue in the last year, how long were you on MELs?	Less than a week	19 (15)
	At least 1 week but less than 2 weeks	30 (23.6)
	At least 2 weeks but less than 4 weeks	30 (23.6)
	At least 4 weeks but less than 8 weeks	17 (13.4)
	At least 8 weeks but less than 6 months	12 (9.4)
	At least 6 months but less than 12 months	10 (7.9)
	Greater than 12 months	9 (7.1)
LBI in last five years	Yes	148 (32.5)
	No	307 (67.5)
Recidivism of LBI (among 129 with prior LBI)	Single episode	33 (25.6)
	2-3 episodes	47 (36.4)
	4-5 episodes	19 (14.7)
	6-10 episodes	10 (7.8)
	>10 episodes	20 (15.5)

Abbreviations: MEL - Medical Employment Limitation; MSK - Musculoskeletal

Table 2. Potential Predictors – Continuous Variables

Variables	Mean (SD) total sample	Mean (SD) with LBI	Mean (SD) no LBI	T-Test T (p-value)	Cut Off Indicating Risk of Injury	ROC Curve AUC (p value)
Age (years)	28.6±6.8	29.4±8.5	28.8±6.9	-3.53 (.724)		
UQYBT Medial Worst Score (cm)	90.5±8.0	88.9±9.3	90.6±8.0	.872 (.383)		
UQYBT Medial Asymmetry (cm)	3.5±2.8	4.1±3.4	3.5±2.8	-.872 (.384)		
UQYBT Inferior-lateral Worst Score (cm)	81.6±9.9	79.4±11.5	81.5±10.0	.905 (.366)		
UQYBT Inferior-lateral Asymmetry (cm)	5.1±4.1	3.4±2.8	5.2±4.0	1.871 (.062)	≧1.5	.630 (.055)
UQYBT Superior-lateral Worst Score (cm)	61.1±10.0	58.2±9.4	61.0±10.2	1.146 (.252)		
UQYBT Superior-lateral Asymmetry (cm)	3.5±2.8	4.1±3.4	3.5±2.8	-.872 (.384)		
UQYBT Composite Worst Score (cm)	86.3±8.1	84.1±10.5	86.4±8.0	1.187 (.236)		
UQYBT Composite Asymmetry (cm)	18.4±3.2	3.2±2.6	3.3±2.7	.111 (.911)		
LQYBT Anterior Worst Score (cm)	63.3±8.2	60.4±8.4	63.4±8.3	1.552 (.121)	≦55.25	.617 (.084)
LQYBT Anterior Asymmetry (cm)	3.3±2.8	2.7±1.7	3.3±2.9	.921 (.357)		
LQYBT Posterior-medial Worst Score (cm)	105.4±9.0	104.8±7.5	105.5±9.1	.327 (.744)		
LQYBT Posterior-medial Asymmetry (cm)	3.8±3.1	3.9±3.1	3.9±3.1	-.067 (.946)		

LQYBT Posterior-lateral Worst Score (cm)	101.6±9.8	101.2±7.4	101.7±9.7	.212 (.832)		
LQYBT Posterior-lateral Asymmetry (cm)	4.3±3.8	4.6±2.8	4.3±3.8	-.352 (.725)		
LQYBT Composite Worst Score (%)	100.6±21.9	96.9±8.3	101.2±23.0	.817 (.059)	≤100	.572 (.061)
LQYBT Composite Asymmetry (cm)	21.1±2.8	1.7±1.5	2.9±2.54	3.271 (.003)	≦2.4	.650 (.027)
Tip of finger to floor: (cm)	11.9±18.8	19.8±26.9	11.7±18.5	-1.706 (.089)	≥15.875	.582 (.238)
Modified-Modified Schober Flexion (cm)	22.6±1.5	22.8±1.8	22.6±1.4	-.695 (.487)		
Modified-Modified Schober Extension (cm)	12.5±1.0	12.6±1.1	12.5±.099	-.363 (.717)		
Side Plank Time Asymmetry (secs)	14.2±14.3	10.3±9.1	14.0±14.1	1.137 (.106)	≥8	0.570 (.062)
Side Plank Worst (secs)	71.5±31.3	64.5±22.3	72.1±31.9	1.017 (.310)		
Ankle Dorsiflexion Worst (º)	42.6±6.0	41.4±4.8	42.6±6.1	.890 (.374)		
Ankle Dorsiflexion Asymmetry (º)	3.4±3.5	2.9±2.9	3.5±3.7	.593 (.554)		
Modified Sorensen Test (secs)	92.6±34.8	80.6±34.1	93.5±35.4	1.561 (.119)	≦86.0	.630 (.055)
Deep Overhead Squat (/18)	7.2±4.1	5.6±4.4	6.7±4.4	1.083 (.279)		
In-Line Lunge Worst (/10)	8.0±2.2	8.1±2.1	8.0±2.2	-.132 (.895)		
In-Line Lunge Asymmetry	1.0±1.4	0.6±1.0	1.0±1.4	1.111 (.267)		
Hurdle Step Worst (/9)	6.4±1.9	6.5±1.3	6.3±2.1	-.452 (.651)		

Hurdle Step Asymmetry	0.8±1.2	0.3±0.7	0.8±1.4	3.076 (.005)	≦0.5	.602(.133)
Active Straight Leg Raise Worst (/6)	2.0±2.1	2.2±1.9	2.0±2.1	.539 (.390)		
Active Straight Leg Raise Asymmetry	0.6±1.3	.21±.63	.69±1.4	3.018 (.006)	≦1.0	.570 (.303)
Trunk Stability Push Up (/12)	8.4±4.5	4.5±5.1	7.9±4.8	3.053 (.002)	≦5	.682 (.007)
Rotary Stability Worst (/6)	2.0±1.0	1.5±0.9	1.9±0.9	1.876 (.061)	<2.0	.586 (.207).
Rotary Stability Asymmetry	0.4±1.1	0.5±1.1	0.4±1.1	-.498 (.619)		
FMS Total Score (/100)	61.2±12.6	58.4±14.1	49.21±16.3	2.762 (.006)	≦52	.671 (.012)

Abbreviations:
UQYBT- Upper Quadrant Y Balance Test
LQYBT - Lower Quadrant Y Balance Test
FMS - Functional Movement Screen

Table 3. Dichotomous, Categorical and Dichotomized Continuous Variable Potential Predictors

Descriptive Variable	Category	Frequency (%) Overall	Frequency (%) No LBI	Frequency (%) LBI	Chi Square (p-value)	Odds Ratio
Historical Variables						
Sex	Male	415 (91.2)	396 (87.0)	19 (4.2)	*Exact* (.168)	3.98 (0.24; 67.21)
	Female	40 (8.8)	40 (8.8)	0 (0.0)		
Smoking	Smoker	182 (40.1)	170 (37.4)	12 (2.6)	4.394 (.033)	2.59 (1.03; 6.55)
	Non-Smoker	272 (59.9)	265 (58.4)	7 (1.5)		
MELs for MSK injury over the last year	Yes	115 (25.3)	109 (24.0)	6 (1.3)	.417 (.341)	1.44
	No	340 (74.7)	327 (71.9)	13 (2.9)		
MSK injury with MEL duration of > 8 weeks in the last year	Yes	29 (6.4)	27 (5.9)	2 (0.4)	*Exact* (.345)	2.13
	No	426 (93.6)	409 (89.9)	17 (3.7)		
LBI or hip/pelvis injury in the last five years	Yes	148 (32.5)	138 (30.3)	10 (2.2)	3.651 (.052)	2.38 (0.97; 5.86)
	No	307 (67.5)	298 (65.5)	9 (2.0)		
LBI or hip/pelvis injury frequency of > once in the last five years	Yes	105 (23.1)	96 (21.1)	9 (2.0)	6.591 (.015)	3.19 (1.29; 7.90)

	No	350 (76.9)	340 (74.7)	10 (2.2)		
Previous Hip/LBI Duration of 8 weeks or more in last five years	Yes	49 (10.8)	45 (9.9)	4 (0.9)	*Exact* (.137)	2.50 (0.84; 7.46)
	No	406 (89.2)	391 (85.9)	15 (3.3)		
Pain Provocation						
LBP during UQYBT	Yes	12 (2.6)	12 (2.6)	0 (0)	.537 (.596)	0.87
	No	443 (97.4)	424 (93.2)	19 (4.2)		
SFMA Flexion LBP	Yes	2 (0.4)	1 (0.2)	1 (0.2)	*Exact* (.082)	23.54 (2.34; 237.28)
	No	453 (99.6)	435 (95.6)	18 (4.0)		
SFMA Extension LBP	Yes	8 (1.8)	8 (1.8)	0 (0.0)	*Exact* (.709)	1.293
	No	447 (98.2)	428 (94.1)	19 (4.2)		
SFMA Rotation LBP	Yes	5 (1.1)	4 (0.9)	1 (0.2)	*Exact* (.193)	7.79 (1.16; 52.39)
	No	450 (98.9)	432 (94.9)	18 (4.0)		
LBP with LQYBT	Yes	9 (2.0)	9 (2.0)	0 (0.0)	*Exact* (.679)	1.15
	No	446 (98.0)	427 (93.8)	19 (4.2)		
LBP with any Side Plank	Yes	35 (7.7)	31 (6.8)	4 (0.9)	*Exact* (.050)	3.74 (1.23; 11.34)
	No	420 (92.3)	405 (89.0)	15 (3.3)		
LBP with Deep Overhead Squat	Yes	17 (3.7)	15 (3.3)	2 (0.4)	*Exact* (.155)	3.88 (0.94; 16.05)
	No	438 (96.3)	421 (92.5)	17 (3.7)		

LBP with In-line Lunge	Yes	3 (0.7)	3 (0.7)	0 (0.0)	*Exact* (.880)	3.17
	No	452 (99.3)	433 (95.2)	19 (4.2)		
LBP with Ankle Dorsiflexion	Yes	1 (0.2)	0 (0.0)	1 (0.2)	*Exact* (.042)	70.78 (2.79; 1797)
	No	454 (99.8)	436 (95.8)	18 (4.0)		
LBP with Hurdle Step	Yes	2 (0.4)	2 (0.4)	0 (0.0)	*Exact* (.918)	4.46
	No	453 (99.6)	434 (95.4)	19 (4.2)		
LBP with Active Straight Leg Raise	Yes	8 (1.8)	8 (1.8)	0 (0.0)	*Exact* (.709)	1.29
	No	447 (98.2)	428 (94.1)	19 (4.2)		
LBP with Trunk Stability Push Up	Yes	33 (7.3)	26 (5.7)	7 (1.5)	25.808 (<.001)	9.29 (3.46; 24.93)
	No	422 (92.7)	410 (90.1)	12 (2.6)		
LBP with Extension Clearance	Yes	27 (5.9)	20 (4.4)	7 (1.5)	33.934 (<.001)	12.19 (4.45; 33.40)
	No	428 (94.1)	416 (91.4)	12 (2.6)		
LBP with Rotary Stability	Yes	1 (0.2)	1 (0.2)	0 (0.0)	*Exact* (.958)	7.44
	No	454 (99.8)	435 (95.6)	19 (4.2)		
LBP with Flexion Clearance	Yes	4 (0.9)	3 (0.7)	1 (0.2)	*Exact* (.157)	10.04 (1.40; 71.90)
	No	451 (99.1)	433 (95.2)	18 (4.0)		
LBP with Modified Sorensen	Yes	76 (16.7)	71 (15.6)	5 (1.1)	1.317 (.196)	1.94
	No	379 (83.3)	365 (80.2)	14 (3.1)		

Passive Lumbar Extension	Yes	9 (2.0)	7 (1.5)	2 (0.4)	*Exact* (.050)	8.14 (1.8; 36.83)
	No	444 (98.0)	427 (94.3)	17 (3.8)		
Prone Instability Test	Yes	42 (9.3)	38 (8.4)	4 (0.9)	*Exact* (.089)	2.98 (0.99; 8.96)
	No	410 (90.7)	395 (87.4)	15 (3.3)		
Movement Based Test						
SFMA Flexion (DN, DP, or FP)	Yes	175 (38.8)	165 (36.6)	10 (2.2)	1.597 (.153)	1.79
	No	276 (61.2)	267 (59.2)	9 (2.0)		
SFMA Extension (DN, DP, or FP)	Yes	77 (17.1)	73 (16.2)	4 (0.9)	*Exact* (.412)	1.42
	No	374 (82.9)	359 (79.6)	15 (3.3)		
SFMA Rotation (DN, DP, or FP)	Yes	165 (36.6)	155 (34.4)	10 (2.2)	2.201 (.109)	1.97
	No	286 (63.4)	277 (61.4)	9 (2.0)		
SFMA Rotation Asymmetry	Yes	8 (1.8)	7 (1.5)	1 (0.2)	*Exact* (.291)	4.64
	No	447 (98.2)	429 (94.3)	18 (4.0)		
Inline Lunge Worst	0	4 (0.9)	4 (0.9)	0 (0.0)	*Exact* (.709)	
	2	16 (3.7)	16 (3.7)	0 (0.0)		
	4	21 (4.8)	19 (4.4)	2 (0.5)		
	6	61 ((14.0)	58 (13.3)	3 (0.7)		
	8	159 (36.5)	153 (35.1)	6 (1.4)		
	10	175 (40.1)	167 (38.3)	8 (1.8)		
Inline Lunge Asymmetry (cm)	0	266 (58.5)	252 (55.4)	14 (3.1)	3.608 (.607)	

	2	136 (29.9)	132 (29.0)	4 (0.9)		
	4	21 (4.6)	21 (4.6)	0 (0.0)		
	6	12 (2.6)	11 (2.4)	1 (0.2)		
	8	12 (2.6)	12 (2.6)	0 (0.0)		
	10	8 (1.8)	8 (1.8)	0 (0.0)		
Continuous Variables Dichotomized						
UQYBT Inferior-lateral Asymmetry ≥1.5	Yes	68 (15.0)	61 (13.4)	7 (1.5)	7.444 (.014)	3.65 (1.42; 9.4)
	No	386 (85.0)	374 (82.4)	12 (2.6)		
LQYBT Anterior Worse ≤55cm	Yes	70 (15.4)	63 (13.9)	7 (1.5)	6.979 (.017)	3.52 (1.37; 9.04)
	No	384 (84.6)	372 (81.9)	12 (2.6)		
LQYBT Composite Asymmetry ≤2.5	Yes	238 (52.4)	223 (49.1)	15 (3.3)	*Exact* (.015)	3.27 (1.13; 9.51)
	No	216 (47.6)	212 (46.7)	4 (0.9)		
LQYBT Composite Worst ≤100%	Yes	260 (57.3)	244 (53.7)	16 (3.5)	*Exact* (.011)	3.69 (1.15; 11.88)
	No	194 (42.7)	191 (42.1)	3 (0.7)		
Fingertip to Floor ≥16cm	Yes	52 (11.9)	46 (10.5)	6 (1.4)	8.263 (.013)	4.19 (1.55; 11.33)
	No	386 (88.1)	374 (85.4)	12 (2.7)		
Modified Sorensen Time ≤86s	Yes	217 (47.8)	202 (44.5)	15 (3.3)	*Exact* (.005)	3.97 (1.37; 11.54)

	No	237 (52.2)	233 (51.3)	4 (0.9)		
Hurdle Step Asymmetry ≤ 0.5 Points	Yes	279 (61.3)	264 (58.0)	15 (3.3)	*Exact* (.071)	2.25 (0.77; 6.53)
	No	176 (38.)	172 (37.8)	4 (0.9)		
Side Plank Asymmetry ≥8s	Yes	202 (44.5)	189 (42.1)	13 (2.9)	4.597 (.028)	2.70 (1.04; 702)
	No	252 (55.5)	246 (54.2)	6 (1.3)		
Active Straight Leg Asymmetry Score ≤ 1.0 Point	Yes	103 (22.8)	101 (22.4)	2 (0.4)	*Exact* (.151)	0.47
	No	348 (77.2)	331 (73.4)	17 (3.8)		
FMS Score ≤ 52	Yes	147 (32.6)	137 (30.4)	10 (2.2)	3.625 (.052)	2.38 (0.97-5.85)
	No	304 (67.4)	295 (65.4)	9 (2.0)		
Trunk Stability Push Up ≤ 5	Yes	206 (45.5)	192 (42.4)	14 (3.1)	6.365 (.017)	3.32 (1.22-9.02)
	No	247 (54.5)	242 (53.4)	5 (1.1)		
Lumbar/Hip Function SANE <90%	Yes	55 (12.1)	47 (10.3)	8 (1.8)	16.812 (.001)	6.06 (2.31; 15.72)
	No	400 (87.9)	389 (85.5)	11 (2.4)		
Rotary Stability Worst < 2.0	Yes	54 (11.9)	49 (10.8)	5 (1.1)	3.957 (.062)	2.97 1.07; 8.28)
	No	401 (88.1)	387 (85.1)	14 (3.1)		

Abbreviations: MEL – Medical Employment Limitation, MSK – Musculoskeletal, FMS – Functional Movement Screen, LBI – Low Back Injury, LBP – Low Back Pain, SANE – Single Analogue Numerical Evaluation, SFMA – Selective Functional Movement Assessment, UQYBT- Upper Quadrant Y Balance Test, LQYBT - Lower Quadrant Y Balance Test, DN - Dysfunctional Non-Painful, DP - Dysfunctional Painful, FP - Functional Painful

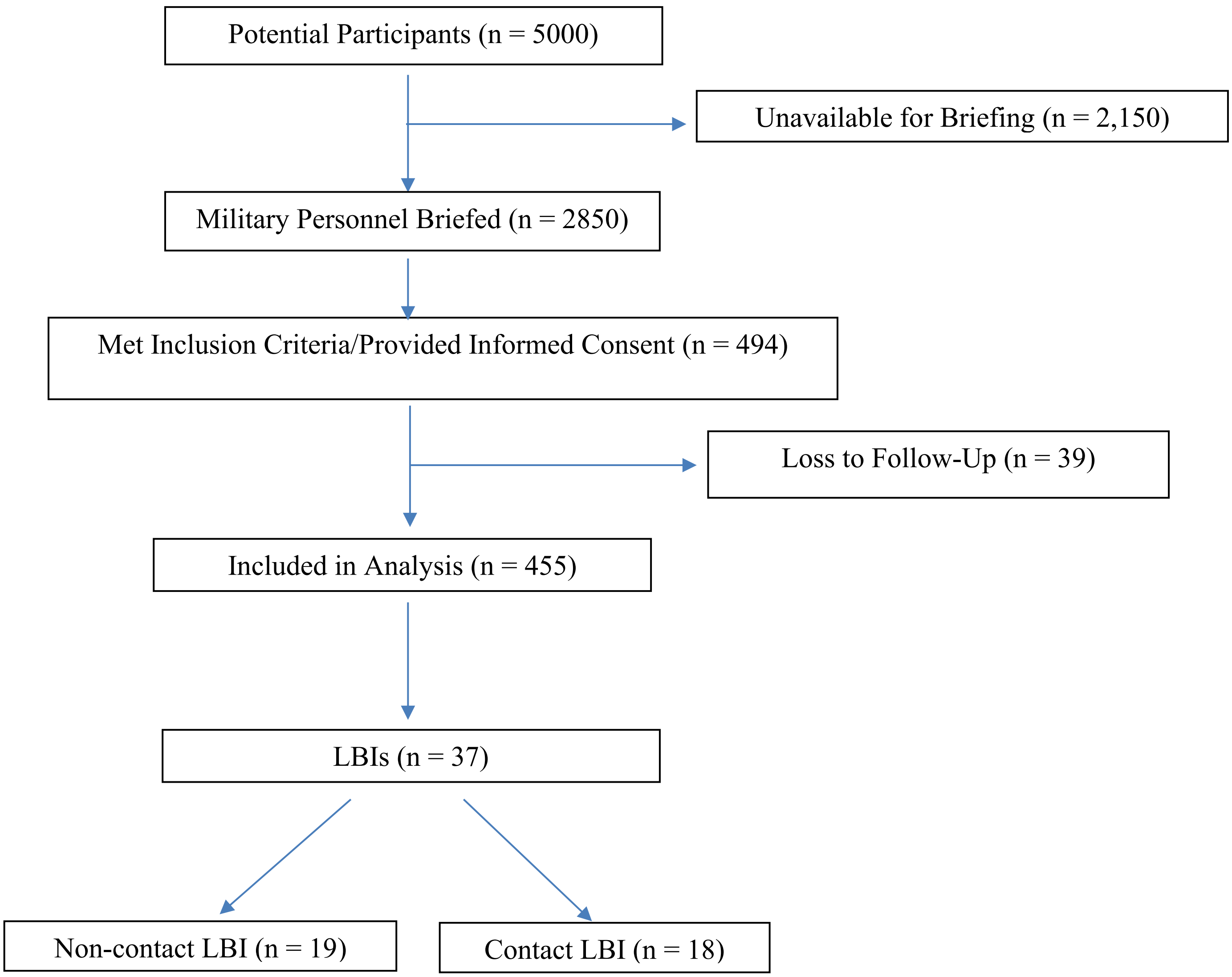
Table 4. Forward Stepwise Logistic Model Summary for Prediction of LBI

Test	**B**	**S.E.**	**Wald**	**Df**	**Sig**	**Exp (B)/OR**	**95% CI (for OR)**
LBP with Extension Clearance Test	2.14	0.63	11.69	1	<.01	8.46	2.49,28.78
LQYBT Composite Worst ≤100%	1.89	0.83	5.11	1	.03	6.58	1.29,33.74
Lumbar/Hip Function (SANE ≤90)	1.82	0.59	9.54	1	<.01	6.16	1.94,19.55
Side Plank Asymmetry (≥8 seconds)	1.15	0.58	3.89	1	<.05	3.14	1.01,9.82
UQYBT Inferolateral Asymmetry (≥1.5cm)	1.14	0.59	3.66	1	.06	3.11	0.97,9.95
Constant	-2.18	0.46	22.20	1	<.01	0.11	

Table 5. Ability to Predict Future LBI when Combining a Different Number of the Predictors Retained in the Logistic Regression Model: Prediction Rule Summary

Number of predictors from the logistic model	**Sensitivity**	**Specificity**	**Negative Likelihood Ratio**	**Positive Likelihood Ratio**	**Cases with combination of predictors**	**True Positive**	**Accuracy**
≥ 5	5.3% (0.1, 26.0)	100% (99.2,100.0)	1.0 (0.9,1.1)	Infinite	1	1	96.0% (93.8,97.6)
≥ 4	21.1% (6.1,45.6)	99.8% (98.7,100.0)	0.8 (0.6,1.0)	91.6 (10.8,780.4)	5	4	96.5% (94.3,98.0)
≥ 3	57.9% (33.5,79.8)	91.5% (88.5,93.9)	0.5 (0.3,0.8)	6.8 (4.2,11.1)	48	11	90.1% (87.0,92.7)
≥ 2	84.2% (60.4,96.6)	59.8% (55.0,64.4)	0.3 (0.1,0.8)	2.1 (1.7,2.6)	191	16	60.8% (56.1,65.3)
≥ 1	100.0% (82.4,100.0)	20.0% (16.3,24.1)	Infinite	1.25 (1.19 to 1.31)	367	19	23.4% (19.5,27.5)

Figure 1. Flow diagram showing recruitment and retention of enrolled participants



Chapter Four: Thesis Discussion/Conclusion

4.1 Summary of Results

To reduce the incidence of LBI, it is vital to be able to identify which individuals are at higher risk as well as the modifiable factors that could mitigate the risk. Our findings suggest that a multifactorial approach including self-reported past medical history and current level of function, movement-based testing, and pain provocation were able to identify healthy CAF personnel at risk for future LBI. The recording of a baseline SANE dysfunction represents a history of LBI in the last five years.

The following self-reported categorical variables presented univariate associations with future LBI: smoking status (OR, 2.59, Chi^2=4.39, p=0.033); or LBI with a frequency of greater than once in the last five years (OR, 2.38, Chi^2=6.591, p=0.015) and baseline SANE ≤90% (OR, 6.06, Chi^2=16.81, p=0.001).

The following movement-based continuous variables presented univariate associations with future LBI: UQYBT inferolateral asymmetry of ≥1.5cm (OR, 3.65, Chi^2=7.44, p=0.014), LQYBT anterior worst ≤55cm (OR, 3.52, Chi^2=6.98, p=0.017), LQYBT composite worst ≤100% (OR 3.69 exact p=0.011), fingertip to floor of ≥16cm (OR, 4.19, Chi^2=8.26, p=0.013), Sorensen ≤86.0 seconds (OR, 3.97, exact p=0.005), Side Plank Asymmetry ≥8 seconds (OR 2.70, Chi^2 4.60, p=0.028) and Trunk Stability push-up ≤5 (OR 3.32, Chi^2 6.365, p=0.017).

While 10 low back pain provocation variables were identified as promising candidate predictors, the following five presented significant univariate association with future LBI: side plank (OR=3.7, exact p=.05, ankle dorsiflexion (OR= 70.78, exact p=.04), trunk stability push up

(FMS, OR=9.29, Chi^2 p<.01), extension clearance (FMS, OR=12.2, Chi^2 p<.01) and Passive Lumbar Extension (OR=8.14, exact p=0.05).

The summation of the number from five modifiable risk factors in the logistic prediction model for LBI (baseline perceived lumbar/hip function ≤90% (SANE), pain with extension clearance test (FMS), UQ-YBT inferolateral asymmetry ≥1.5cm, side plank time asymmetry ≥8s and LQ-YBT composite worst score of ≤100cm) produced a moderately sensitive and highly specific test cluster, which can be used to identify people at higher risk of LBI. Those with three or more of the five predictors (11 injured out of 48 with 3+ predictors in our study) had a greater risk of LBI (6.8, 95% CI 4.2-11.1) in the next six months with a high specificity (91.5% CI 88.5-93.9). When two or less predictors were present, our model was highly sensitive (84.2% CI 60.4, 96.6) for remaining uninjured.

When comparing our results with the prediction model from Teyhen et al.[16] for MSK injury (not LBI specific), it included more variables (n=11) including age, sex, injury history, perceived full recovery from prior injury, pain, and performance on movement tests (UQ and LQ-YBT metrics). They found that presenting with seven or more risk factors yielded high specificity (94% CI 89-95%), whereas 2 or fewer risk factors was highly sensitive (89% CI 84-91%) allowing to rule out LBI in such cases. Our model demonstrates similar specificity and sensitivity to the findings from Teyhen et al.[16] predicting MSK injuries with only five predictor variables in the model and it demonstrates the ability to predict specifically future LBI rather than any MSK injury in a healthy population. The prediction rule developed in this thesis offers clear prediction for the whole sample with those who present with three or more predictors being classified as “at risk” and offers confidence that those with two or less predictors will not experience a future LBI. With our prediction rule, there is a minimal number of participants in the grey zone where classification would be unclear.

Comparatively, in the five-year study by McGill et al.[13] with elite police officers (n=53), he assessed four subsets of grouped variables: fitness (6), hip ROM (6), movement competency (20), and FMS movement competency. Through logistic regression analysis, he found seven variables best predicted those who would suffer a back injury with 64% sensitivity and 95% specificity for an overall concordance of 87%. These variables were: abdominal endurance (sit up posture), low back extensor endurance (Sorensen), ratio of abdominal to extensor endurance, side plank duration, hip extension with knee flexed, and hip extension with knee extended. McGill suggested that because the ability to rule out back injury was not as high as desired (sensitivity = 64%), there was more complexity to this relationship than was explained with the variables he studied. McGill did not take the extra step of presenting his model as a prediction rule and may have had power issues trying to predict 14 injuries over five years while considering over 45 variables with 53 participants. Nevertheless, McGill et al.'s findings were consistent with our study by finding that the Modified Sorensen and side plank tests help predict future LBI.

The potential benefits of applying a quadrant specific injury prevention program to only those at higher risk of LBI may include decreased costs, decreased use of medical assets, decreased lost days, and increased deployability of military personnel while not affecting the whole unit by applying the program only to those who may not require it and focusing the program on quadrant specific deficits. The final test cluster to predict LBI requires very little equipment (YBT kit and watch) and can be performed in approximately 20 minutes per person, with very little training (one-hour online course for YBT) and in any environment.

By combining the LBI prediction model with the upper injury prediction model developed by a physical medicine and rehabilitation resident using our dataset we find overlap of predictors (self-report function and UQYBT). The upper quadrant (cervicothoracic spine, shoulder, arm and hand) injury prediction model included smoking history, UQ SANE ≤90%, and UQYBT composite score ≤81.1%. Two or more upper injury predictors resulted in good specificity (85.6%, OR = 4.8; 95% CI=2.2-10.8) and at least one predictor resulted in 81.5% sensitivity (OR= 3.2; 1.2-8.7). Therefore, completing the SANE scale and UQYBT would satisfy the requirement for both the prediction of upper quadrant injury and LBI, thereby saving time. We are completing the lower quadrant (hip, knee, ankle, foot) injury prediction analysis with the intention of creating a full body injury prediction model in the near future.

To create the full body injury prediction screen (UQ, LQ and Spine), the equipment and time requirements would still be minimal. This combined screening could be easily completed using multiple screening test stations in order to test large numbers of military members during one session as demonstrated during our baseline testing. The screen would provide each person with a clear indication of their injury risk by quadrant and then a specific injury prevention training program could be investigated for its ability to decrease their specific movement-based deficits and injury risk(s). As a whole, the results from this thesis project supported our hypothesis that LBI can be predicted in a healthy military population by combining self-reporting of past medical history and SANE function score, movement-based tests including the LQYBT composite score, UQYBT of which the inferolateral measurement can contribute to the LBI risk model, bilateral side plank as well as pain provocation testing (extension clearance). The full body prediction model would require a questionnaire, mat, stopwatch and YBT kit to complete and would take less than 20 minutes to administer.

4.2 Comparing predictors identified in this thesis to the literature

Our study confirmed prior MSK injury prediction literature that smoking, previous injury, perceived level of function, pain provocation, and performance on movement-based tests were individually associated with injury risk. A past history of injury and perceived level of function have consistently been found to be self-reported risk factors for future MSK injuries in military populations.[11,16,72] Our findings also support research demonstrating a relationship between future MSK injury and pain with movement,[11,16,46] and/or deficits in movement and postural stability in military and athletic populations.[11,16,73,74]

One question to ask at this point is whether these predictors are causative of LBI or simply associated with future LBI and possibly an indirect indicator of the risk of future LBI. A statistical association between two variables merely implies that knowing the value of one variable provides information about the value of the other. It does not necessarily imply that one *causes* the other. Hence the mantra: “association is not causation.”[75] In order to determine causation, one must first rule out two possible issues that lead to a non-causal association: confounding and collider bias. Confounding occurs when an exposure and an outcome share a common cause. In their example, Lee et al.[75] they use the relationship of knee trauma and osteoarthritis with the confounder of exposure to high impact sports. In high impact sports, acute joint trauma may occur more often than in the general public. We have controlled for some confounding by applying the same baseline testing process with a specific population (military) sharing similar exposure to LBI and then using regression analysis to identify the role of significant LBI predictors in presence of multiple other key predictors. Nevertheless, it is still possible that some predictors not entering our prediction rule would still share a common cause with some of the predictors in the model and the LBI outcomes. Future research examining the effect of modifying the status on the different predictors on the risk of LBI would be needed to clarify whether the predictors present a causal association with future LBI.

Collider bias occurs when an exposure and outcome share a common effect (the collider). Continuing with the example above, it is plausible that people with knee joint trauma and osteoarthritis are more likely to have knee surgery (collider). Collider bias should not be controlled. In the example, if we study a group of individuals who received surgery (only as a result of joint trauma or knee osteoarthritis), knowing that a patient underwent surgery because of joint trauma will tell us that the patient is less likely to have knee osteoarthritis and vice versa. In other words, knee osteoarthritis becomes dependent on joint trauma within a sample of patients who undergo surgery (even though they are independent in the wider population). We avoid collider bias in our study by collecting all the specific LBIs we wanted to predict (non-contact) prospectively. Theoretically, a future LBI, which by definition was not present at baseline, would not be able to show a causal association with a baseline collider variable even if there was a causal link between a baseline predictor and the collider variable.

Specific to previous LBI prediction research, our findings support the association between movement deficits (e.g., Modified Sorensen and side plank) and future LBI in the general public and tactical athlete populations.[62,76,77] On the other hand, our study did not demonstrate a clear ability to predict future LBI with asymmetry in the anterior plane with the Star Excursion Balance Test[78] or LQYBT[16,37] as in other MSK injury prediction studies but did find agreement with asymmetry with UQYBT inferolateral reach. Teyhen et al.[16] found that an asymmetry of >7.75cm was predictive of non-contact MSK injury vs. our findings of an asymmetry of >1.5cm was predictive of non-contact LBI.

Despite finding that a UQ-YBT inferolateral asymmetry ≥1.5cm and side plank time asymmetry ≥8.3s were included in our final model, for other variables, we found that smaller asymmetries were more predictive of LBI than larger ones on some other variables (e.g. LQ-YBT composite score asymmetry (<2.4cm). This counterintuitive result was secondary to poor composite scores bilaterally in participants at risk of LBI. This variable was not considered in our logistic model analysis.

The work by Teyhen et al.[16] demonstrated the ability to combine multiple risk factors having shown promise in univariate analyses (Teyhen 35 vs. 27 for this study), as identified in our study, into a test cluster (11 variables for Teyhen vs 5 for this study) in order to determine MSK injury risk resulting in a time-loss in a similar population. Of the final test clusters from Teyhen et al. 2020 study[16], we overlapped on presenting a past injury, perceived level of function (<92.5% vs <90%), pain on movement and UQYBT inferolateral reach asymmetry (>7.75 vs >1.5cm). With regards to Teyhen et al.[11] 2015 study, our final test clusters overlapped on previous injury, pain with FMS clearance tests and smoking. To our knowledge, our study is the first to determine if a multiple test cluster could predict future LBI in a healthy military population.

4.3 Avenues for future research

A future practical application of the research includes further model validation and the use of the predictive tests to identify those at high risk in order to investigate if they would benefit from a preventative low back training program specific to their movement deficit(s). The potential benefits of early identification of “at risk” personnel are decreased costs, decreased use of medical assets, decreased lost days, and increased deployability of military personnel.

Other possible predictors that could have been studied include aerobic fitness testing,[15] as well as hip mobility[13], as there is evidence that their inclusion may make for a more robust injury prediction model. Another consideration would be adding functional testing which has demonstrated predictive ability in the lower quadrant[11] (e.g., hop test), but I am unaware of any research supporting this approach specific to LBI.

Functional Capacity Evaluations (FCE), where patients complete various functional tasks, are often used to determine readiness or ability for safe return to work following musculoskeletal injury, implying a low risk of future recurrence. Gross and Battié[79] actually found the opposite as the lower number of failed FCE tasks was consistently associated with higher risk of recurrence. In a Cochrane review, Schaafsma et al.[80] to evaluate the effectiveness of pre-employment examinations of job applicants in preventing occupational injury, disease and sick leave, they found inconsistent evidence for the effect on lowering musculoskeletal injuries of a job-specific pre-employment examination compared to a general pre-employment examination. There is little evidence supporting the use of an FCE in the prediction of future LBI.

4.4 Clinical implications

This research supports the utilization of self-report, movement-based tests, and pain provocation to predict future LBI in a healthy military population. As part of a full body screen, we may be able to identify individual injury risk based upon their low back, upper quadrant, and lower quadrant scores and, thereby target prevention strategies while respecting the limited funding, manpower, and time available to conduct injury risk screening and preventative programming. The process must be seen as being achievable and sustainable and be acceptable to all branches of the military in all their operation settings. Specific to the screen for LBI, very few resources (YBT kit and watch), minimal training and very little time is required to complete the screen (<20 minutes) which can be completed in even austere environments. Potentially, because a large portion of our sample had experienced a previous injury, this screen could be investigated to determine if those recently treated due to an LBI could be predicted by our model to be at a low risk of future LBI before authorizing return to duty in order to decrease recidivism rates. The CAF currently employs a quadrant-based training program (Rehabilitation for Performance (R4P)) through the physiotherapy and physical training departments to minimize movement deficits prior to discharge from treatment, hoping to decrease reinjury rates. Once the models for these regions are finalized, this grouped category of predictors could be investigated as a quadrant specific response to those at high risk for not only LBI, but possibly also for upper and lower quadrant injuries as well.

4.5 Limitations

Limitations in our study include the low frequency of participants reporting LBIs meeting our definition over the 6-month follow-up period (n=19). This limitation may be addressed in our future analysis using twelve months of follow-up data although the six-month duration is relevant considering the average deployment time for foreign operations. The combining of low back, pelvis and hip complaints into one group as back injuries often refer pain in these areas[81], may have wrongly included true pelvis and hip injury which may affect our ability to predict. However, our model showed a good ability to predict this grouped category. Another limitation may be the reliance on the self-reporting of LBIs, but the anonymous self-reporting strategy can be considered a strength of the study in that it allowed participants to report LBI without fear of workplace restrictions which play a role in injury reporting behaviors as documented by Carragee et al.[82] in the US military population. Further, we attempted to avoid recall bias by surveying for injuries on a monthly basis. Nevertheless, in the future, working with CAF medical facilities to track visits should be considered to capture more injuries and for confirming the diagnosis of LBI rather than misclassifying other medical issues referring pain in this region.

The study involved military personnel only; therefore, results may not apply to the general population, although the demographics and LBI rates of CAF members are similar to the working general population. Testing was only conducted at one CAF base, potentially limiting generalizability to other locations or to Air Force and Navy personnel. However, this location is highly representative of the CAF Army demographics. Still, very few women completed the study (n=40), and none reported injuries. Therefore, the results may be less reliable for this group. Ideally, this study should be repeated at other bases with Navy and Airforce personnel and with a higher population of female members.

4.6 Final conclusion

We developed a novel multivariable predictive model that can identify healthy military personnel at risk of future LBI. Our final model included baseline perceived lumbar/hip function ≤90% (SANE), pain with extension clearance test (FMS), UQ-YBT inferolateral asymmetry ≥1.5cm, side plank time asymmetry ≥8s and LQ-YBT composite worst score of ≤100cm. As hypothesized, other univariate predictors that may have predictive values were also identified among movement tests specifically testing the low back including for example fingertip to floor of ≥16cm and Modified Sorensen test of ≤86.0 seconds, and other more general movement-based tests such as Trunk Stability Push Up ≤5, as well as, among low back specific pain provocation predictors such as the Passive Lumbar Extension or with LBP with the Side Plank or Trunk Stability Push Up from the FMS. The predictors in included in our model can be captured in 20 minutes with minimal equipment and basic training in any environment. Combining three or more predictors from our multivariate models is associated with a greater risk of LBI (OR 6.8) with high specificity (91.5%) and having two or less predictors has high sensitivity (84.2%) for low risk of being injured. This combination produced a specific model that may be valuable for informing a screening strategy to predict LBI that can be completed in any environment with minimal resources. Our promising model requires further validation, but this model could be used in a military setting to predict future LBI with minimal cost or allocation of resources. In the future, this multifactorial LBI screen may link those with high risk for a future LBI to a targeted prevention program that could be investigated for its ability to ultimately result in reduced medical cost, decreased time lost and improve combat readiness.

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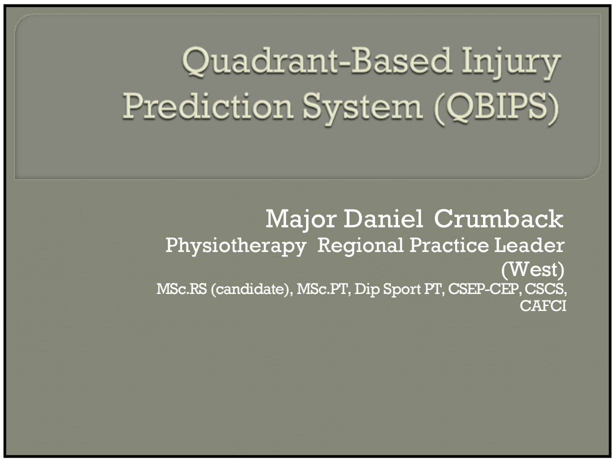
Appendix A. Unit PowerPoint Recruitment Presentation



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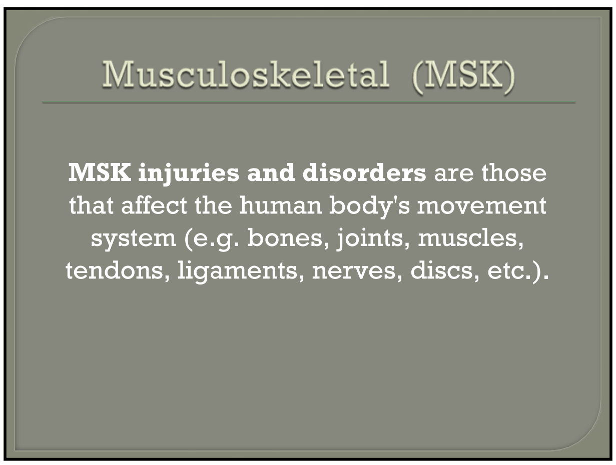

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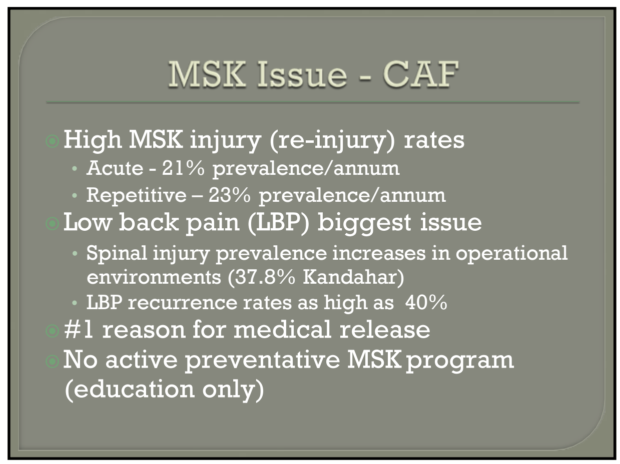

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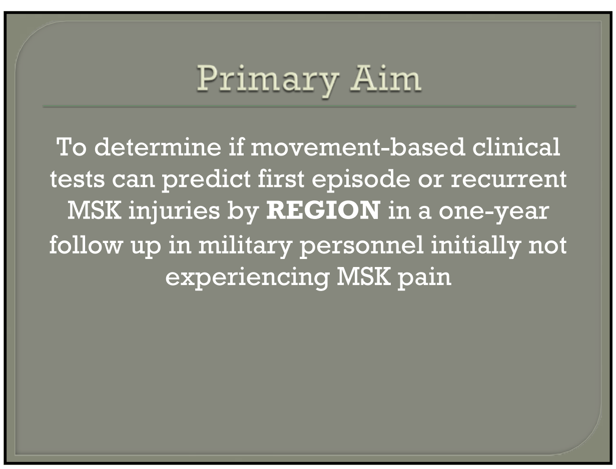

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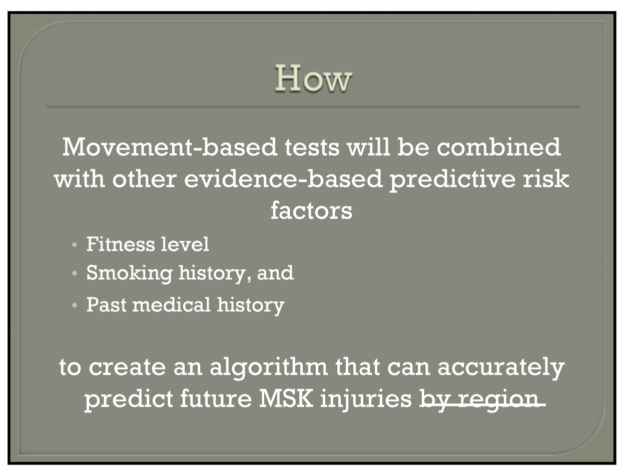

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Vehicles vs. Humans

- Vehicle Off Road (VOR)
- Describe the current status of each human in their command
- Build in standardized inspections (monthly/quarterly/annual) of their troops
- Build in repair time onto the operational schedule annually

7

Confidentiality

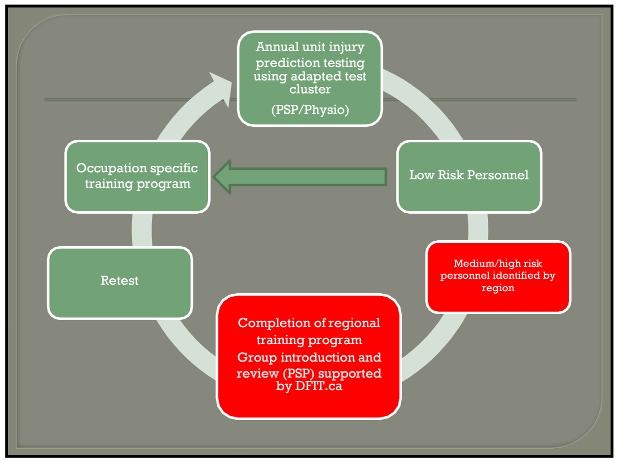
- All data will be kept separate from the individuals personal information
- No personal information will be used during data analysis
- Individual data results will not be analysed
- Information will NOT affect MELs, categories, or VA claims
- CoC will NOT be informed of individual's results

8

Future

- Preventative regional training programs will be completed by all personnel who score medium or high risk for a regional MSK injury IOT:
  - Decrease any modifiable injury/re-injury risk,
  - Improve performance,
  - Improve quality of life,
  - Ensure the availability of deployable soldiers to operational commanders.

9



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Theory

- e.g. NFL Combines
- Identifies strengths and weaknesses
- Reports to team
- Completes general position/team training program (offensive lineman)
- ~~Completes athlete specific training program to eliminate/minimize deficits identified during Combines~~
- Decreases injury risk and improves performance

11

Study Process

- Baseline Questionnaire/Informed Consent (10 minutes)
- Movement-Based Test Cluster (60 minutes)
  - Manned by specifically trained PSP, PT, and 1 Fd Amb staff
- Monthly Questionnaire x 12 months (5 minutes/month)
  - Incidence of MSK dysfunction in the last reporting period

12

Station	Test
1	Upper Quadrant Y-Balance Test
2	SFMA Lumbar Multi-Segmental Mobility
3	Modified Modified Schober
4	Lower Quadrant Y-Balance Test
5	Double Leg Side Plank/Bridge (right)
6	Ankle Mobility
7	Deep Overhead Squat Hurdle Step
8	In Line Lunge Shoulder Mobility Shoulder Impingement
9	Double Leg Side Plank/Bridge (left)
10	Active Straight Leg Raise
11	Trunk Stability Push Up Rotary Stability Lumbar Clearance
12	Modified Sorensen (endurance)
13	Passive Lumbar Extension (provocation) Prone Instability Test (provocation)

13

Inclusion Criteria

- Male or Female
- Regular Force
- 18-60 years of age
- Speak/Read English

14

Exclusion Criteria - Pregnancy

- Must not be pregnant
- Will be able to withdraw if you become pregnant throughout the six month follow up

15

Exclusion Criteria - Surgery

- Must not have had MSK related or abdominal surgery within the last 12 months
- Must not have any pending MSK related surgeries booked in the next six months
- Must not have had **ANY** spinal surgery **EVER**

16

Exclusion Criteria - Treatment

- Must not be currently receiving treatment (e.g. physio) or have received treatment for any MSK condition in the **last three months**
- Must not be currently using ~~prescribed~~ pain or anti-inflammatory medications for a MSK condition (OTC is ok)
- Must not have received any injection related to an MSK condition in the **last three months**

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Exclusion Criteria - Out

PAIN

- Must not have had >2/10 MSK pain for > three consecutive days over the last three months
- Must have <2/10 MSK pain on the day of the test

AND

FUNCTION

- Must not have experienced <90% of normal ability to function (work or home) for >24 hours secondary to MSK pain

18

Examples

- Low back pain at 3/10 each AM x first 10 minutes with no limit to normal function at home or work - IN
- Episodic shoulder pain lasting one – two days after weights x 4 months – uses ibuprofen/tylenol as needed – IN
- Hamstring pain >3/10 for 5 days – unable to run for last week - OUT

19

Testing

1. Prior to testing, view the test review video on YouTube
2. Wear shorts, t-shirt, running shoes (all testing done in bare feet)
3. Arrive at Physical Rehabilitation Department (PRD) at Garrison Fitness Centre at least 10 minutes early on test day to register, be given Study ID Number, and Data Collection Sheet (DCS)
4. Complete 13 Station – 19 Test Cluster in Upper Gym
5. Return completed DCS to PRD for completion check
6. Will be given Monthly Questionnaire Information Sheet

20

Other Volunteers

Those personnel who were not able to attend the QBIPS Recruitment presentations can request to be included in the study by contacting Major Crumback.

21

If you meet the inclusion criteria AND wish to volunteer for the study:

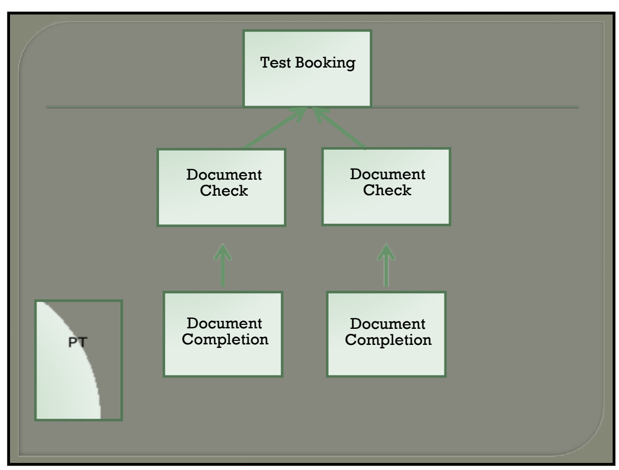
1. Complete and sign the Informed Consent
2. Complete the Baseline Questionnaire
3. Have documents reviewed (middle front tables)
4. Book Test Cluster appointment with Cathy (middle back table)
5. If you have specific questions ref the Inclusion Criteria, see the PTs located on either side

22

Comments

- Deployment – domestic/international
- Injury type
  - Sudden Onset – Contact
  - Sudden Onset – Non-Contact

23



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Thank you for your support

Be part of the solution – complete ALL your monthly questionnaires!

25

Appendix B. Information and Consent Form

Daniel J Crumback, MSc.RS (candidate), BSc.PT
Graduate Student, Faculty of Rehabilitation Medicine
University of Alberta
Corbett Hall, University of Alberta

Quadrant-Based Injury Prediction System (QBIPS) Participant Information Letter and Consent Form

Title of Study: The Use of Movement-Based Clinical Tests to Predict Musculoskeletal Injuries in Canadian Armed Forces Personnel
Sponsor: Department of National Defense (DND), Surgeon General Research Group (SGRG) **University of Alberta Health Research Ethics Board Protocol number**: Pro00065519
Principal Investigator: Major Daniel Crumback MSc.RS (candidate), BSc.PT ph: 587-336- 8966;
Co-Investigators: Dr. Eric Parent, Dr. Jacqueline Hebert, University of Alberta

Why am I being asked to take part in this research study?

You are being asked to participate in this research study because you are a healthy volunteer and interested in participating in a research study that investigates the ability of movement- based clinical tests to predict which military personnel are at higher risk of experiencing a musculoskeletal injury (e.g. joint, muscle, nerve, bone) in the next twelve months. The purpose of this information sheet is to provide you with the information needed to decide if you wish to participate in this study. Before you make a decision, one of the researchers will go over this form with you. You are encouraged to ask questions if you feel anything needs to be made clearer. You will be given a copy of this form for your records.

We are looking for 500 CAF military personnel who do not currently have any musculoskeletal (MSK) pain WITH an associated loss of function in the last three months to participate in this study. Pain, in this case, is defined as >2/10 pain for more than three consecutive days in the last three months AND must not have experienced <90% of normal ability to function (work or home) for >24 hours secondary to MSK pain. Participants will be asked to complete an Informed Consent Form, Baseline Questionnaire, and a 13-station 19 test cluster. For twelve months after testing, you will be emailed a Monthly Questionnaire to determine if you have experienced a new MSK injury during that report period. We will then analyze the data to determine if one or more of these tests could predict the development of MSK injuries.

What is the reason for doing the study?

Musculoskeletal injuries are a major issue in the Canadian Armed Forces (CAF). We are completing this study in order to develop an evaluation tool that could help us determine which personnel are at greater risk of a MSK injury. If we are able to predict which personnel will develop a MSK injury, including where and when the injury will occur, we could then pre-emptively prescribe an exercise program that could decrease the member's modifiable risk.
This would improve CAF members' quality of life, increase the deployability of the soldier, decrease the burden of MSK injuries on the CF Healthcare Services (CFHS), and ultimately improve performance.

Daniel J Crumback, MSc.RS (candidate), BSc.PT
Graduate Student, Faculty of Rehabilitation Medicine
University of Alberta
Corbett Hall, University of Alberta

What will I be asked to do?

If you agree to participate, you will complete an Informed Consent Form, and a Background Questionnaire (20 minutes) that includes basic demographic information (e.g. age/trade), smoking history, training habits, and past MSK medical history. You will be given access to a video demonstrating each test in the cluster. Each participant will be expected to view the 30 minutes video prior to their test day in order to familiarize themselves with the test protocol.

You will then be invited by email to attend a test cluster session at the Garrison Fitness Centre at CFB Edmonton. You are required to wear shorts and a t-shirt for the testing. You will report to the Physical Rehabilitation Department to be issued your study number. You will then report to the Upper Gym to be taken through a 13-station 19 test cluster which will include tests of your range of motion, flexibility, endurance, strength, and balance (60 minutes). After testing, we will follow you monthly for a one-year period, through emailed questionnaires (10 minutes), to determine if you have had a MSK injury over the last month.

What are the risks and discomforts?

There are no significant risks to this study. If you feel tired or uncomfortable at any time, we can take a break or stop the study and data collection with no impact on you.

It is not possible to know all of the risks that may happen in a study, but the researchers have taken all reasonable precautions to minimize any known risks to a study participant. If you become ill or injured as a result of being in this study, you will receive necessary medical treatment through the CAF medical services. By signing this consent form, you are not releasing the investigator(s), institution(s) and/or sponsor(s) from their legal and professional responsibilities.

What are the benefits to me?

The information gained will guide the development of a screening tool to predict MSK injuries in CAF personnel which ultimately may be used to develop an injury prevention program that will decrease injury risk and improve performance and thereby improve the quality of life for all CAF personnel.

Do I have to take part in the study?

Being in this study is your choice. If you decide to be in the study, you can change your mind and stop your participation in the study at any time; and it will in no way affect you. If you decide to end your participation in the study, you can inform the researchers at any time. If the data collection has been completed, we will use your information anonymously. If you withdraw before the data collection is completed, you can withdraw all of your data.

Will I be paid to be in the research?

You will not be paid for your participation in this research project.

Will my information be kept private?

During the study, we will be collecting data such as age, trade, and past medical history. The University of Alberta and SGRG will keep data stored for a minimum of 5 years after the end of the study; after which time the raw data is destroyed.

We will do everything we can to make sure that this data is kept private. No data relating to this study that includes your name will be released outside of the researcher's office or published by the researchers. Sometimes, by law, we may have to release your information including your name so we cannot guarantee absolute privacy. However, we will make every legal effort to make sure that your information is kept private.

People outside the University of Alberta may need to see your data for this study but your personal information will not be shared. Examples include other DND departments such as the SGRG and their agents. The study is being conducted/sponsored by the SGRG and DND through Individual Learning Plan (ILP) funding.

What if I have questions?

If you have any questions about the research now or later, please contact Major Daniel Crumback at 780-973-4011(4243) or at daniel.crumback@forces.gc.ca.

If you have any questions regarding your rights as a research participant, you may contact the Health Research Ethics Board at 780-492-2615. This office has no affiliation with the study investigators.

Participant Consent

Title of Study: The Use of Movement-Based Clinical Tests to Predict Musculoskeletal Injuries in Canadian Armed Forces Personnel
HREB Protocol number: Pro00065519
Principal Investigator: Major Daniel Crumback **Phone Number:** 780-973-4011 (4243)

	Yes	No
Do you understand that you have been asked to be in a research study?	☐	☐
Have you read and received a copy of the (attached) Information Sheet?	☐	☐
Do you understand the benefits and risks involved in taking part in this research study?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Do you understand that you are free to leave the study at any time without having to give a reason; and without penalty?	☐	☐
Has the issue of confidentiality been explained to you to your satisfaction?	☐	☐
Do you understand who will have access to your study records?	☐	☐
Do you wish to be contacted as a participant in further studies related to this research?	☐	☐

Who explained this study to you?

____

I agree to take part in this study:

Signature of Research Participant

____

Printed Name: ____

Date:______________________________

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

Signature of Investigator ______________________________Date _______________

THE INFORMATION SHEET MUST BE ATTACHED TO THIS CONSENT FORM AND A COPY GIVEN TO THE RESEARCH PARTICIPANT

Appendix C. Ethics Approval

Approval Form

Date:	July 13, 2016
Study ID:	Pro00065519
Principal Investigator:	Eric Parent
Study Title:	The Use of Movement-Based Clinical Tests to Predict Low Back Pain in Canadian Armed Forces Personnel.
Approval Expiry Date:	Wednesday, July 12, 2017

Approved Consent Form:	Approval Date 7/13/2016	Approved Document QBIPS Information and Consent Form

Thank you for submitting the above study to the Health Research Ethics Board - Health Panel . Your application, including the following, has been reviewed and approved on behalf of the committee;

- Baseline Questionnaire (5/29/2016)
- Monthly Questionnaire (7/12/2016)
- Data Collection Sheet (5/29/2016)
- Station Descriptions (5/29/2016)
- QBIPS Protocol 02Jun16

A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the Health Research Ethics Board does not encompass authorization to access the patients, staff or resources of Alberta Health Services or other local health care institutions for the purposes of the research. Enquiries regarding Alberta Health Services approvals should be directed to (780) 407-6041. Enquiries regarding Covenant Health should be directed to (780) 735-2274.

Sincerely,

Anthony S. Joyce, Ph.D.
Chair, Health Research Ethics Board - Health Panel

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Appendix D. Baseline Questionnaire

The information gathered on this page is so that we can provide you a print out of your findings:

Subject ID ____

This questionnaire will help us collect participant demographic and baseline health information. This information is strictly confidential and will not be shared with your chain of command. Any personal information (name or contact information) will not be stored with your answers within the questionnaire or with your test cluster results. Smoking history, fitness level, and past medical history have been proven to be predictors of future injury, therefore the reason for their inclusion in the questionnaire. The information obtained establishes a baseline that will be used to help develop appropriate programs that are aimed at decreasing a person's potential for future injury.
Instructions: Please answer every question by placing a mark in the ONE box that best fits. Please answer every question as accurately as possible and if you have any questions, please notify staff for help.

Subject ID Number: ______________________________

Background Information (Everyone Answers):

1. **Age (years) ____**

2. **Gender**
   a. ☐ **Male**
   b. ☐ **Female**

Smoking Questions ***(If you answer NO to both questions 3 and 4; skip questions 5 -7):***

3. **Do you smoke cigarettes regularly?**
   a. ☐ **No**
   b. ☐ **Yes (*If yes, please answer all questions in this section*)**

4. **Have you smoked at least 100 cigarettes in your lifetime?**
   a. ☐ **No**
   b. ☐ **Yes (*If yes, please answer all questions in this section*)**

5. **On average during all the years that you have smoked, how many cigarettes did you usually smoke per day?**
   a. ☐ **1-10**
   b. ☐ **11-20**
   c. ☐ **21-40**
   d. ☐ **More than 40**

6. **Except for the times that you quit, how many years all together have you smoked cigarettes?**
   a. ☐ **0-5**
   b. ☐ **6-10**
   c. ☐ **11-20**
   d. ☐ **More than 20 Years**

7. **Are you interested in receiving information on smoking cessation?**
   a. ☐ **No**
   b. ☐ **Yes**

Service Questions:

8. **Select branch of service**
   a. ☐ **Army**
   b. ☐ **Air Force**
   c. ☐ **Navy**
   d. ☐ **SOF**

9. **Select Status**
   a. ☐ **Regular Force**
   b. ☐ **Reserve (Class A or B <180 days)**
   c. ☐ **Reserve (Class B > 180 days or Class C)**

10. **How long have you been in the military?**
    a. ☐ **< 5 months**
    b. ☐ **At least 5 months but less than 1 year**
    c. ☐ **At least 1 year but less than 3 years**
    d. ☐ **At least 3 years but less than 5 years**
    e. ☐ **At least 5 years but less than 10 years**
    f. ☐ **At least 10 years but less than 15 years**
    g. ☐ **At least 15 years but less than 20 years**
    h. ☐ **At least 20 years but less than 25 years**
    i. ☐ **At least 25 years but less than 30 years**
    j. ☐ **Over 30 years**

11. **What is your rank? ______________**

12. **What is your MOSID? __________________**

13. **Unit: ____**

14. **In a typical week, how much of your time is involved in physical demanding activity (i.e., lifting, physical training, combatives, marching, wearing combat load, and maintenance of vehicles)?**
    ☐ **0-25% of my time requires physical demanding tasks**
    ☐ **26-50% of my time requires physical demanding tasks**
    ☐ **51-75% of my time requires physical demanding tasks**
    ☐ **76-100% of my time requires physical demanding tasks**

Fitness Level:

---

15. **Over the last year, how would you assess your activity level?**
    a. ☐ **Inactive**
    b. ☐ **Average**
    c. ☐ **Active**
    d. ☐ **Very Active**

16. **On average, how many days per week have you exercised more than 30 minutes over the last year?**
    ☐ **None**
    ☐ **Once a week**
    ☐ **2-3 days per week**
    ☐ **4-5 days per week**
    ☐ **6-7 days per week**

Injury Profile Data:

17. **Over the last year, have you been placed on Medical Employment Limitation (MELs) for a muscle, bone, nerve, or joint problem?**
    - ☐ **No** ***(If no, skip to question #58)***
    - ☐ **Yes**

18. **If "Yes", how many weeks of unit physical training (physical activity) did you miss?**
    - ☐ **Less than 1 week**
    - ☐ **At least 1 week but less than 2 weeks**
    - ☐ **At least 2 weeks but less than 4 weeks**
    - ☐ **At least 4 weeks but less than 8 weeks**
    - ☐ **At least 8 weeks but less than 6 months**
    - ☐ **At least 6 months but less than 12 months**
    - ☐ **Greater than 12 months**

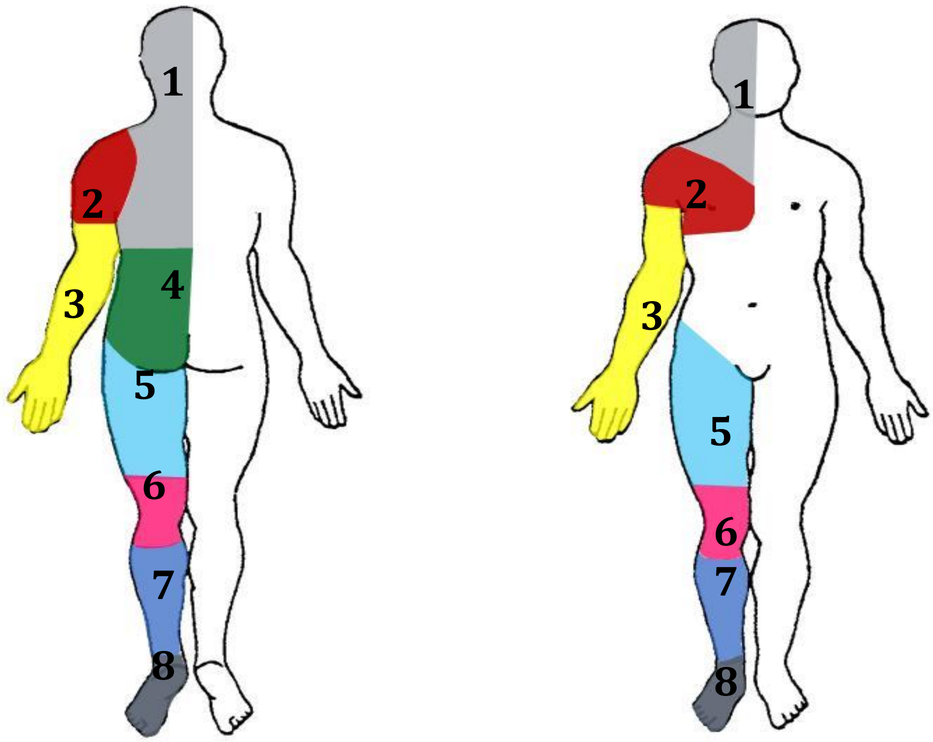
19. **Are you currently in pain due to any muscle, bone, nerve, or joint problem?**
    - ☐ **No** ***(If no, skip to question #58)***
    - ☐ **Yes**

20. **Are you currently on MELs or seeking medical care for this problem?**
    - ☐ **No**
    - ☐ **Yes**

21. **In the past 5 years have you had a significant injury or painful event that caused you to seek medical care or MELs greater than 7 days?**
    - ☐ **No** ***(If no, skip to question #58)***
    - ☐ **Yes**

22. **If you have had any problem in the last 5 years, select the region of body that was injured/causing pain (you may select more than 1 region)**

☐ 1 - Upper back/Head/Neck



☐ 2 - Shoulder
☐ 3 - Elbow/Wrist/Hand
☐ 4 - Lower Back
☐ 5 - Hip/Thigh/Groin
☐ 6 - Knee
☐ 7 - Lower Leg
☐ 8 - Foot/Ankle

Previous Injury ***(Will be dependent based on answer to previous question):***

Upper Back/Head/ Neck

23. Was the pain in your upper back, neck or head region caused by:

☐ **Trauma (unpredictable event i.e. whiplash, car accident, contact injury)**

☐ **Sudden Onset (non-traumatic) or Overuse/Recurrence of prior injury (i.e. neck pain, headaches – unsure as to cause or possible multiple causes)**

Answer questions #24-27, if you have had upper back, head, or neck pain in the last 5 years, and answered yes to area #1 in question #23.

24. How long did this pain/injury result in limited duty/MELs?

☐ **Less than 1 week**
☐ **At least 1 week but less than 2 weeks**
☐ **At least 2 weeks but less than 4 weeks**
☐ **At least 4 weeks but less than 8 weeks**
☐ **At least 8 weeks but less than 6 months**
☐ **At least 6 months but less than 12 months**
☐ **Greater than 12 months**

Please check which side (you may check all if applicable)

☐ **Right side**
☐ **Central**
☐ **Left side**

25. How many times have you had this same type of pain/injury in the past?

☐ **Only one time**
☐ **2-3 times**
☐ **4-5 times**
☐ **6-10 times**
☐ **> 10 times**

26. Global Rating: on a scale of 0 to 100, please rate your function of your upper back, neck region currently (0-100%)

0 = no function; 100 = full function

☐ **0% (no function)**
☐ **5%**
☐ **10%**
☐ **15%**
☐ **20%**
☐ **25%**
☐ **30%**
☐ **35%**
☐ **40%**
☐ **45%**
☐ **50%**
☐ **55%**
☐ **60%**
☐ **65%**
☐ **70%**
☐ **75%**
☐ **80%**
☐ **85%**
☐ **90%**
☐ **95%**
☐ **100% (full function)**

Shoulder

27. Was the pain in your shoulder region caused by:

- ☐ **Trauma (Single event i.e. dislocation, subluxation, fracture)**
- ☐ **Overuse/Recurrence of prior injury "developed over time" (i.e. bursitis, tendinitis)**

Answer questions #28-31, if you have had shoulder pain in the last 5 years and answered yes to area #2 in question #23. **Please check which side (you may check both if applicable)**

- ☐ **Right side**
- ☐ **Left side**

28. How long did this pain/injury result in limited duty/profile/activity restrictions?

- ☐ **Less than 1 week**
- ☐ **At least 1 week but less than 2 weeks**
- ☐ **At least 2 weeks but less than 4 weeks**
- ☐ **At least 4 weeks but less than 8 weeks**
- ☐ **At least 8 weeks but less than 6 months**
- ☐ **At least 6 months but less than 12 months**
- ☐ **Greater than 12 months**

29. How many times have you had this same type of pain/injury in the past?

- ☐ **Only one time**
- ☐ **2-3 times**
- ☐ **4-5 times**
- ☐ **6-10 times**
- ☐ **> 10 times**

30. Global Rating: on a scale of 0 to 100, please rate your function of your shoulder currently (0-100%)

0 = no function; 100 = full function

- ☐ **0% (no function)**
- ☐ **5%**
- ☐ **10%**
- ☐ **15%**
- ☐ **20%**
- ☐ **25%**
- ☐ **30%**
- ☐ **35%**
- ☐ **40%**
- ☐ **45%**
- ☐ **50%**
- ☐ **55%**
- ☐ **60%**
- ☐ **65%**
- ☐ **70%**
- ☐ **75%**
- ☐ **80%**
- ☐ **85%**
- ☐ **90%**
- ☐ **95%**
- ☐ **100% (full function)**

Elbow/Wrist/Hand

Answer questions #32-35, if you have had elbow, wrist, or hand pain in the last 5 years and answered yes to area #3 in question #23. **Please check which side (you may check both if applicable)**

- ☐ **Right side**
- ☐ **Left side**

31. Was the pain in your elbow, wrist, and hand region caused by:

- ☐ **Trauma (Single event i.e. dislocation, subluxation, fracture)**
- ☐ **Sudden (Sprain) and Overuse/Recurrence of prior injury "developed over time" (i.e. tennis elbow, golfers elbow, carpal tunnel syndrome)**

32. How long did this pain/injury result in limited duty/profile/activity restrictions?

- ☐ **Less than 1 week**
- ☐ **At least 1 week but less than 2 weeks**
- ☐ **At least 2 weeks but less than 4 weeks**
- ☐ **At least 4 weeks but less than 8 weeks**
- ☐ **At least 8 weeks but less than 6 months**
- ☐ **At least 6 months but less than 12 months**
- ☐ **Greater than 12 months**

33. How many times have you had this same type of pain/injury in the past?

- ☐ **Only one time**
- ☐ **2-3 times**
- ☐ **4-5 times**
- ☐ **6-10 times**
- ☐ **> 10 times**

34. Global Rating: on a scale of 0 to 100, please rate your function of your elbow, wrist, and hand currently (0-100%)

0 = no function; 100 = full function

- ☐ **0% (no function)**
- ☐ **5%**
- ☐ **10%**
- ☐ **15%**
- ☐ **20%**
- ☐ **25%**
- ☐ **30%**
- ☐ **35%**
- ☐ **40%**
- ☐ **45%**
- ☐ **50%**
- ☐ **55%**
- ☐ **60%**
- ☐ **65%**
- ☐ **70%**
- ☐ **75%**
- ☐ **80%**
- ☐ **85%**
- ☐ **90%**
- ☐ **95%**
- ☐ **100% (full function)**

Lower Back

Answer questions #36-39, if you have had lower back pain in the last 5 years and answered yes to area #4 in question #23.

Please check which side (you may check all if applicable)

- ☐ **Right side**
- ☐ **Central**
- ☐ **Left side**

35. Was the pain in your lower back caused by:

- ☐ **Trauma (Single event i.e. car accidentl, , etc.)**
- ☐ **Sudden Onset (lift Overuse/Recurrence of prior injury "developed over time" (i.e. mechanical low back pain, chronic low back pain, etc.)**

36. How long did this pain/injury result in limited duty/profile/activity restrictions?

- ☐ **Less than 1 week**
- ☐ **At least 1 week but less than 2 weeks**
- ☐ **At least 2 weeks but less than 4 weeks**
- ☐ **At least 4 weeks but less than 8 weeks**
- ☐ **At least 8 weeks but less than 6 months**
- ☐ **At least 6 months but less than 12 months**
- ☐ **Greater than 12 months**

37. How many times have you had this same type of pain/injury in the past?

- ☐ **Only one time**
- ☐ **2-3 times**
- ☐ **4-5 times**
- ☐ **6-10 times**
- ☐ **> 10 times**

38. Global Rating: on a scale of 0 to 100, please rate your function of your lower back currently (0-100%)

0 = no function; 100 = full function

- ☐ **0% (no function)**
- ☐ **5%**
- ☐ **10%**
- ☐ **15%**
- ☐ **20%**
- ☐ **25%**
- ☐ **30%**
- ☐ **35%**
- ☐ **40%**
- ☐ **45%**
- ☐ **50%**
- ☐ **55%**
- ☐ **60%**
- ☐ **65%**
- ☐ **70%**
- ☐ **75%**
- ☐ **80%**
- ☐ **85%**
- ☐ **90%**
- ☐ **95%**
- ☐ **100% (full function)**

Hip/Thigh/Groin

Answer questions #40-43, if you have had hip, groin or thigh pain in the last 5 years and answered yes to area #5 in question #23. **Please check which side (you may check both if applicable)**

☐ **Right side**
☐ **Left side**

39. Was the pain in your hip and thigh region caused by:

☐ **Trauma (Single event i.e. Fracture, hematoma/contusion)**
☐ **Overuse/Recurrence of prior injury "developed over time" (i.e. bursitis, tendinitis, stress fracture)**

40. How long did this pain/injury result in limited duty/profile/activity restrictions?

☐ **Less than 1 week**
☐ **At least 1 week but less than 2 weeks**
☐ **At least 2 weeks but less than 4 weeks**
☐ **At least 4 weeks but less than 8 weeks**
☐ **At least 8 weeks but less than 6 months**
☐ **At least 6 months but less than 12 months**
☐ **Greater than 12 months**

41. How many times have you had this same type of pain/injury in the past?

☐ **Only one time**
☐ **2-3 times**
☐ **4-5 times**
☐ **6-10 times**
☐ **> 10 times**

42. Global Rating: on a scale of 0 to 100, please rate your function of your hip and thigh region currently (0-100%)

0 = no function; 100 = full function

☐ **0% (no function)**
☐ **5%**
☐ **10%**
☐ **15%**
☐ **20%**
☐ **25%**
☐ **30%**
☐ **35%**
☐ **40%**
☐ **45%**
☐ **50%**
☐ **55%**
☐ **60%**
☐ **65%**
☐ **70%**
☐ **75%**
☐ **80%**
☐ **85%**
☐ **90%**
☐ **95%**
☐ **100% (full function)**

Knee

Answer questions #44-47, if you have had knee pain in the last 5 years and answered yes to area #6 in question #23.
Please check which side (you may check both if applicable)
☐ **Right side**
☐ **Left side**

43. Was the pain in knee caused by:
☐ **Trauma (Single event i.e. ligamentous injury, meniscal injury, fracture)**
☐ **Overuse/Recurrence of prior injury "developed over time" i.e. bursitis, iliotibial band friction syndrome, tendinitis, patellofemoral pain syndrome)**

44. How long did this pain/injury result in limited duty/profile/activity restrictions?
☐ **Less than 1 week**
☐ **At least 1 week but less than 2 weeks**
☐ **At least 2 weeks but less than 4 weeks**
☐ **At least 4 weeks but less than 8 weeks**
☐ **At least 8 weeks but less than 6 months**
☐ **At least 6 months but less than 12 months**
☐ **Greater than 12 months**

45. How many times have you had this same type of pain/injury in the past?
☐ **Only one time**
☐ **2-3 times**
☐ **4-5 times**
☐ **6-10 times**
☐ **> 10 times**

46. Global Rating: on a scale of 0 to 100, please rate your function of knee currently (0-100%)

0 = no function; 100 = full function

☐ **0% (no function)**
☐ **5%**
☐ **10%**
☐ **15%**
☐ **20%**
☐ **25%**
☐ **30%**
☐ **35%**
☐ **40%**
☐ **45%**
☐ **50%**
☐ **55%**
☐ **60%**
☐ **65%**
☐ **70%**
☐ **75%**
☐ **80%**
☐ **85%**
☐ **90%**
☐ **95%**
☐ **100% (full function)**

Lower Leg

Answer questions #48-51, if you have had lower leg pain in the last 5 years and answered yes to area #7 in question #23. **Please check which side (you may check both if applicable)**

- ☐ **Right side**
- ☐ **Left side**

47. Was the pain in your lower leg caused by:

- ☐ **Trauma (Single event i.e. fracture, acute compartment syndrome, achilles rupture)**
- ☐ **Overuse/Recurrence of prior injury "developed over time" (i.e. stress fracture, shin splints, tendinitis, nerve injury)**

48. How long did this pain/injury result in limited duty/profile/activity restrictions?

- ☐ **Less than 1 week**
- ☐ **At least 1 week but less than 2 weeks**
- ☐ **At least 2 weeks but less than 4 weeks**
- ☐ **At least 4 weeks but less than 8 weeks**
- ☐ **At least 8 weeks but less than 6 months**
- ☐ **At least 6 months but less than 12 months**
- ☐ **Greater than 12 months**

49. How many times have you had this same type of pain/injury in the past?

- ☐ **Only one time**
- ☐ **2-3 times**
- ☐ **4-5 times**
- ☐ **6-10 times**
- ☐ **> 10 times**

50. Global Rating: on a scale of 0 to 100, please rate your function of your lower leg currently (0-100%)

0 = no function; 100 = full function

- ☐ **0% (no function)**
- ☐ **5%**
- ☐ **10%**
- ☐ **15%**
- ☐ **20%**
- ☐ **25%**
- ☐ **30%**
- ☐ **35%**
- ☐ **40%**
- ☐ **45%**
- ☐ **50%**
- ☐ **55%**
- ☐ **60%**
- ☐ **65%**
- ☐ **70%**
- ☐ **75%**
- ☐ **80%**
- ☐ **85%**
- ☐ **90%**
- ☐ **95%**
- ☐ **100% (full function)**

Foot/ Ankle

Answer questions #52-55, if you have had foot or ankle pain in the last 5 years and answered yes to area #8 in question #23.
Please check which side (you may check both if applicable)
☐ **Right side**
☐ **Left side**

51. Was the pain in your foot and/or ankle caused by:
☐ **Trauma (Single event i.e. fracture, sprain, strain)**
☐ **Overuse/Recurrence of prior injury "developed over time" (i.e. stress fracture, tendinitis, plantar fasciitis, heel pain)**

52. How long did this pain/injury result in limited duty/profile/activity restrictions?
☐ **Less than 1 week**
☐ **At least 1 week but less than 2 weeks**
☐ **At least 2 weeks but less than 4 weeks**
☐ **At least 4 weeks but less than 8 weeks**
☐ **At least 8 weeks but less than 6 months**
☐ **At least 6 months but less than 12 months**
☐ **Greater than 12 months**

53. How many times have you had this same type of pain/injury in the past?
☐ **Only one time**
☐ **2-3 times**
☐ **4-5 times**
☐ **6-10 times**
☐ **> 10 times**

54. Global Rating: on a scale of 0 to 100, please rate your function of your foot and/or ankle currently (0-100%)

0 = no function; 100 = full function

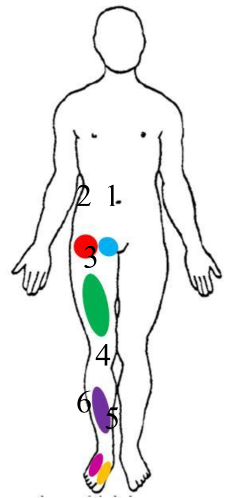
☐ **0% (no function)**
☐ **5%**
☐ **10%**
☐ **15%**
☐ **20%**
☐ **25%**
☐ **30%**
☐ **35%**
☐ **40%**
☐ **45%**
☐ **50%**
☐ **55%**
☐ **60%**
☐ **65%**
☐ **70%**
☐ **75%**
☐ **80%**
☐ **85%**
☐ **90%**
☐ **95%**
☐ **100% (full function)**

55. Have you had a stress fracture (a fracture caused by repetitive use and not trauma)?

- ☐ **No** ***(If no, skip to question #58)***
- ☐ **Yes**

56. If yes, please select what type of stress fracture

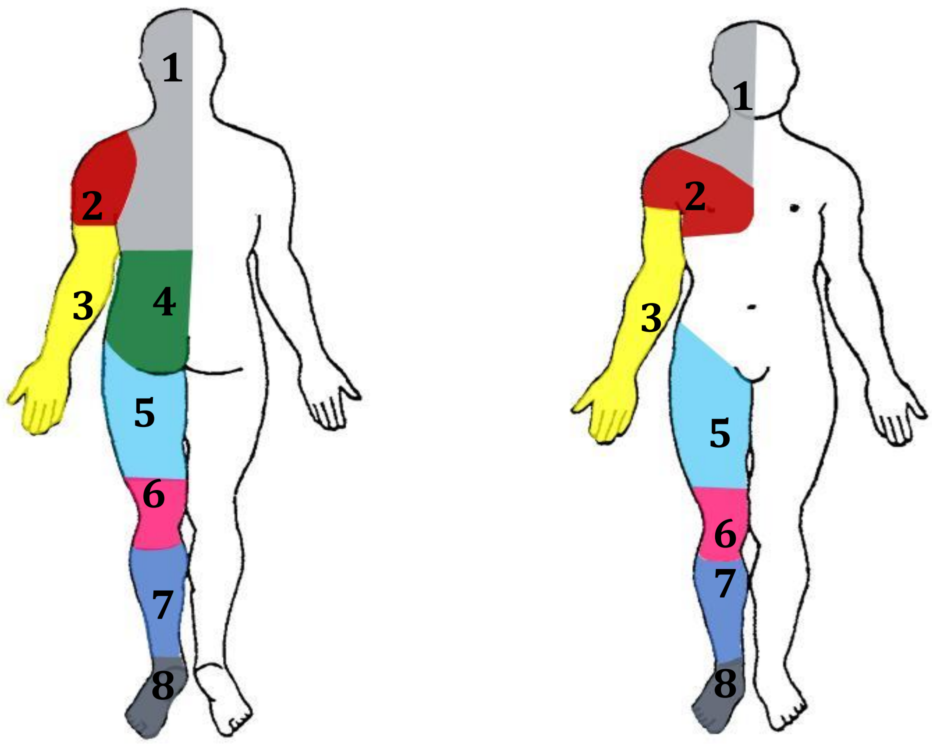
- ☐ **1-Pubic Ramus Stress Fracture**
- ☐ **2-Femoral Neck Stress Fracture**
- ☐ **3-Femoral Shaft Stress Fracture**
- ☐ **4-Tibial Stress Fracture**
- ☐ **5- 2nd or 3rd Metatarsal Stress Fracture**
- ☐ **6- 4th or 5th Metatarsal Stress Fracture**
- ☐ **Other (heel, fibular, sacral, etc.)**



Previous Surgeries:

57. Have you ever had surgery for a muscle, joint, bone, or nerve injury?
    - ☐ No
    - ☐ Yes

58. If yes, where was the surgery? (Select all that are applicable)



- ☐ 1 - Upper back/Head/Neck
- ☐ 2 - Shoulder
- ☐ 3 - Elbow/Wrist/Hand
- ☐ 4 - Lower Back
- ☐ 5 - Hip/Thigh/Groin
- ☐ 6 - Knee
- ☐ 7 - Lower Leg
- ☐ 8 - Foot/Ankle

59. What was the year of your last surgery?______________________________________

Injections – or other exclusion factors (if you have had an injection secondary to a muscle or joint issue, please provide area and year of last injection.

____

Thank You for participating in the
Quadrant Based Injury Prevention System (Q-BIPS) Study
Please let a study staff member know that you are done with the survey

Appendix E. Station testing order and instructions for assessors

Table Test Cluster Order Description

Station	Test
1	Upper Quadrant Y-Balance Test
2	SFMA Lumbar Multi-Segmental Mobility
3	Modified-Modified Schober
4	Lower Quadrant Y-Balance Test
5	Double Leg Side Plank (right)
6	Ankle Mobility
7	Deep Overhead Squat Hurdle Step
8	In-Line Lunge Shoulder Mobility Shoulder Impingement
9	Double Leg Side Plank (left)
10	Active Straight Leg Raise
11	Trunk Stability Push Up Extension Clearance Rotary Stability Flexion Clearance
12	Modified Sorensen back endurance test
13	Passive Lumbar Extension Prone Instability Test

Station 1 – Upper Quadrant Y-Balance Test (Stabilizing Arm Measured)

1. Equipment Needed:

- 2 YBT Measuring Device
- 2 Practice YBT Station (taped to floor)
- 2 Clipboards/Pens
- 2 Station Scripts
- 1 Roll of Tape

2. Verbal Instructions - The following is a script to use while administering the Upper Quarter Y Balance Test. For consistency throughout all testing this script should be used during each test:

- Please let me know if there is any pain while performing any portion of the test
- Please remove your shoes while performing the test
- Place your right/left hand on the center of the stance plate with your thumb just behind and parallel to the red starting line with the other hand on top of the reach indicator
- While maintaining the right/left-hand on the platform, push the reach indicator in the red target area as far as possible with the opposite hand out to the side, then under and across, and finally over and across without resting between directions
- The reach hand must maintain contact with the reach indicator on the target area while it is motion (i.e.. cannot shove the reach indicator)
- Do not use the reach indicator for stance support (i.e. don't place hand on top of reach indicator)
- Return the reach hand to the starting position under control
- Repeat two more times and then use the opposite arm in the same three directions
- Do you understand the instructions?

*Have the participant perform each movement three times before changing the supporting arm.

3. Rater Instructions - Once you have given the client testing instructions, have the client perform two practice trials of all three reach directions sequentially on each arm prior to formal testing. The test will be completed with shoes off:

- Start by having the participant place the right thumb just behind and parallel to the red line in a pushup position with feet shoulder-width apart and hands directly under the shoulders
- The participant will push the reach indicator with the left hand in the red target area to the left as far as possible

- While maintaining the same position, have the client push the inferolateral box as far as possible, and finally, push the superolateral box as far as possible without setting the reach hand down
- Read the reach distances while the client rests, and then repeat the test two more times with the right hand on the stance plate
- The client will then complete three trials in the same manner with the opposite limb
- Unlike the lower quarter YBT, all three reach directions are performed sequentially, one right after another without setting the reach hand down between reach directions
- When rested, the client will return to the starting position to perform the next trial
- Once ready to complete the formal testing, have the participant start with the right hand on the center plate and perform all three trials while reaching in the three directions in the specific testing order
- Measure the maximal reach distance by reading the tape measure at the edge of the reach indicator, at the point where the most distal part of the hand reached in half centimeters (e.g. 68.5, 69.0, 69.5 cm)
- Three trials in each direction for each arm will be collected and the maximal reach in each direction will be included for analysis
- If there are failed attempts, a maximum of six trials will be performed for any stance arm in a single direction
- If the participant has more than four failed attempts, record a zero for that trial
- Starting Position
- Medial Reach
- Inferolateral Reach
- Superolateral Reach

4. Scoring:

- There should not be a greater than four centimeter right and left reach distance difference in the medial, inferolateral and superolateral reach directions
- Also, the composite score—the sum of three reach directions is divided by three times limb length, then multiplied by 100—should not be less than the cut points that are specific for the age, gender and sport of the individual

5. Predictive Value - This can be obtained by using the Move2Perform software available at www.move2perform.com

Station 2 – SFMA Lumbar Multi-Segmental Mobility

1. Equipment Needed:

   - FMS Dowel
   - Clipboard/Pen
   - Station Script

2. Verbal Instructions - The following is a script to use while administering SFMA Lumbar Multi-Segmental Mobility Testing. For consistency throughout all testing this script should be used during each test.

   Multi-segmental Flexion
   - Stand erect with the feet together (shoes off) and the toes pointing forward.
   - Bend forward at the hips and attempt to touch the ends of your fingers to the tips of your toes without bending your knees.

   Multi-segmental Extension
   - Stand erect with the feet together (shoes off) and the toes pointing forward.
   - While keeping your elbows extended, raise your arms directly overhead until they are aligned with your ears.
   - Bend backwards as far as possible, keeping your arms aligned.

   Multi-segmental Rotation
   - Stand erect with the feet together (shoes off), toes pointing forward and arms out to your side.
   - Rotate your entire body as far as possible to the right/left without moving your feet.

3. Rater Instructions –

Flexion:

Look for a normal unrestricted forward bend. The patient should be able to easily touch their toes and return to the standing position without pain. Measure the distance of the patient's fingers from the floor if they are unable to reach the floor. Note the presence of pain and its location.

Extension

Mid-hand line should drop behind the shoulders at the top of the extension pattern. The spine of their scapula must clear their heels. ASIS must clear their toes. UE does not achieve or maintain 170º. Non-uniform spinal curve. Excessive effort and/or lack of motor control. Note the presence of pain and its location.

Rotation

Look for normal rotational mobility in the neck, trunk, pelvis, hips, knees and feet. Pay close attention to each segment of the body noting Pelvis rotation, Shoulders rotation, Spine/pelvis deviation, Excessive knee flexion and Excessive effort. Note an asymmetry and/or the presence of pain and its location.

4. Scoring - (Assessment Categories and Clinical Meaning):

   SFMA places each movement assessment into one of four categories:
   - Functional Non-Painful (FN): Full movement without pain
   - Functional Painful (FP): Full movement with pain
   - Dysfunctional Painful (DP): Limited movement with pain
   - Dysfunctional Non-Painful (DN): Limited movement without pain

5. Predictive Values - Multi-Segmental Flexion ≥10 cm tips of fingers to floor. http://dynamicchiropractic.com/mpacms/dc/article.php?id=55136

Station 3 – Modified-Modified Schőber & Upper Limb Length

1. Equipment Needed:

   - 2 Cloth tape measure
   - 2 Non-permanent felt tip pens
   - 2 Clipboards/Pens
   - 2 Station Scripts

2. Verbal Instructions - The following is a script to use while administering Modified-Modified Schőber & Upper Limb Length testing. For consistency throughout all testing this script should be used during each test.

   Modified-Modified Schőber

   - Begin in the standing positon with your shoulders aligned with your hips
   - Slowly bend forward at the waist as far as possible
   - Hold this position while a measurement is taken
   - Now return to the standing position with shoulders and hips aligned. We will repeat this movement three times - once three maximal measurements are recorded return to the neutral position
   - Now slowly bend backwards at the waist while allowing your hips to move forward
   - Hold this position while a measurement is taken
   - Now return to the standing position with shoulders and hips aligned. We will repeat this movement three times - once three maximal measurements are recorded return to the neutral position

   Upper Limb Length

   - Please stand while we measure your right arm length
   - We will be palpating for landmarks and then making the measurement
   - The rater will palpate for landmarks when taking the measurement

3. Rater Instructions.

   Modified-Modified Schőber:

   - Prior to testing mark a point with a felt tip pen at the base of the spine perpendicular to the SIPS (Spina Illiaca Posterior Superior – aka PSIS)
   - Measure 15 cm above the first mark along the spine using a cloth tape measure – make a second marking at this point
   - When the patient is bent forward to their fullest - measure the distance between the two felt tip markings for the flexion flexibility score (≥ 15 cm)

- When the patient is bent backwards to their fullest – measure the distance between the two felt tip markings and subtract this score from 15 cm for extension flexibility score (≤ 15 cm)
- Measurements are taken to the nearest half (0.5) cm.

Upper Limb Length

- Make a mark to identify the Cervica 7 (C7) spinous process
- Determine the client's arm length in standing by measuring the distance from the C7 spinous process—most bony prominence at the base of the neck—to the distal tip of the third digit to the nearest half centimeter with the arm elevated to 90 degrees—out to side
- If you are unable to determine the location of the C7 spinous process, have the participant flex and extend the neck; the C7 spinous process will remain prominent throughout
- Only measure the right arm

4. Scoring:

   - Measurements are taken to the nearest half (0.5) cm for the Modified-Modified Schőber and Upper Limb Length measurements

5. Predictive Values:

   Modified-Modified Schőber Predictive Scores over 12 years of age PV are independent of age, gender and body length. MMDC = 1cm
   www.rguhs.ac.in/cdc/onlinecdc/uploads/09_T006_22117.doc

   Predictive Value & More detailed instructions:
   https://www.researchgate.net/publication/7724668_The_Modifed-Modifed_Schober_Test_for_range_of_motion_assessment_of_lumbar_flexion_in_patients_with_low_back_pain_A_study_of_criterion_validity_intra-_and_inter-rater_reliability_and_minimum_metrically

Station 4 - Lower Quadrant Y-Balance Test (Standing Leg Measured)

1. Equipment Needed:

   - 2 YBT Kits
   - 2 Practice YBT Station (tapped to floor)
   - 2 Clipboards/Pens
   - 2 Station Scripts
   - 1 Roll of Tape

2. Verbal Instructions - The following is a script to use while administering the Lower Quarter Y Balance Test. For consistency throughout all testing this script should be used during each test:

   - Please let me know if there is any pain while performing any portion of the test
   - Please remove your shoes while performing the test
   - Place your right/left foot on the center of the foot plate with your toes just behind the starting line
   - While maintaining the foot on the platform, push the reach indicator in the red target area as far as possible with the opposite leg
   - The reach foot must maintain contact with the reach indicator on the target area while it is motion (i.e. cannot kick the reach indicator)
   - Do not use the reach indicator for stance support (i.e. place foot on top of reach indicator)
   - Return the reach foot to the starting position under control (i.e. return the reach foot to the floor behind the angle, next to the stance platform)
   - Do you understand the instructions?
   - The participant will perform each movement three times before alternating the supporting foot in the same direction
   - Once completed in the same direction for both feet, continue with the next direction

3. Rater Instructions:

   - After giving the testing procedure instructions, have the client perform six practice trials in each of the three directions prior to formal testing
   - Start by having the client stand with the foot on the center foot plate, with the most distal aspect of the toes just behind the red starting line
   - While maintaining a single-limb stance, have the client reach with the free limb in one of three directions (anterior, posteromedial or posterolateral), and then return to the starting position
   - Once ready to complete the formal testing, have the participant start with the right foot on the center of the foot plate and perform three attempts while reaching in one of the three directions

- Then the participant will place the left foot on the center foot plate and repeat with the opposite limb
- Alternating stance legs between trials will ensure adequate rest for accurate results
- The maximal reach distance is measured by reading the tape measure at the edge of the reach indicator, at the point where the most distal part of the foot reached in half centimeters (e.g. 68.5, 69.0, 69.5 cm)
- Three trials in each direction for each foot will be collected and the maximal reach in each direction will be included for analysis
- If there are failed attempts, perform a maximum of six trials in a single direction. If the participant has more than four failed attempts, a zero should be recorded for that trial

4. Scoring:

- Measurements are taken to the nearest 0.5cm for the Lower Quadrant Y-Balance Test

5. Predictive Values:

- There should not be greater than 4.0cm right and left reach distance difference in the anterior reach direction
- There should not be greater than a 6.0cm. reach distance difference in the posteromedial and posterolateral directions
- Also, the composite score—the sum of three reach directions divided by three times limb length, then multiplied by 100—should not be less than the cut points specific for the age, gender and sport/activity of the individual
- This can be obtained by using the Move2Perform software available at www.move2perform.com

Station 5 – Double Leg Side Plank/Bridge (Right Side Bottom Leg)

1. Equipment Needed:

   - Exercise Mat (thickness = 2.5 cm)
   - Timer
   - Clipboard/Pen
   - Station Script

2. Verbal Instructions - The following is a script to use while administering the Double Leg Side Plank/Bridge Test. For consistency throughout all testing this script should be used during each test:

   - Adopt a side lying position on your right side
   - Insure that your top foot/left foot is placed in front of the lower foot/right foot on the mat for support
   - Ensure that the toe of your rear foot is touching the heel of your top foot
   - Now lift your hips off the mat and maintain a straight line over the full length of your body
   - Use your bottom elbow and both feet for support
   - The uninvolved arm should be placed on your left hip
   - Hold this position for as long as possible
   - This is a timed test
   - You can receive up to two corrections during the test. For example - “Hip”, “Legs”, “Trunk” or “Rolling” – no encouragement is to be given
   - You may begin now

3. Rater Instructions:

   - Ensure proper positioning of the client prior and during the test
   - The goal is to maintain the position for ≥ 180 seconds
   - Verbal corrective feedback on positioning can be offered on a maximum of two occasions with the statements “Hip”, “Legs”, “Trunk” or “Rolling” – no encouragement is to be given
   - The endurance time is recorded to the nearest tenth of a second
   - The time is started from when the client assumes the position to when they are unable to continue or unable to maintain the test position despite two warnings
   - Ensure that the client has approximately 5 min of rest between each endurance task
   -

4. Scoring:

   - Measurements are to be taken with a stop watch to the nearest tenth of a second

5. Predictive Values:

- There should be no difference in unity of the Right and Left Side Bridge (RSB and LSB).
- Mathematically this is written: $0.95 \leq RSB/LSB \text{ Ratio} \leq 1.05$
- This uniformity is based upon the RSB and LSB scores and outside this muscle balance is UNACCEPTABLE
- Mean scores for Males = RSB 95 seconds LSB 99 seconds with a SD RSB 32 seconds LSB 37 seconds
- Mean scores for Females = RSB 75 seconds LSB 78 seconds with a SD RSB 32 seconds LSB 32 seconds
- Cause for concern is a score 1x SD below Mean scores
- Stuart McGill states that the ratio b/w flex and extensor strength is also a primary predictive value
- McGill states that imbalance is more predictive than a weakness http://www.sfu.ca/~leyland/Kin143%20Files/TrunkEnduranceTesting.pdf

Station 6 – Ankle Mobility

1. Equipment Needed:

- 2 iPhone with iHandy Level (Free iPhone App)
- 2 Non-permanent felt tip pens
- 2 Clipboards/Pens
- 2 Station Scripts
- 1 Roll Athletic Tape – line on floor (knee alignment)

2. Verbal Instructions - The following is a script to use while administering the Ankle Mobility Test. For consistency throughout all testing this script should be used during each test:

- Before testing please perform two 30-sec calf stretches on the right and left legs to warm up
- Please kneel on your left knee while placing your right foot along the YBT kit
- Lunge your right knee as far forward along the line as either stiffness or pain will allow while keeping your heel on the ground
- You may use your hands for support
- While your knee is advanced as far as possible, we will take a measurement with the measuring device
- Once two maximal measurements are recorded on the right side, we will repeat this activity with the left foot

3. Rater Instructions:

- Client will remove shoes for testing. Subject starts kneeling on one knee and the other foot aligned on the edge the stance plate of the YBT kit
- Prior to testing mark a point just distal to the tibial tuberosity along the anterior border of the tibia on each leg – mark this point with a felt tipped pen
- Align border of foot being tested (1st metatarsal to calcaneus) along the tape line on the floor
- Place the top of the smartphone at this marking in line with the tibial crest when scoring
- The subject will bring the knee forward and keep the knee over the 4th ray
- Contact with the heel must be maintained and the client is directed to replace heel down if it does come up
- Score the maximum angle with the iPhone two times on each side. During testing ensure that the heel is flat on the ground
- The greatest score value will be used for each side

4. Scoring:

   - Measurements will be taken to the nearest degree using the smart phone and recorded on the score sheet

5. Predictive Values:

   - Optimal closed kinetic chain dorsiflexion is ≥ 40 º
   - Minimal passing score is ≥ 35 º
   - Even more important than total angle, is asymmetry
   - Predictive Value ≥ 5 º asymmetry http://www.humankinetics.com/acucustom/sitename/Documents/DocumentItem/07_J3708_JSR_Krause%20333_344.pd

Station 7 – Deep Overhead Squat, Shoulder Mobility & Impingement Clearance

1. Equipment Needed:

    - FMS Kit
    - Clipboard/Pen
    - Station Scripts

2. Verbal Instructions - The following is a script to use while administering the Deep Overhead Squat, Shoulder Mobility & Impingement Clearance Test. For consistency throughout all testing this script should be used during each test.

    Deep Overhead Squat:

    - Your feet should be approximately shoulder width apart and aligned evenly
    - Your feet should also be pointing forward
    - Adjust your hands on the dowel as it is balance on top of your head so that your elbows are at a 90-degree angle
    - Now press the dowel overhead with the shoulders flexed and abducted the elbows fully extended
    - Now descend slowly into a squat position as deeply as possible
    - This position should be assumed with the heels on the floor, head and chest facing forward and the dowel maximally pressed overhead
    - Your knees should be kept aligned over the feet

    Shoulder Mobility (Upper Arm Measured)

    - Make a fist with each hand with the thumb inside the fist
    - Now try to touch your hands together as closely as possible as demonstrated (measured arm goes behind head and opposite behind back). Start so that the right arm is measured
    - During the test the hands should remain in a fist and they should be placed behind the back in one smooth motion
    - We will repeat the test and take measurements on 3x attempts
    - We will now repeat the test with the arm movement reversed to measure the opposite side (so that the left side is measured)

    Impingement Clearance

    - Please place your right hand on your left shoulder as demonstrated
    - Now attempt to point the elbow upward
    - Do you have any pain?
    - We will now test the opposite arm
    - Please place your right hand on your left shoulder as demonstrated
    - Now attempt to point the elbow upward
    - Do you have any pain?

3. Raters Instructions.

   Deep Overhead Squat:

   - You may perform 3x repetitions but there is no need to repeat if the initial movement falls within the criteria
   - If the criterion for a score of III is not achieved, then perform the test with the FMS kit under the heels.
   - All other positioning should not change except for the heels on the FMS kit
   - When in doubt, score low
   - Try not to interpret the score while testing
   - Make sure to view the individual from the front and side

   Shoulder Mobility

   - Use the FMS kit to measure the distance from the distal wrist crease to the tip of the third (longest digit)
   - Perform the shoulder mobility test as many as 3x bilaterally
   - If one repetition is completed successfully there is no reason to perform the test again
   - The flexed shoulder identifies the side being scored, this simply represents the pattern and does not imply the functional ability of a body part or side
   - Always remember you are screening patterns, not parts
   - If the hand measurement is exactly the same as the distance between the two points then score low
   - Make sure the individual does not try to 'walk' the hands toward each other following the initial placement
   - The clearance exam is to follow testing

   Impingement Clearance

   - The test is considered positive if there is pain or the elbow does not break the horizontal plane

4. Scoring.

   Deep Overhead Squat:

   - Refer to DCS
   - Scoring will be done on the 0-100 rating scale as this is more sensitive for scientific research.

Shoulder Mobility

- Use the FMS dowel to measure the distance from landmark to landmark

- Measure up to 3x on each arm
- Record the measurement to the closest 0.5cm

Impingement Clearance

- If there is pain associated with this movement a score of zero is given

5. Predictive Values:

- Predictive Scores have a Bimodal distribution. Clients with a score of ≤ 14 have an increased risk of injury, clients with a score of 15-17 have a lower risk of injury and clients with a score of ≥ 18 have an increased risk of injury. https://ergoweb.com/functional-movement-screening-fms-not-predictive-of-msds-in-military-study/
- Solider specific study. http://www.ncbi.nlm.nih.gov/pubmed/26657573
- http://www.strengthandconditioningresearch.com/functional-movement-screen-fms/

Station 8 – In Line Lunge (Forward Leg) & Hurdle Step (Moving Leg)

1. Equipment Needed:

   - 2 FMS Kits
   - 2 Clipboards/Pens
   - 2 Station Scripts

2. Verbal Instructions - The following is a script to use while administering the In Line Lunge & Hurdle Step Test. For consistency throughout all testing this script should be used during each test.

   In Line Lunge

   - Place your heel your front foot at the line indicated on the FMS kit
   - Place the dowel behind the back as demonstrated
   - The hand opposite the front foot should be the hand grasping the dowel at the cervical spine
   - The other hand grasps the dowel at the lumbar spine
   - Make sure the dowel is vertical before you try to step into the lunge position and try to maintain the position of the dowel throughout testing (downward and upward movement)
   - The back knee must touch the board behind the heel of the front foot and then return to the starting position
   - The lunge can be performed up to 3x on each side

   Hurdle Step Movement Pattern Test:

   - Please allow us to identify an important landmark
   - Now stand with the outside of the right foot against the base of the hurdle, in line with one of the hurdle uprights
   - Place both feet together while standing directly behind the center of the hurdle base
   - Both feet will be together, touching at both the heels and toes and aligned with the toes touching the base of the hurdle
   - The dowel is positioned across the shoulders below the neck
   - Now step over the hurdle and touch your heel (not toe) to the floor while maintaining and extended supporting hip/leg
   - All weight should be born on the right stance leg
   - The knee and ankle can flex slightly on the stance leg
   - The moving leg is then returned to the starting position
   - The Hurdle Step should be performed slowly and under control
   - Each Leg will be scored independently.

3. Raters Instructions.

In Line Lunge

- Attain the individual's tibal length, by measuring it from the floor to the tibial tuberosity
- Mark the tibia measurement on the FMS kit for the client to note
- The lunge can be performed up to three times on each side in a slow controlled fashion
- If one repetition is completed successfully there is no reason to perform the test again on that side and a three is given for the in line lunge test on that side
- The front leg identifies the side being scored, this simply represents the pattern and does not imply the functional ability of a body part or side
- Always remember you are screening patterns and not parts
- Ensure the dowel remains vertical and in contact with the head, thoracic spine and sacrum during the lunge
- The front heel remains in contact with the board and back heel touches the board when returning to the starting position
- When in doubt score low
- Watch for the loss of balance
- Remain close to the individual in a position to prevent a collapse or complete loss of balance

Hurdle Step Movement Pattern Test:

- Identify the tibial tuberosity as a reliable landmark
- Adjust the hurdle to the correct height
- Slide the marker cord to the level to the center of the tibial tuberosity on both legs
- Individuals have 3x chances per stepping leg to perform the hurdle step
- As soon as a hurdle step meets the criterion there is no need to repeat the test on that side
- Score each side independently
- Score the leg that is stepping over the hurdle, this simply represents the pattern and does not imply the functional ability of a body part or side
- Always remember you are screening patterns and not parts
- Make sure the individual maintains a stable torso with no movement above the waist
- Make sure the toes keep in contact with the hurdle during and after each repetition
- Tell the individual to be as tall as possible when starting the test, but no to lock their knees during testing
- Maintain proper alignment with the string and tibial tuberosity
- When in doubt score low
- Do not try to interpret the score when testing

4. Scoring.

In Line Lunge

- See FMS booklet for details
- Scoring will be done on the 0-100 rating scale as this is more sensitive for scientific research.

Hurdle Step Movement Pattern Test:

- See FMS booklet for details
- Scoring will be done on the 0-100 rating scale as this is more sensitive for scientific research.

5. Predictive Values:

- Predictive Scores have a Bimodal distribution. Clients with a score of ≤ 14 have an increased risk of injury, clients with a score of 15-17 have a lower risk of injury and clients with a score of ≥ 18 have an increased risk of injury. https://ergoweb.com/functional-movement-screening-fms-not-predictive-of-msds-in-military-study/
- Solider specific study. http://www.ncbi.nlm.nih.gov/pubmed/26657573
- http://www.strengthandconditioningresearch.com/functional-movement-screen-fms/

Station 9 – Double Leg Side Plank/Bridge (Left Side Down)

1. Equipment Needed:

- Exercise Mat (thickness = 2.5 cm)
- Timer
- Clipboard/Pen
- Station Scripts

2. Verbal Instructions - The following is a script to use while administering the Double Leg Side Plank/Bridge Test. For consistency throughout all testing this script should be used during each test:

- Adopt a side lying position on your left side.
- Insure that your top foot/right foot is placed in front of the lower foot/left foot on the mat for support
- Ensure that the toe of your rear foot is touching the heel of your top foot.
- Now lift your hips off the mat and maintain a straight line over the full length of your body
- Use your bottom elbow and both feet for support.
- The uninvolved arm should be placed on your right hip
- Hold this position for as long as possible.
- This is a timed test
- You can receive up to two corrections during the test. For example - "Hip", "Legs", "Trunk" or "Rolling" – no encouragement is to be given
- You may begin now

3. Rater Instructions:

- Ensure proper positioning of the client prior and during the test.
- The goal is to maintain the position for ≥ 180 seconds
- Verbal corrective feedback on positioning can be offered on a maximum of two occasions with the statements "Hip", "Legs", "Trunk" or "Rolling" – no encouragement is to be given.
- The endurance time is recorded to the nearest tenth of a second
- The time is started from when the client assumes the position to when they are unable to continue or unable to maintain the test position despite two warnings.
- Ensure that the client has approximately 5 min of rest between each endurance task

4. Scoring:

- Measurements are to be taken with a stop watch to the nearest tenth of a second

5. Predictive Values:

- There should be no difference in unity of the Right and Left Side Bridge (RSB and LSB)
- Mathematically this is written: $0.95 \leq$ RSB/LSB Ratio ≤ 1.05
- This uniformity is based upon the RSB and LSB scores and outside this muscle balance is UNACCEPTABLE
- Mean scores for Males = RSB 95 seconds LSB 99 seconds with a SD RSB 32 seconds LSB 37 seconds
- Mean scores for Females = RSB 75 seconds LSB 78 seconds with a SD RSB 32 seconds LSB 32 seconds
- Cause for concern is a score 1x SD below Mean scores
- Stuart McGill states that the ratio b/w flex and extensor strength is also a primary predictive value
- McGill states that imbalance is more predictive than a weakness http://www.sfu.ca/~leyland/Kin143%20Files/TrunkEnduranceTesting.pdf

Station 10 – Lower Limb Length (Right) & Active Straight Leg Raise (Moving Leg)

1. Equipment Needed:

- Tape Measure
- FMS kit
- Pen
- Station script

2. Verbal Instructions - The following is a script to use while administering the Lower Limb Length and Active Straight Leg Raise Test. For consistency throughout all testing this script should be used during each test.

Lower Limb Length:

- The marker is going to take a measurement from two landmarks
- Please lie supine on the table without sock and shoes
- Start with both knees bent and feet flat on the floor
- Now raise your hips off and then return your hips to the floor
- Straighten your knees
- A staff member will pull evenly on your legs
- Measurements will be taken of the right leg

Active Straight Leg Raise

- Position yourself on your back with both arms 30 degrees from your side with your palms up and your head flat on the floor
- We are now going to place an FMS board under your knees
- Both feet should be pointing towards the ceiling
- Now lift one leg while keeping your toe pointed towards the ceiling
- During this test the opposite leg should stay in contact with the FMS board and the head flat on the floor
- Once the end range is achieved a measurement will be taken
- We will take up to 3x measurements on each side

3. Raters Instructions.

Lower Limb Length:

- Measure from the ASIS to the medial malleolus on the right side

Active Straight Leg Raise

- Ensure both ankles are in a neutral position with the sole of the foot perpendicular to the floor
- Identify the mid-point between the ASIS and the joint line of the knee
- This usually corresponds to the mid-point of the patella, but confirm the joint line by flexing and extending the knee until the joint line between the tibia and femur are evident
- The dowel is then placed at this position perpendicular to the ground
- Once the end range is achieved note the position of the ankle
- The test should be performed as many as 3x bilaterally
- If one repetition is completed successfully there is no reason to perform the test again
- The flexed hip identifies the side being scored, this simply represents the pattern and does not imply the functional ability of a body part or side
- Always remember you are screening patterns and not parts
- Make sure the leg on the floor does not externally rotate at the hip
- Both knees remain extended and the knee on the extended hip remains touching the board
- If the dowel resides at exactly the mid-point, score low

4. Scoring.

   Lower Limb Length:

   - Record the measurement to the nearest 0.5cm on each leg

   Active Straight Leg Raise:

   - Once the end range is achieved, note the position of the ankle
   - If the malleolus passes the dowel a score of 3 is recorded
   - If the malleolus does not pass the dowel then the dowel is aligned along the malleolus of the test leg, perpendicular to the floor and a scored as per the criteria
   - See FMS book for details

5. Predictive Values:
   - Predictive Scores have a Bimodal distribution. Clients with a score of ≤ 14 have an increased risk of injury, clients with a score of 15-17 have a lower risk of injury and clients with a score of ≥ 18 have an increased risk of injury. https://ergoweb.com/functional-movement-screening-fms-not-predictive-of-msds-in-military-study/
   - Solider specific study. http://www.ncbi.nlm.nih.gov/pubmed/26657573
   - http://www.strengthandconditioningresearch.com/functional-movement-screen-fms/

Station 11a – Trunk Stability Push Up/Extension Clearance

Station 11b - Rotary Stability (Moving Arm)/Flexion Clearance

1. Equipment Needed:

   - FMS kit (11b)
   - 2 Clipboards/Pens
   - 2 Station Scripts

2. Verbal Instructions - The following is a script to use while administering the Trunk Stability Push Up, Rotary Stability & Flexion/Extension Clearance Tests. For consistency throughout all testing this script should be used during each test.

   Trunk Stability Push Up:

   - Please assume a resting push up position on the floor with your feet together and toes pulled up.
   - Place your hands where instructed and extend your legs fully so your knees are off the ground
   - Now perform one push up in a smooth fashion with your body moving as a single unit.
   - Males: Test begins with their thumbs lined up with their forehead and their A/C joints. If unsuccessful the test is repeated with their thumbs lines up at their chin level and A/C joints.
   - Females: Test begins with their thumbs lined up with their chin and their A/C joints. If unsuccessful the test is repeated with their thumbs lined up with their clavicle and A/C joints.
   - Note presence and location of pain

   *If the client cannot perform a push up complete the clearing exam

   Spinal Extension Clearance:

   - Position yourself on the floor on your front. Place your arms as though you were going to perform a push-up. Extend your elbows without lifting your hips/pelvis off the floor.
   - Did you experience pain with this movement?

   Rotary Stability Movement Test:

   - Please assume a 4-point position with the FMS board between the knees and hands
   - Your knees and hands should be positioned as close to the board as possible
   - Your hands should be opened as wide as possible with the thumbs touching the board
   - Now extend the right arm and the left knee
   - Now touch both limbs under your torso
   - Now return to the rest position

- Now extend the left arm and the right knee
- Now touch both limbs under your torso
- Now return to the rest position

Flexion Clearance:

- Please assume the "Child's Pose" position
- Make sure that you rock back and touch your buttocks to your heels and your chest to your thighs
- Try to stretch your body out as far as possible
- Did you experience any pain?

3. Rater Instructions.

Trunk Stability Push Up:

- Make sure the ankles are neutral with the soles of the feet perpendicular to the floor
- Ensure that the body is lifted as a unit with no 'lag' in the lumbar spine
- Ensure that the hand position is maintained throughout testing
- Make sure that the stomach and chest come off the floor at the same instance
- When in doubt score low

Spinal Extension Clearance:

- Make sure to note any pain and the location of pain

Rotary Stability Movement Test:

- Make sure the spine is flat and parallel to the board with the hips and shoulders at 90 degrees relative to the torso
- The knees should be positioned at 90 degrees and the ankles neutral with the soles perpendicular to the floor
- The leg and hand should only be raised enough to clear the floor approximately 6-12"
- The client may have up to 3x attempts if needed
- If one repetition is successful there is no reason to perform the test again
- Make sure the knee and elbow remain over the board to achieve a score of three
- Make sure the knee and elbow meet over the board to achieve a score of two
- Make sure the spine is flat and the hips and shoulders are at right angles at the start of the test
- Provide cueing to let the individual know that he/she does not need to raise the hip and arm above the 6-12" off the floor
- When in doubt score low

Flexion Clearance:

- The clearance exam will be performed after the rotary stability test
- The movement is not scored, but it is performed to observe a pain response

4. Scoring.

Trunk Stability Push Up:
Note the location of their hands for a successful push up.

Spinal Extension Clearance:

- Score as positive or negative based on pain reports

Rotary Stability Movement Test:

Check position in which subject is able to touch elbow to knee directly over board

Unilateral repetition:
-Performs one correct unilateral repetition while keeping their spine parallel to the board. Knee and elbow touch inline over the board.

Diagonal repetition:
- Performs one correct diagonal repetition while keeping their spine parallel to the board. Knee and elbow touch inline over the board.

Failure of diagonal repetition: Inability to perform diagonal repetitions.

- Note presence and location of pain

Flexion Clearance Test:

- Score as positive or negative based on pain reports

5. Predictive Values:

- Predictive Scores have a Bimodal distribution. Clients with a score of ≤ 14 have an increased risk of injury, clients with a score of 15-17 have a lower risk of injury and clients with a score of ≥ 18 have an increased risk of injury. https://ergoweb.com/functional-movement-screening-fms-not-predictive-of-msds-in-military-study/
- Solider specific study. http://www.ncbi.nlm.nih.gov/pubmed/26657573
- http://www.strengthandconditioningresearch.com/functional-movement-screen-fms/

Station 12 – Modified Sorensen

1. Equipment Needed:

   - 2 Plinths
   - 6 x belts/straps
   - 2 Timers
   - 2 Clipboards/Pens
   - 2 Station Script
   - 2 half rolls

2. Verbal Instructions - The following is a script to use while administering the Modified Sorensen Test. For consistency throughout all testing this script should be used during each test:

   - Adopt a face down position on the bed with the half roll under your shins
   - We will secure you to the bed with three straps
   - Now touch your hands to your ears
   - Place your elbows out to the side
   - Keep your trunk and head level in a neutral position while maintaining a neutral alignment for as long as possible
   - We will be measuring the time you can maintain this position
   - Hold this position for as long as possible
   - You may begin when ready

3. Rater Instruction:

   - Secure the patient in a prone position on the bed
   - The lower body from the iliac crest downward should be secured to the table using three straps
   - Strap one at the level of the buttocks
   - Strap two below the buttocks
   - Strap three on the lower leg below the knee
   - Ensure that proper form is maintained during timing
   - Verbal corrective feedback on positioning can be offered on a maximum of two occasions "arms", "chest", or "neck".
   - The time is started from when the client assumes the position to when they are unable to continue or unable to maintain the test position despite two warnings
   - No encouragement is to be provided

4. Scoring:

   - This is a timed test

- The time is started from when the client assumes the position to when they are unable to continue or unable to maintain the test position despite two warnings
- The endurance time is recorded to the nearest tenth of a second

5. Predictive Values:

- Predictive Scores for Healthy Patients are dependent upon the specific research paper. For example – one series determined a mean for males and females at a value of ≥133 seconds while another series determined sex specific scores at ≥116 seconds for females and ≥142 seconds for males. http://cdn.intechopen.com/pdfs/36700/InTech-Muscular_performance_assessment_of_trunk_extensors_a_critical_appraisal_of_the_literature.pdf

Station 13 – Passive Lumbar Extension (PLE) and Prone Instability Test (PIT)

1. Equipment Needed:

   - Plinth
   - Clipboard/Pen
   - Station Script

2. Verbal Instructions - The following is a script to use while administering PLE and PIT testing. For consistency throughout all testing this script should be used during each test:

   PLE:

   - Adopt a face down position on the table
   - This is a passive test
   - One staff member will elevate your legs by adjusting the end of the bed by 30 degrees – please remain relaxed
   - Is there any change to how you physically feel in this new position?
   - One staff member will now gently pull on both your legs.
   - Is there any change to how you physically feel in this new position?
   - We will now lower the bed to the starting positon.
   - Is there any change in how you physically feel in this new position?

   PIT:

   - While standing support your upper body on table as demonstrated
   - There is a passive and active component to this test – please relax – we will provide instructions throughout the test
   - Describe how you are physically feeling in this start position
   - The Physiotherapist will now apply pressure at multiple levels along the spine – please relax throughout testing – do not contract your abdominals during testing
   - Are you experiencing any increased pain/numbness at this level? (Repeat this question at each level)
   - We will now continue to the second portion of the test
   - Please use your hands and grab onto the bed
   - While holding onto the bed – lift your legs off the floor
   - The Physiotherapist will now apply pressure along your spine at various levels while your legs lifted off the floor
   - Are you experiencing any increased pain/numbness at this level? (Repeat this question at each level)

3. Rater Instructions:

   PLE:

- Ensure proper positioning of the client prior and during the test

PIT:

- Ensure proper positioning of the client prior to and during the test
- Posterior to Anterior pressure will be applied at levels T12 to L5 in both test positions
- At each level the scorer will check for pain and or neuro symptoms
- Findings will be recorded appropriately
- The test is positive if pain is present in the resting position (initial position) but subsides in the active position (second position)
- A positive test suggests lumbar-pelvic instability
- Any adverse event will be documented as appropriate and care provided as necessary

4. Scoring:

PLE:

- Pain lumbar or lumbar associated peripheral during testing indicates a positive test.

PIT:

- The test is positive if pain is present in the resting position (initial position) but subsides in the active position (second position)
- Record finding appropriately on the score sheet

5. Predictive Values:

PLE:

- Positive Predictive Value = 80.0% Negative Predictive Value = 92.7% http://ptjournal.apta.org/content/86/12/1661.full.pdf?origin=publication_detail

PIT:

https://lumbarspineassessment.wordpress.com/?s=Prone+Instability+Test

Appendix F. Data Collection Sheet for Testers

Subject # ____________

<u>Station 1 - UQ YBT</u>

Direction	Right 1	Right 2	Right 3	Left 1	Left 2	Left 3
Medial						
Inferolateral						
Superolateral						

Right Pain Yes No Area: ___________________________

Left Pain Yes No Area: ___________________________

Direction	Greatest Right	Greatest Left
Medial		
Inferiolateral		
Superiolateral		
Total		

<u>Station 2 - SFMA</u>

SFMA Multisegmental LSpine

Flexion FN FP DN DP ______ cms tip of finger to floor

Extension FN FP DN DP

R Rotation FN FP DN DP

L Rotation FN FP DN DP

<u>Station 3 – Modified-Modified Schober/Upper Limb Length</u>

Flexion ______ cms

Extension ______ cms

Upper Limb Length ______ cms

Station 4 - LQ YBT

Direction	Right 1	Right 2	Right 3	Left 1	Left 2	Left 3
Anterior						
Posteriomedial						
Posteriolateral						

Right Pain Yes No Area: ______________________________

Left Pain Yes No Area: ______________________________

Direction	Greatest Right	Greatest Left
Anterior		
Posteriomedial		
Posteriolateral		
Total		

Station 5 – Double Leg Side Plank/Bridge (Right)

R ________s

Reason for stopping Timed Out/Fatigue/Pain

Station 6 - Ankle Mobility

R ______ degrees Pain Yes No Area: TC/ST

L ______ degrees Pain Yes No Area: TC/ST

Difference _______ degrees Limited Side ______

Station 7 – Deep Overhead Squat/Hurdle Step

Deep Overhead Squat

Without board	
Upper torso parallel with tibia	6
Knees aligned over feet	8
Dowel aligned over feet	4
With board	
Femur below horizontal	2
Upper torso parallel-tibia parallel	2
Knees aligned over feet	2
Dowel aligned over feet	2

Pain: Yes No Area________________________

Hurdle Step (moving leg)

Right

Foot clears cord (no touch)	5
Hips/knees/ankles aligned	2
Minimal movement in Lsp	1
Dowel/hurdle parallel	1

Pain: Yes No Area_______________________

Left

Foot clears cord (no touch)	5
Hips/knees/ankles aligned	2
Minimal movement in Lsp	1
Dowel/hurdle parallel	1

Pain: Yes No Area_______________________

Station 8 –In Line Lunge/Shoulder Mobility/Shoulder Impingement

In Line Lunge (forward leg)

Right

Knee touches behind heel	2
Dowel/feet in sagittal plane	2
Dowel contacts maintained	2
Dowel remains vertical	2
No torso movement	2

Pain: Yes No Area____________________

Left

Knee touches behind heel	2
Dowel/feet in sagittal plane	2
Dowel contacts maintained	2
Dowel remains vertical	2
No torso movement	2

Pain: Yes No Area____________________

Shoulder mobility (top hand)

Right

Fists within one hand length	4
Fists within 1.5 hand lengths	2
Fists NOT within 1.5 hand lengths	0

Pain: Yes No Area_____________________

Left

Fists within one hand length	4
Fists within 1.5 hand lengths	2
Fists NOT within 1.5 hand lengths	0

Pain: Yes No Area______________________

Shoulder Impingement

Right +/- Left +/-

Station 9 – Double Leg Side Plank/Bridge (Left)

L _______s

Reason for stopping Timed Out/Fatigue/Pain

Station 10 – Lower Limb Length/Active Straight Leg Raise

Lower Limb Length _______ cms

Active Straight Leg Raise

Right

Malleolus between mid-thigh and ASIS	6
Malleolus between mid-thigh & joint line	2
Malleolus below joint line	0

Pain: Yes No Area_____________________

Left

Malleolus between mid-thigh and ASIS	6
Malleolus between mid-thigh & joint line	2
Malleolus below joint line	0

Pain: Yes No Area_____________________

<u>Station 11a) – Trunk Stability Push Up/ Extension Clearance</u>

Trunk Stability Push Up

Men

Thumbs at forehead level	12
Thumbs at chin level	5
Failure at chin level	0

Pain: Yes No Area ________________________

Women

Thumbs at forehead level	12
Thumbs at chin level	5
Failure at chine level	0

Pain: Yes No Area______________________

Extension Clearance Pain Yes No Area:________________________

<u>Station 11b) - Rotary Stability (upper moving limb indicates side tested)</u>

Right

Unilateral repetition	6
Diagonal repetition	2
Failure of diagonal repetition	0

Pain Yes No Area______________________

Left

Unilateral repetition	6
Diagonal repetition	2
Failure of diagonal repetition	0

Pain Yes No Area______________________

Flexion Clearance Pain Yes No Area: __________________________

Station 12 - Modified Sorensen

Time ________s

Reason for stopping Timed Out/Fatigue/Pain

Station 13 – Lumbar Provocation

Passive Lumbar Extension (PLE) Positive Negative

Prone Instability Test (PIT) Positive Negative

Appendix G. Monthly questionnaire

Confidential

QBIPS Monthly Questionnaire

Study ID: [baseline_arm_1][bstudy_id]

Test date: [baseline_arm_1][test_date]

PLEASE REMEMBER TO CLICK THE "SUBMIT" AND "CLOSE SURVEY" BUTTONS WHEN YOU ARE DONE IN ORDER TO FINALIZE THE QUESTIONNAIRE.

PLEASE DO NOT REPORT ON INJURIES SUSTAINED IN PREVIOUS REPORTING PERIOD.

Study ID: [baseline_arm_1][bstudy_id]

Test date: [baseline_arm_1][test_date]

Today's date:

____

1. Where have you spent your time over the last month?

Please select all that apply.

☐ In Garrison
☐ On Exercise
☐ On Deployment
☐ On Course
☐ On Leave

1 How many weeks in Garrison:
(round up days to 1 week, max. 4 weeks)

____

How many weeks on Leave:
(round up days to 1 week, max. 4 weeks)

____

How many weeks on Exercise:
(round up days to 1 week, max. 4 weeks)

____

How many weeks on Deployment:
(round up days to 1 week, max. 4 weeks)

____

How many weeks on Course:
(round up days to 1 week, max. 4 weeks)

____

2. In the last reporting period have you had a NEW musculoskeletal (MSK) injury or painful event that meets the following criteria:

a) pain greater than 2/10 for more than 3 consecutive days; AND

b) limited your ability to exercise or perform work for more than 24 hours?

(If you answered NO to question 2, please hit SUBMIT)

◯ Yes
◯ No

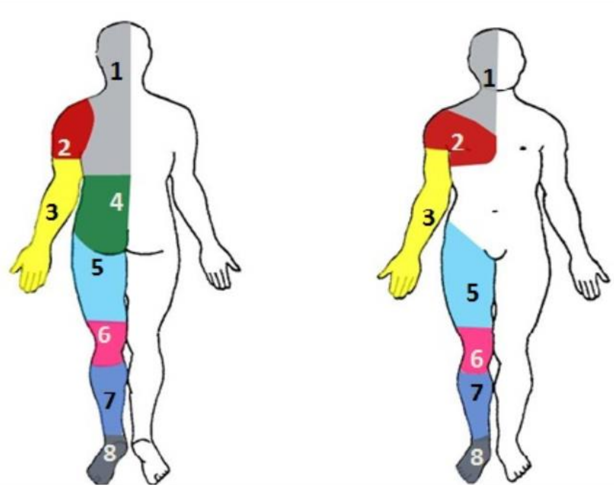
3. Did you seek medical care for the injury?

◯ Yes
◯ No

4. Were you placed on Medical Employment Limitation (MELs)/chit?

◯ Yes
◯ No

5. Please select the region of the body that was injured/causing pain (you may select more than 1 region)



Please select all that apply

☐ 1. Upper back/Head/Neck
☐ 2. Shoulder
☐ 3. Elbow/Wrist/Hand
☐ 4. Lower Back
☐ 5. Hip/Thigh/Groin
☐ 6. Knee
☐ 7. Lower Leg
☐ 8. Foot/Ankle

Please answer the questions related to the region(s) of the body that you selected on question 5.

UPPER BACK/ HEAD/ NECK

6a. Was the pain/symptom(s) in your upper back, neck, or head region caused by:
(SELECT ONE ANSWER ONLY)

○ Sudden Onset - Contact (unpredictable event requiring an external force; e.g., car accident, hit into boards in hockey)
○ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g., sudden pain with a quick movement)
○ Overuse/ Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

6b. Date of injury/ onset:

____

6c. Please check which side is affected (you may check all if applicable)

☐ Left side
☐ Central
☐ Right side

7. How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

8. On a scale of 0 to 100, please rate the functionality of your upper back, neck, or head region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

SHOULDER

9a. Was the pain/symptom(s) in your shoulder region caused by:
(SELECT ONE ANSWER ONLY)

◯ Sudden Onset - Contact (unpredictable event requiring an external force; e.g., hit into boards in hockey)
◯ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g., sudden pain with a hard throw)
◯ Overuse/Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

9b. Date of injury/onset:

____

9c. Please check which side is affected (you may check both if applicable)

☐ Left side
☐ Right side

10. LEFT SHOULDER: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

10. RIGHT SHOULDER: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

11. LEFT SHOULDER: On a scale of 0 to 100, please rate the functionality of your shoulder region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

11. RIGHT SHOULDER: On a scale of 0 to 100, please rate the functionality of your shoulder region currently (0-100%):
(SELECT ONE ANSWER ONLY)

- ◯ 0% (unable to function)
- ◯ 5%
- ◯ 10%
- ◯ 15%
- ◯ 20%
- ◯ 25%
- ◯ 30%
- ◯ 35%
- ◯ 40%
- ◯ 45%
- ◯ 50%
- ◯ 55%
- ◯ 60%
- ◯ 65%
- ◯ 70%
- ◯ 75%
- ◯ 80%
- ◯ 85%
- ◯ 90%
- ◯ 95%
- ◯ 100% (fully functional)

ELBOW/ WRIST/ HAND

12a. Was the pain/ symptom(s) in your elbow, wrist, and hand region caused by:
(SELECT ONE ANSWER ONLY)

- ◯ Sudden Onset - Contact (unpredictable event requiring an external force; e.g., fall onto outstretched arm)
- ◯ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g., sudden pain with bicep curl or pull-up)
- ◯ Overuse/ Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

12b. Date of injury/ onset:

____

12c. Please check which side affected (you may check both if applicable)

- ☐ Left side
- ☐ Right side

13. LEFT ELBOW/ WRIST/ HAND: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

- ◯ Only one time
- ◯ 2-3 times
- ◯ 4-5 times
- ◯ 6-10 times
- ◯ More than 10 times

13. RIGHT ELBOW/ WRIST/ HAND: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

14. LEFT ELBOW/ WRIST/ HAND: On a scale of 0 to 100, please rate the functionality of your elbow, wrist, and hand region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

14. RIGHT ELBOW/ WRIST/ HAND: On a scale of 0 to 100, please rate the functionality of your elbow, wrist, and hand region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

LOWER BACK

15a. Was the pain/symptom(s) in your lower back region caused by:
(SELECT ONE ANSWER ONLY)

◯ Sudden Onset - Contact (unpredictable event requiring external force; e.g., car accident, hit into boards in hockey)
◯ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g., sudden pain when picking up an object)
◯ Overuse/Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

15b. Date of injury/onset:

____

15c. Please indicate side affected (you may check all if applicable)

☐ Left side
☐ Central
☐ Right side

16. How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

17. On a scale of 0 to 100, please rate the functionality of your lower back region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

HIP/ THIGH/ GROIN

18a. Was the pain/ symptom(s) in your hip and thigh region caused by:
(SELECT ONE ANSWER ONLY)

◯ Sudden Onset - Contact (unpredictable event requiring an external force; e.g., hit into boards in hockey)
◯ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g., sudden pain in region with stride in hockey)
◯ Overuse/ Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

18b. Date of injury/ onset:

____

18c. Please indicate side affected (you may check both if applicable)

☐ Left side
☐ Right side

19. LEFT HIP/ THIGH/ GROIN: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ > 10 times

19. RIGHT HIP/ THIGH/ GROIN: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ > 10 times

20. LEFT HIP/ THIGH/ GROIN: On a scale of 0 to 100, please rate the functionality of your hip and thigh region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

20. RIGHT HIP/ THIGH/ GROIN: On a scale of 0 to 100, please rate the functionality of your hip and thigh region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

KNEE

21a. Was the pain/symptom(s) in knee region caused by:
(SELECT ONE ANSWER ONLY)

- ◯ Sudden Onset - Contact (unpredictable event requiring an external force; e.g., hit into boards in hockey)
- ◯ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g., sudden pain with cutting movement in sport)
- ◯ Overuse/Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

21b. Date of injury/onset:

____

21c. Please indicate side affected (you may check both if applicable)

- ☐ Left side
- ☐ Right side

22. LEFT KNEE: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

- ◯ Only one time
- ◯ 2-3 times
- ◯ 4-5 times
- ◯ 6-10 times
- ◯ More than 10 times

22. RIGHT KNEE: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

- ◯ Only one time
- ◯ 2-3 times
- ◯ 4-5 times
- ◯ 6-10 times
- ◯ More than 10 times

23. LEFT KNEE: On a scale of 0 to 100, please rate the functionality of your knee region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

23. RIGHT KNEE: On a scale of 0 to 100, please rate the functionality of your knee region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

LOWER LEG

24a. Was the pain/symptom(s) in your lower leg region caused by:
(SELECT ONE ANSWER ONLY)

◯ Sudden Onset - Contact (unpredictable event requiring an external force; e.g., sliding tackle in soccer)
◯ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g., sudden pain while accelerating during sport)
◯ Overuse/Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

24b. Date of injury/onset:

____

24c. Please indicate side affected (you may check both if applicable)

☐ Left side
☐ Right side

25. LEFT LEG: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

25. RIGHT LEG: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

26. LEFT LEG: On a scale of 0 to 100, please rate the functionality of your lower leg region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

26. RIGHT LEG: On a scale of 0 to 100, please rate the functionality of your lower leg region currently (0-100%):
(SELECT ONE ANSWER ONLY)

◯ 0% (unable to function)
◯ 5%
◯ 10%
◯ 15%
◯ 20%
◯ 25%
◯ 30%,
◯ 35%
◯ 40%
◯ 45%
◯ 50%
◯ 55%
◯ 60%
◯ 65%
◯ 70%
◯ 75%
◯ 80%
◯ 85%
◯ 90%
◯ 95%
◯ 100% (fully functional)

FOOT/ANKLE

27a. Was the pain/symptom(s) in your foot and/or ankle region caused by:
(SELECT ONE ANSWER ONLY)

◯ Sudden Onset - Contact (unpredictable event requiring an external force; e.g., jumping from vehicle)
◯ Sudden Onset - Non-Contact (no other person or object involved in injury; e.g.; sudden pain from rolling ankle in sport)
◯ Overuse/Repetitive (e.g., came on gradually, unsure as to cause or possible multiple causes)

27b. Date of injury/onset:

____

27c. Please indicate side affected (you may check both if applicable)

☐ Left side
☐ Right side

28. LEFT FOOT/ANKLE: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

◯ Only one time
◯ 2-3 times
◯ 4-5 times
◯ 6-10 times
◯ More than 10 times

28. RIGHT FOOT/ ANKLE: How many times have you had this same type of pain/injury in the past?
(SELECT ONE ANSWER ONLY)

- ◯ Only one time
- ◯ 2-3 times
- ◯ 4-5 times
- ◯ 6-10 times
- ◯ More than 10 times

---

29. LEFT FOOT/ ANKLE: On a scale of 0 to 100, please rate the functionality of your foot and/or ankle region currently (0-100%):
(SELECT ONE ANSWER ONLY)

- ◯ 0% (unable to function)
- ◯ 5%
- ◯ 10%
- ◯ 15%
- ◯ 20%
- ◯ 25%
- ◯ 30%,
- ◯ 35%
- ◯ 40%
- ◯ 45%
- ◯ 50%
- ◯ 55%
- ◯ 60%
- ◯ 65%
- ◯ 70%
- ◯ 75%
- ◯ 80%
- ◯ 85%
- ◯ 90%
- ◯ 95%
- ◯ 100% (fully functional)

---

29. RIGHT FOOT/ ANKLE: On a scale of 0 to 100, please rate the functionality of your foot and/or ankle region currently (0-100%):
(SELECT ONE ANSWER ONLY)

- ◯ 0% (unable to function)
- ◯ 5%
- ◯ 10%
- ◯ 15%
- ◯ 20%
- ◯ 25%
- ◯ 30%,
- ◯ 35%
- ◯ 40%
- ◯ 45%
- ◯ 50%
- ◯ 55%
- ◯ 60%
- ◯ 65%
- ◯ 70%
- ◯ 75%
- ◯ 80%
- ◯ 85%
- ◯ 90%
- ◯ 95%
- ◯ 100% (fully functional)